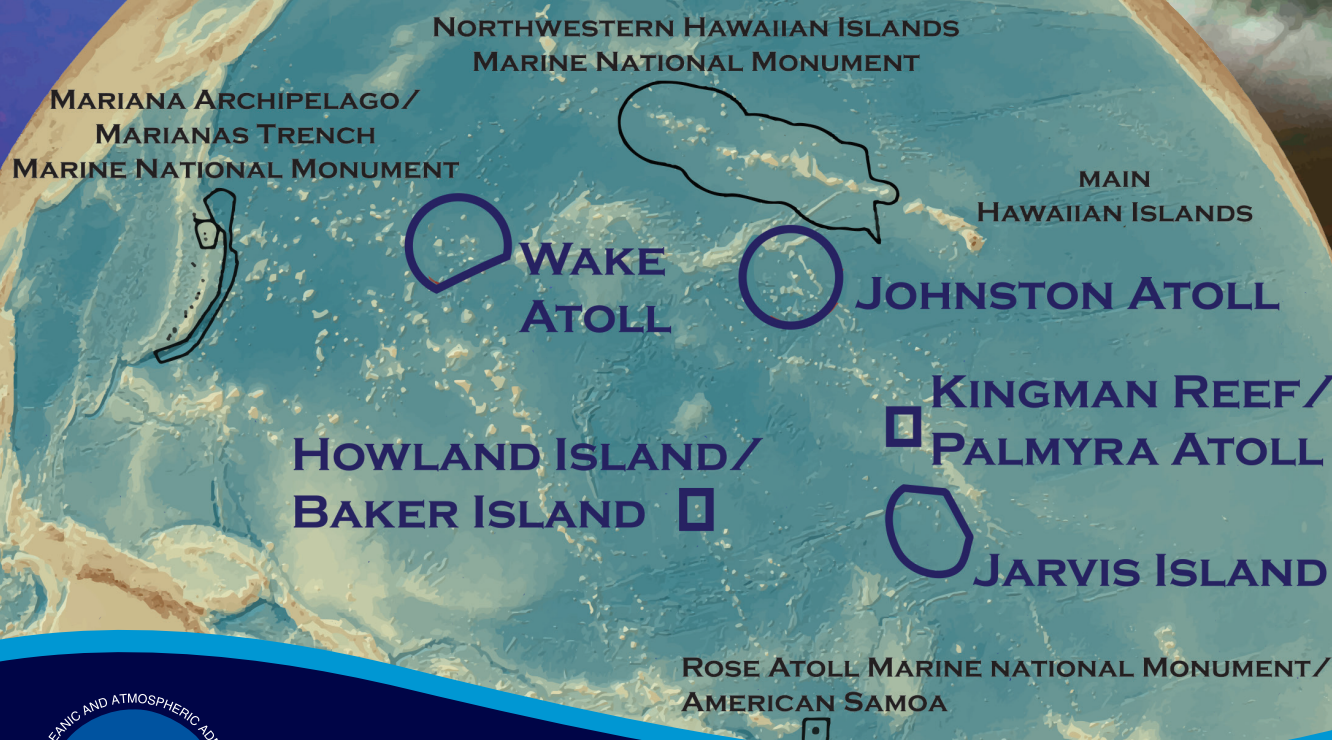


CORAL REEF ECOSYSTEM MONITORING REPORT FOR THE PACIFIC REMOTE ISLANDS MARINE NATIONAL MONUMENT

2000–2017

CHAPTER 9 PACIFIC-WIDE CONTEXT



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Coral Reef Ecosystem Monitoring Report for the Pacific Remote Islands Marine National Monument 2000–2017

Chapter 9: Pacific Remote Islands Marine National Monument in the Pacific-wide Context

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Front Cover: Grey reef shark (*Carcharhinus amblyrhynchos*) at Palmyra Atoll. Photo: James Morioka, NOAA Fisheries; Map of the U.S. Pacific Islands region survey area for the Pacific Reef Assessment and Monitoring Program including the Pacific Remote Islands Marine National Monument (PRIMNM), the Mariana Archipelago, the Hawaiian Archipelago, American Samoa, and the Rose Atoll Marine National Monument. The boundaries of the PRIMNM are shown in blue; other Marine National Monument boundaries are shown in black.

Back Cover:

Top two rows reading top (portraying back cover of each island chapter) to bottom (portraying front cover of each island chapter), from left to right. All images courtesy NOAA Fisheries.

Palmyra Atoll: *Carcharhinus amblyrhynchos* within coral reef ecosystem, Photo: Jeff Milisen; *Chaetodon Trifasciatus*, Photo: James Maragos, USFWS.

Kingman Reef: *Lutjanus bohar*, Photo: James Morioka; *Tridacna maxima*, Photo: Megan Moews-Asher.

Jarvis Island: *Carcharhinus amblyrhynchos* among *Sphyrna qenie*, Photo: James Morioka; *Carcharhinus amblyrhynchos* and *anthias*, Photo: Andrew E. Gray.

Wake Atoll: *Myripristis berndti*; *Bolbometopon muricatum*, Photos: Andrew E. Gray.

Bottom two rows reading top (portraying front cover of each island chapter) to bottom (portraying back cover of each island chapter), from left to right. All images courtesy NOAA Fisheries.

Johnston Atoll: Coral reef ecosystem, Photo: Marc Nadon; coral reef ecosystem and array of reef fish, unknown photographer.

Howland Island: *Chlorurus frontalis*, Photo: Jacob Asher; *Chaetodon meyeri*, Photo: Ariel Halperin.

Baker Island: *Acropora* and *Caranx lugubris*; *Acropora* and several *anthias*, Photos: Jeff Milisen.

Map of the U.S. Pacific Islands region survey area for the Pacific Reef Assessment and Monitoring Program including the Pacific Remote Islands Marine National Monument (PRIMNM), the Mariana Archipelago, the Hawaiian Archipelago, and American Samoa. The boundaries of the PRIMNM are shown in blue; other Marine National Monument boundaries are shown in black.

Table of Contents

Executive Summary	5
Acknowledgements.....	7
9.1 Introduction.....	10
Report Overview	10
Chapter Overview	10
9.2 Benthic Characterization	12
9.3 Ocean and Climate Variability	16
Climatology.....	17
Interannual Variability	18
Calcium Carbonate Accretion.....	19
9.4 Coral Reef Benthic Communities	22
9.5 Cryptofauna Biodiversity	32
9.6 Microbiota	36
Microbial biomass on reefs.....	36
Microbial Composition and Diversity	37
9.7 Reef Fishes	40
Reef fish biomass.....	40
9.8 Ecosystem Integration	48
9.9 References.....	53
9.10 Appendices.....	55
APPENDIX A.....	55
APPENDIX B.....	57

Executive Summary

The work presented within the *Coral Reef Ecosystem Monitoring Report for the Pacific Remote Islands Marine National Monument 2000–2017* is a direct result of nearly 20 years of research in the U.S. Pacific Remote Islands Marine National Monument (PRIMNM) conducted over hundreds of field days aboard National Oceanic and Atmospheric Administration (NOAA) ships by dozens of contributors from NOAA, University of Hawaii–Joint Institute for Marine and Atmospheric Research, and partner scientists. For their efforts, we are eternally grateful and appreciative of their work.

Here, we examine seven islands and atolls within the PRIMNM, using a variety of methods across multiple disciplines in order to gauge how these unique ecosystems have fared through time. In brief, this report describes and highlights the spatial patterns and temporal trends of marine ecosystems associated with Johnston Atoll, Howland Island, Baker Island, Jarvis Island, Palmyra Atoll, Kingman Atoll, and Wake Atoll, along with cross-comparative assessments among the islands, reefs, and atolls of the PRIMNM and other island areas of the U.S. Pacific Islands region in “Chapter 9: Pacific Remote Islands Marine National Monument in the Pacific-wide Context.”

Each island, reef, and atoll chapter, along with the Pacific-wide chapter, is constructed as follows: Introduction, Benthic Characterization, Ocean and Climate Variability, Coral Reef Benthic Communities, Cryptofauna Biodiversity (in the Pacific-wide chapter only), Microbiota, Reef Fishes, Marine Debris, and Ecosystem Integration.

Key Findings

- Given the wide geographic extent and large variance in oceanographic conditions experienced across the PRIMNM, it is more informative to consider the PRIMNM as three groupings: the northernmost oligotrophic islands of Johnston and Wake Atolls, the central transition islands of Kingman Reef and Palmyra Atoll, and the equatorial upwelling islands of Howland, Baker, and Jarvis Islands.
- Due to the combined effects of equatorial and locally-intense topographic upwelling of the eastward-flowing subsurface Equatorial Undercurrent, Jarvis Island, and to a lesser extent Howland and Baker Islands, are subject to noticeably cooler mean sea surface temperatures (SSTs) than their nearest neighbors (Palmyra Atoll and Kingman Reef). The upwelling routinely experienced by these islands further results in the highest chlorophyll *a* (chl-*a*) concentrations and associated biological productivity measured across the PRIMNM. In contrast, the lower chl-*a* concentrations observed at Wake and Johnston Atolls are similar to concentrations within the Mariana Archipelago and American Samoa, which are located in the oligotrophic gyres of the North Pacific and South Pacific.
- Higher aragonite saturation values correspond to the greater availability of carbonate ions, and thus favor the growth of corals, crustose coralline algae, and other marine calcifiers. The PRIMNM’s northernmost oligotrophic islands (Johnston and Wake Atolls) retained two of the lowest average carbonate accretion rates in the U.S. Pacific Islands, indicating low reef growth over time.

- Jarvis Island experienced a massive decline in coral cover in response to acute thermal stress associated with the 2015–2016 El Niño warming event; Jarvis has shown no substantial recovery in coral cover since. Coral cover at Baker Island and Kingman Reef also declined from 2015 to 2018, reflecting a 13% decline over 3 years at both islands.
- Calcifiers comprised approximately half of the benthic communities at Howland Island, Kingman Reef, and Baker Island. Despite Jarvis’s catastrophic decline in coral cover in 2016, the recent proportion of calcifiers at Jarvis Island remains high, likely due to a marked increase in cover of crustose coralline algae (CCA) observed in 2018.
- Across the PRIMNM, the crown-of-thorns sea star (*Acanthaster planci*, COTS) was consistently observed only at Kingman Reef and Johnston Atoll, though densities at these islands fluctuated across survey years. Localized outbreaks that were synchronized in timing across central Pacific reefs appeared to be genetically independent, rather than spread via the planktonic larvae released from a primary outbreak source.
- Mean reef fish biomass varied by a factor of >15 among all U.S. Pacific islands surveyed. The equatorial upwelling and central transition islands of the PRIMNM were among the islands that retained the highest biomass, especially of piscivores and planktivores, although Wake Atoll was an exception to this trend.
- The PRIMNM has also been notable for supporting larger abundances of species listed under the Endangered Species Act (ESA), including the greatest densities of the green sea turtle (*Chelonia mydas*) observed in the U.S. Pacific.

Scientists are increasingly recognizing the magnitude of ongoing and projected effects from global warming and ocean acidification on coral reef ecosystems. As such, this report provides an essential scientific foundation for informed decision making for the long-term conservation and management of the coral reef ecosystems within the PRIMNM. By summarizing trends in ecosystem response across space and time, this report is the first step towards assessing ecosystem resilience and identifying potential underlying drivers that impede or promote such resilience. Understanding these trends can inform the prioritization among candidate areas for management, as well as among the various types of policies and management actions themselves. In conclusion, the individual island, reef, atoll and Pacific-wide comparison chapters give resource managers and policymakers an unprecedented scale of spatial status and temporal trends to examine each ecosystem throughout the PRIMNM, with the hope of protecting and conserving these unique resources for generations to come.

Acknowledgements

We would like to give credit to all National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Fisheries Science Center (PIFSC) and Research Corporation of the University of Hawaii/Joint Institute for Marine and Atmospheric Research (JIMAR) scientists and staff, and the numerous partners who provided support to the Pacific Reef Assessment and Monitoring Program (Pacific RAMP) during 2000–2017, and contributed to the development of this report. We extend a special thanks to the officers and crews from the NOAA Ships *Townsend Cromwell*, *Oscar Elton Sette*, and *Hi 'ialakai* who provided field support for the Pacific RAMP surveys. We further express our sincere appreciation to PIFSC, JIMAR, the NOAA Coral Reef Conservation Program (CRCP), and Pacific Islands Regional Office (PIRO) for funding and providing collaborative resources throughout these efforts.

We specifically acknowledge Malia Chow as PIRO branch chief for the Essential Fish Habitat-Pacific Marine National Monuments, along with PIRO's Heidi Hirsh and Richard Hall for their collaboration, reviews, and inputs throughout this report's genesis, along with their participation in associated workshops. We would like to recognize the United States Fish and Wildlife Service Pacific Islands Refuges and Monuments Office for their partnership throughout Pacific RAMP history and their participation in the workshops associated with the report. In addition, we appreciate their reviews and those of PIRO interns, Jesi Bautista and Savannah Smith of Kupu Hawaii, who collectively provided valuable inputs toward the "History and Human Influences" sections for each island, reef, and atoll chapter. We further extend our thanks to the United States Air Force, 611th CES/CEIE, Joint Base Pearl Harbor, Hawaii for their collaborative efforts at Wake Atoll and inputs toward the report and at workshops.

We would like to recognize PIFSC Editorial Services, in particular, Jill Coyle, Katie Davis, and Hoku Johnson for their inputs throughout the editorial process, Donald Kobayashi, PIFSC, for his extensive time and insights in conducting chapter technical reviews, and PIFSC Director Michael Seki and PIFSC ESD Director Frank Parrish for their support and reviews. In addition, we wish to express our gratitude to the CRCP Coral Reef Information System and JIMAR data managers for their efforts to manage and make Pacific RAMP data publicly accessible and compliant with the Public Access to Research Results requirements.

Lastly, we are appreciative of Tom Hourigan and Dale Brown of NOAA Fisheries, two of the earliest visionaries in the establishment of the first Pacific long-term, integrated ecosystem-based monitoring program.

PIFSC has been fortunate to work with many partners who contributed to Pacific RAMP and associated efforts, and while this list is by no means comprehensive, we sincerely thank each and every one of you. Your contributions helped make this report possible, and as a result, we have collectively provided valuable inputs to the management and conservation of the coral reef ecosystems of the Pacific Remote Islands Marine National Monument.

Coral Reef Ecosystem Monitoring Report for the Pacific Remote Islands Marine National Monument 2000–2017

Chapter 9: Pacific Remote Islands Marine National Monument in the Pacific-wide Context



Figure 1. Map of the U.S. Pacific Islands Region that is the study area for the Pacific Reef Assessment and Monitoring Program including the Pacific Remote Islands Marine National Monument (PRIMNM), the Mariana Archipelago, the Hawaiian Archipelago, American Samoa, and the Rose Atoll Marine National Monument. The boundaries of the PRIMNM are shown in red; other Marine National Monument boundaries are shown in black.

9.1 Introduction

Report Overview

The *Coral Reef Ecosystem Monitoring Report for the Pacific Remote Islands Marine National Monument 2000–2017* provides an overview of key spatial patterns and temporal trends of the environmental and oceanographic conditions, biological resources, and composition of coral reef ecosystems across the seven islands, atolls, and reefs of the Pacific Remote Islands Marine National Monument (PRIMNM). The data compiled for this report are from Pacific Reef Assessment and Monitoring Program (Pacific RAMP) research surveys conducted over the period from 2000 through 2017 by the National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Fisheries Science Center (PIFSC) Ecosystem Sciences Division (ESD) and external collaborating scientists.

This report represents one of many installments of ESD’s ongoing efforts to bring resource managers and interested stakeholders the best available, ecosystem-based data to help them make informed decisions about the sustainable use and conservation of the resources they manage; in this case, coral reef ecosystem in the PRIMNM. The information herein serves three main purposes:

- Provide snapshots of the status and condition of coral reef resources around each of the islands, atolls, and reefs in the PRIMNM over the course of the survey periods.
- Provide a foundation of knowledge regarding ecosystem conditions in the PRIMNM for ongoing monitoring of temporal changes to the ecosystem.
- Serve as a resource for stakeholders and resource managers for understanding marine areas of interest and formulating evolving management questions about how to best manage and conserve marine resources in the face of climate and ocean changes.

The report consists of nine chapters. In addition, attached to this chapter are Appendix A, “Total Generic Richness of Hard Corals in the PRIMNM,” and Appendix B, “Reef Fish Encounter Frequency in the PRIMNM.” For more information on the report as a whole, operational background, Pacific RAMP methods, and Public Access to Research Results, refer to “Chapter 1: Overview.”

Chapter Overview

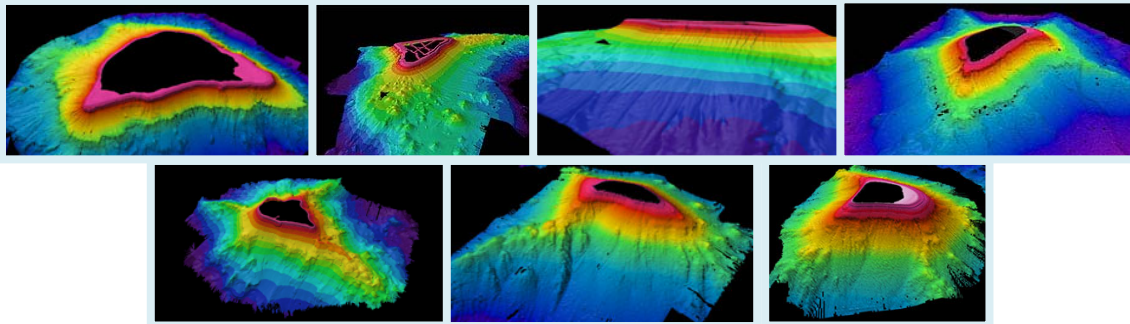
The purpose of this chapter is to provide information to assist managers in making informed decisions relative to coral reef ecosystems of the PRIMNM in the context of and in comparison with the rest of the islands/archipelagoes of the U.S. Pacific Islands region (Figure 1). This includes the Mariana Archipelago, American Samoa, the main Hawaiian Islands, and the Northwestern Hawaiian Islands. Structured similarly to the other island, reef, and atoll chapters, this chapter includes “Benthic Characterization” to set the stage, followed by “Oceanographic and Climate Variability,” “Coral Reef Benthic Communities,” “Cryptofauna Biodiversity” (in this chapter only), “Microbiota,” and “Reef Fishes.” Information from these sections is tied together in the “Ecosystem Integration” section to provide a big-picture understanding of the interactions and relationships among the PRIMNM ecosystem components in the context of the broader U.S. Pacific Islands region.



*East Terrace at Baker Island.
Photo: Ariel Halperin, NOAA Fisheries.*

Benthic Characterization

9.2 Benthic Characterization



3-D perspective views of multi-beam bathymetry showing all 7 islands, reefs, and atolls of the Pacific Remote Islands Marine National Monument. Top row, left to right: Johnston Atoll, Kingman Reef, Palmyra Atoll (north side flank), and Jarvis Island. Bottom row, left to right: Wake Atoll, Howland Island, and Baker Island. Images: NOAA Fisheries.

The PRIMNM is comprised of a diverse group of widely spaced islands and atolls that straddle various island chains and oceanic features (i.e., Phoenix Islands, Line Islands, Mid-Pacific Mountains oceanic plateau) rather than a single geologic archipelago like the Hawaiian and Mariana Islands (Figure 1). From north to south, Johnston Atoll, Kingman Reef, Palmyra Atoll, and Jarvis Island are geologically part of the northwest–southeast trending Line Islands submarine ridge, a major and very complex feature of the central Pacific. Johnston is the northernmost of the submerged Line Islands Ridge, Kingman and Palmyra are part of the Northern Line Islands group, and Jarvis is part of the Central Line Islands group (Koppers et al. 2003). Located to the west of the Line Islands, Howland and Baker Islands are geologically part of the northwest–southeast trending Tokelau submarine ridge and geographically considered northerly outliers of the Phoenix Islands group of islands to the southeast. The Tokelau submarine ridge, possibly formed from the Macdonald hotspot located southeast of the Samoa hotspot in the south Pacific, extends southeast through the western Phoenix Islands to the Tokelau Islands and Swains Island, which is politically part of American Samoa. Rose Atoll, geologically separate from the Samoa hotspot that formed the high islands of American Samoa, may have also been formed from the Macdonald hotspot (Finlayson et al. 2018). Johnston and Wake are associated with the Mid-Pacific Mountain range, which extends from the Hawaiian Ridge southwest/west to Wake Atoll and beyond.

Wake is the oldest of the islands and atolls in the PRIMNM, estimated to have formed 90 to 85 million years ago (Ma; Hein et al. 2005). Howland, Baker, Johnston, Kingman, and Palmyra all formed (either from evidence or from close association) 72 to 69 Ma (Maragos et al. 2008). Jarvis Island is estimated to have formed between 70 and 40 Ma and is either similar in age or younger than its PRIMNM counterparts in the Line Islands (Hein et al. 2005). The geologic age of the PRIMNM contrasts the younger islands and atolls of the Hawaiian and Mariana Archipelagos and American Samoa, the oldest of which formed approximately 30 Ma. The reefs of each of the islands and atolls in the PRIMNM began developing when the original volcanoes were still emergent islands. The volcanoes have eroded/subsided as the coral reefs have grown, maintaining proximity to the sea surface for a long period of time considering their geologic age.

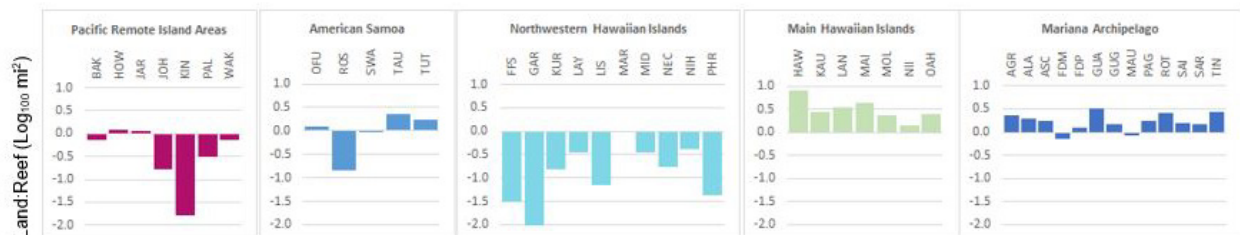
Howland, Baker, and Jarvis Islands are nearly flat, sandy, coral/reef islands encircled by shallow fringing reefs without a lagoon. Palmyra, Wake, and Johnston are coral atolls, consisting of coral reefs encircling deep lagoons and supporting many islets. Kingman, an atoll reef, is the most geologically progressed of the PRIMNM with no remaining emergent land.

The reef area (defined here as hard bottom substrate within depths of 0–30 m) among the islands and atolls of the U.S. Pacific Islands Region is highly variable (Figure 2a). The Hawaiian Islands have the greatest amount of reef area; though when considering reef area in proportion to the area of emergent land, the islands of the PRIMNM and the Northwestern Hawaiian Islands are the dominant regions of reef area (Figure 2b). Values less than zero in this panel indicate greater reef area underwater than emergent land area above water. Furthermore, both the PRIMNM and Northwestern Hawaiian Islands are remote and accordingly support the lowest human population densities of all the areas surveyed as part of Pacific RAMP (Figure 2c).

A) Reef Area



B) Land Area:Reef Area

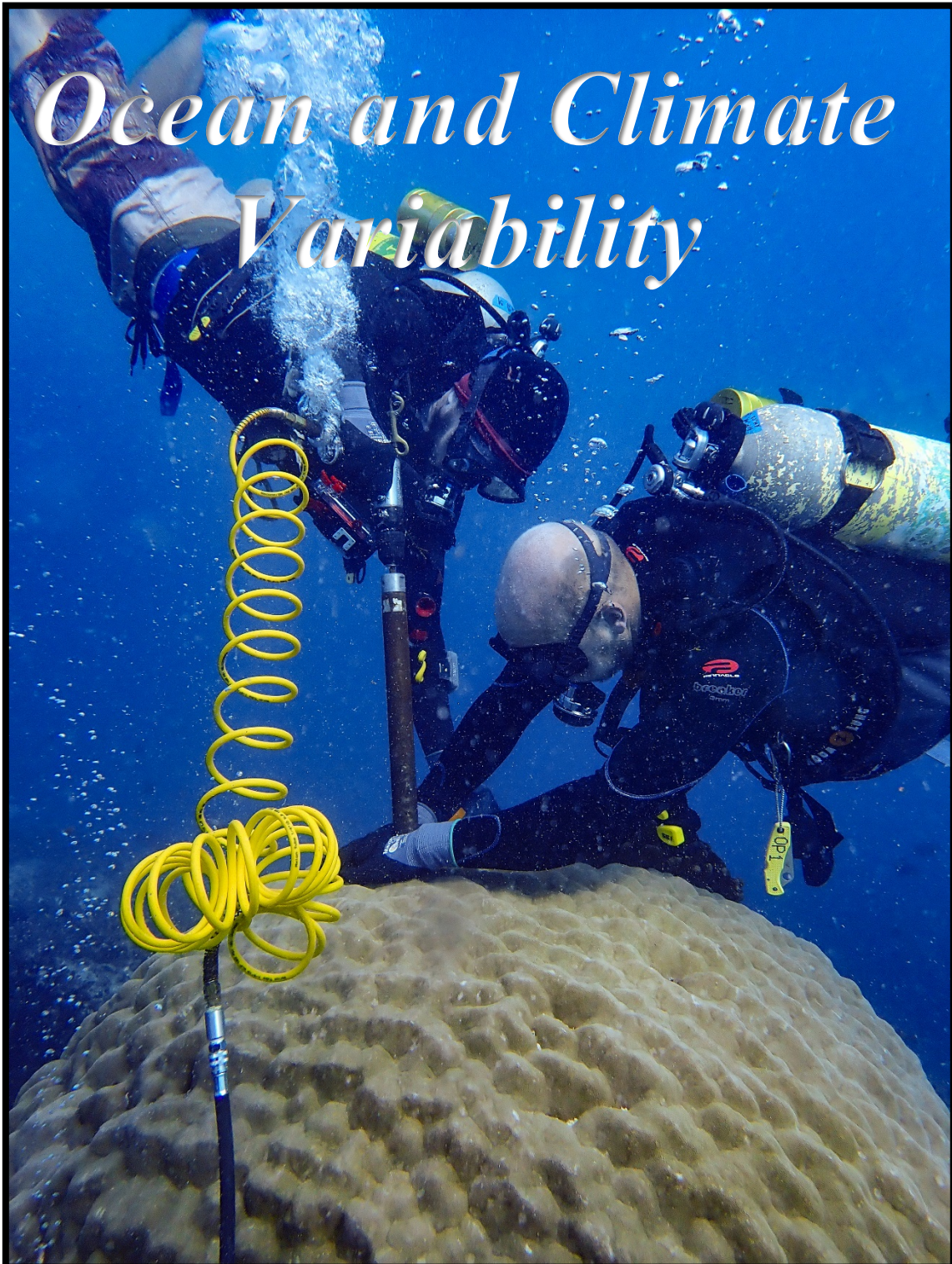


C) Population Density



Figure 2. Comparison of (A) reef area (mi²) from 0 to 30 m, (B) the ratio of log₁₀₀ transformed reef area (mi²) to log₁₀₀ transformed land area (mi²), and (C) population density (total population/land area [mi²]) across the five regions surveyed by Pacific RAMP.

The PRIMNM is comprised of islands and atolls that span a relatively wide geographic spread, and therefore, encompasses a wide range of oceanographic conditions making it unique from other U.S. Pacific jurisdictions surveyed by the PIFSC Ecosystem Sciences Division. Rather than viewing these islands and atolls as a homogeneous archipelago, it is more informative to consider the PRIMNM as consisting of three unique groupings: the northernmost oligotrophic islands of Johnston and Wake Atolls, the central transition islands of Kingman Reef and Palmyra Atoll, and the equatorial upwelling islands of Howland, Baker, and Jarvis. The equatorial islands are especially productive as they benefit from the combined effects of regional equatorial upwelling and localized topographic upwelling of the subsurface Equatorial Undercurrent that collectively bring cool, nutrient-rich waters to the sunlit surface where photosynthesis thrives. In contrast, the northernmost islands are found in the nutrient poor waters of the central gyre characterized by low biological productivity. The central transition islands, located at the northern edge of the enhanced productivity region, experience a moderate level of biological productivity.

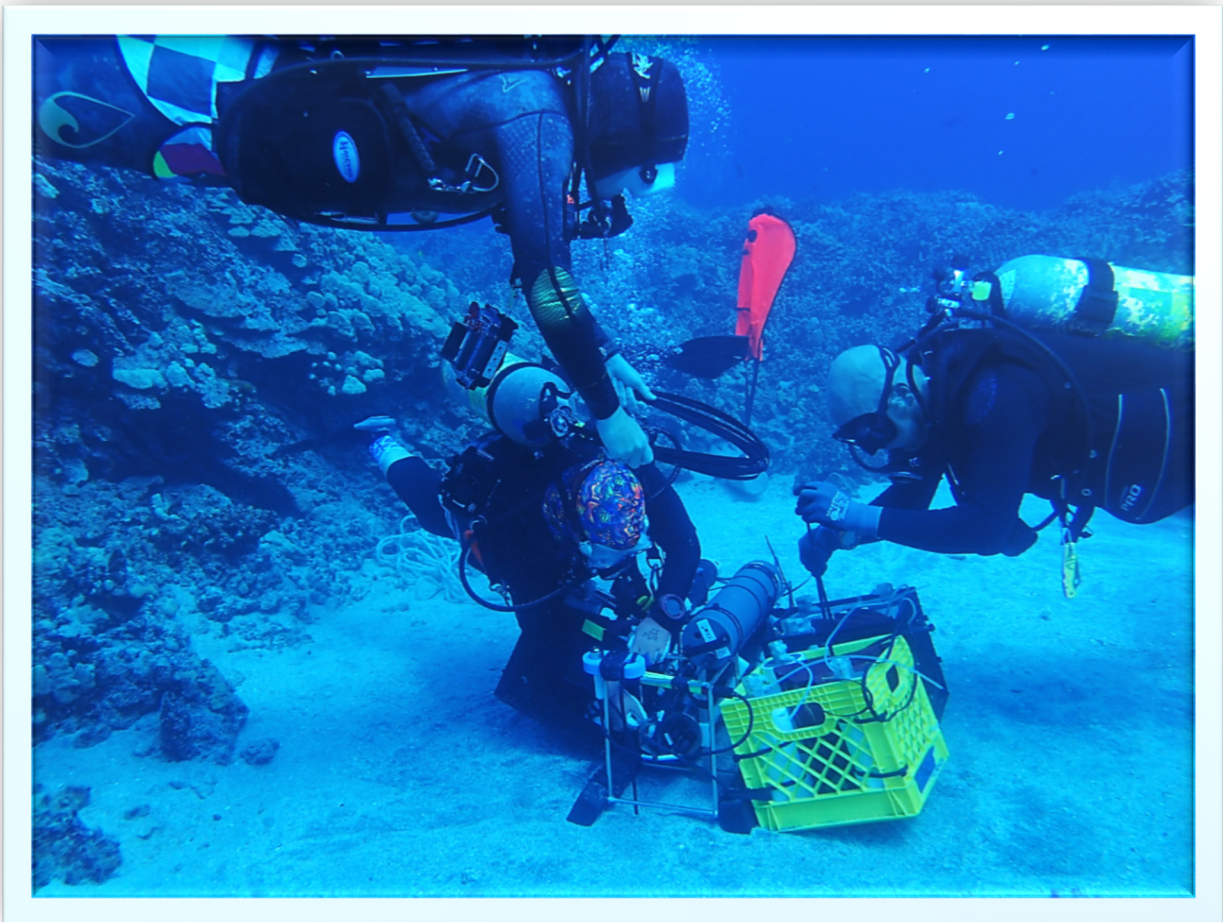


Ocean and Climate Variability

Scientists Noah Pomeroy and Ariel Halperin work carefully to extract a core of skeleton from a Porites coral head at Baker Island. This core acts as a record, allowing scientists back in the lab to learn more about the coral's history and possible ocean conditions over time.

Photo: Hannah Barkley, NOAA Fisheries.

9.3 Ocean and Climate Variability



NOAA Divers Laura Rock, Hannah Barkley, and Ariel Halperin install an instrument package on the reef at Palmyra Atoll to measure oceanographic changes throughout tidal/daily cycles. Photo: Greg Asner, Arizona State University, courtesy NOAA Fisheries.

A diverse suite of oceanographic and environmental factors, including but not limited to temperature, wind, waves, currents, nutrients, carbonate chemistry, light, and productivity, influences coral reef ecosystems. These drivers vary both spatially around individual islands and across the Pacific, and temporally over time scales ranging from seconds (waves) to hours (squalls) to days (diel and tidal) to months (lunar tidal cycles) to seasons to interannual (El Niño Southern Oscillation; ENSO) to decadal (Pacific Decadal Oscillation; PDO) and longer. A combination of satellite-derived data and in-situ information collected during Pacific RAMP surveys was analyzed to assess the spatial and temporal variability of many of these oceanographic and environmental drivers across the U.S. Pacific Islands. Satellite observations provided broad spatial coverage and a historical context of surface processes, whereas in-situ observations provided subsurface measurements of the physical and chemical conditions directly influencing coral reef communities. Synthesis and integration of these datasets increase our

understanding of the ecological processes that influence the status and trends in the condition of coral reef ecosystems in the PRIMNM and how those compare with other reef systems across the U.S. Pacific Islands.

Climatology

Long-term mean sea surface temperatures (SSTs) varied spatially across the Pacific Islands and among the widely-separated islands of the PRIMNM (Figure 3a). Jarvis Island, and to a lesser extent Howland and Baker Islands, experienced noticeably cooler mean SSTs than its closest neighbors, Palmyra Atoll and Kingman Reef, due to the combined effects of equatorial and locally-intense topographic upwelling of the eastward flowing subsurface Equatorial Undercurrent (Gove et al. 2006). Of the U.S. Pacific Islands, the Hawaiian Archipelago experienced the coolest mean SSTs (23–27 °C), whereas the islands of the Mariana Archipelago and American Samoa experienced the warmest mean SSTs (28–29 °C). Mean SSTs at Wake and Johnston Atolls were between these extremes.

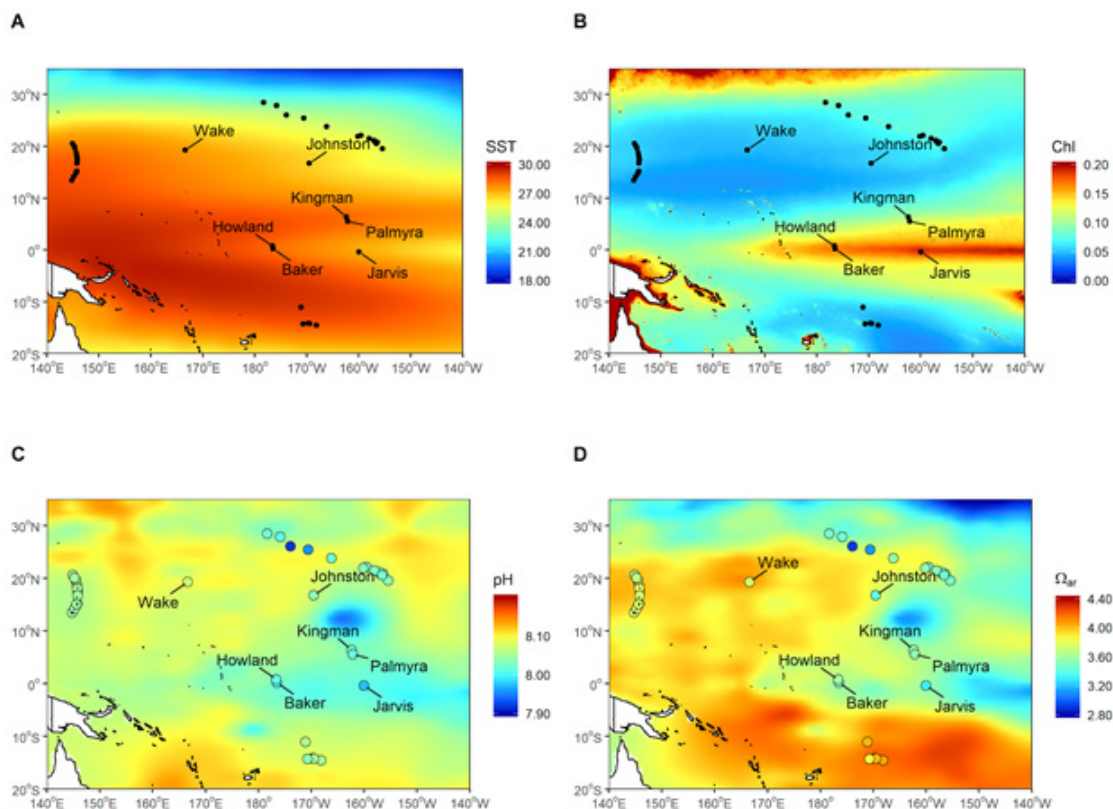


Figure 3. Pacific-wide climatology for the U.S. Pacific Islands (PRIMNM islands are labeled) for (A) sea surface temperature (SST, °C), (B) chlorophyll-a (Chl, mg m⁻³), (C) pH, and (D) aragonite saturation state (Ω_A). SST data are the means of monthly observations from December 1981 to April 2018 from the Optimum Interpolation SST (OISST) data set. Chlorophyll-a concentration data are the means of monthly data from July 2002 to July 2018 from the Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua. pH and Ω_A data are from the GLODAP Ocean Data Analysis Project (GLODAP) v2 mapped global climatologies, with 2010–2017 mean in situ pH and Ω_A values plotted (colored circles) for each island.

Similar to SST, long-term mean chlorophyll-*a* concentrations (chl-*a*; a proxy for primary productivity) showed significant variability across the Pacific Islands (Figure 3b). Highest chl-*a* concentrations, and associated biological productivity, occurred at Jarvis (0.2 mg m⁻³), Howland, and Baker Islands. These islands, located in the Pacific equatorial cold tongue, routinely experience equatorial upwelling as the force of the earth's rotation on the northeast and southeast trade winds causes divergent surface flows northward and southward from the equator. The lower chl-*a* concentrations observed at Wake and Johnston Atolls were similar to concentrations within the Mariana Archipelago and American Samoa, located in the oligotrophic gyres of the North Pacific and South Pacific, respectively. Palmyra Atoll and Kingman Reef are situated in the transition zone between the highly productive equatorial islands and the low productivity of the oligotrophic gyres, and therefore experienced moderate levels of oceanic productivity.

Across the Pacific Basin, there are strong natural gradients in pH and the saturation state of aragonite (Ω_A ; Figure 3c, d). Greater values of Ω_A correspond to greater availability of the carbonate ion (CO₃²⁻) and thus favor the growth of corals, crustose coralline algae, and other marine calcifiers. However, under the process of ocean acidification, increased dissolution of carbon dioxide in seawater leads to the decrease in seawater pH, Ω_A , and concentrations of CO₃²⁻. This makes it more difficult for corals and calcifying organisms to grow. Measurements of Ω_A ranged from 2.9 at Lisianski Island in the Northwestern Hawaiian Islands to 4.0 at Swains Island in American Samoa (Figure 3d). At Lisianski, pH was correspondingly low. Within the PRIMNM, both pH and Ω_A was greatest at Wake Atoll and lowest at Jarvis Island. American Samoa and the Mariana Archipelago exhibited the highest regional mean aragonite saturation states of 4.0 and 3.7, respectively. The PRIMNM, Northwestern Hawaiian Islands, and main Hawaiian Islands all possessed average aragonite saturation states within the 3.2–3.7 range.

Interannual Variability

ENSO events have substantial influence on temperature and chlorophyll anomalies across the U.S. Pacific Islands, with ENSO variability causing dramatic interannual differences in SST and chl-*a* that have subsequent impacts on the PRIMNM islands depending on the locations of the anomalies relative to the islands. The maps in Figure 4 show the average anomalies in both of these variables during a strong El Niño and La Niña event to highlight spatial patterns in impacts. During El Niño, easterly trade winds slacken, slowing the westward movement of surface water and reducing equatorial upwelling. As a result, temperatures warm and chlorophyll concentrations are lower than normal. These impacts are felt most strongly at Jarvis, Howland, and Baker Islands, where topographic upwelling of the Equatorial Undercurrent becomes minimal to nonexistent. Kingman Reef and Palmyra Atoll are located at the outer edge of the equatorial epicenter for El Niño activity, so they experience El Niño impacts to a lesser extent. Johnston and Wake Atolls are largely outside the area of intense El Niño warming. The opposite patterns occur during La Niña events, during which trade winds strengthen and the intensity of equatorial and topographic upwelling increases. This causes temperatures to cool and chlorophyll and nutrient concentrations to rise in the central equatorial Pacific.

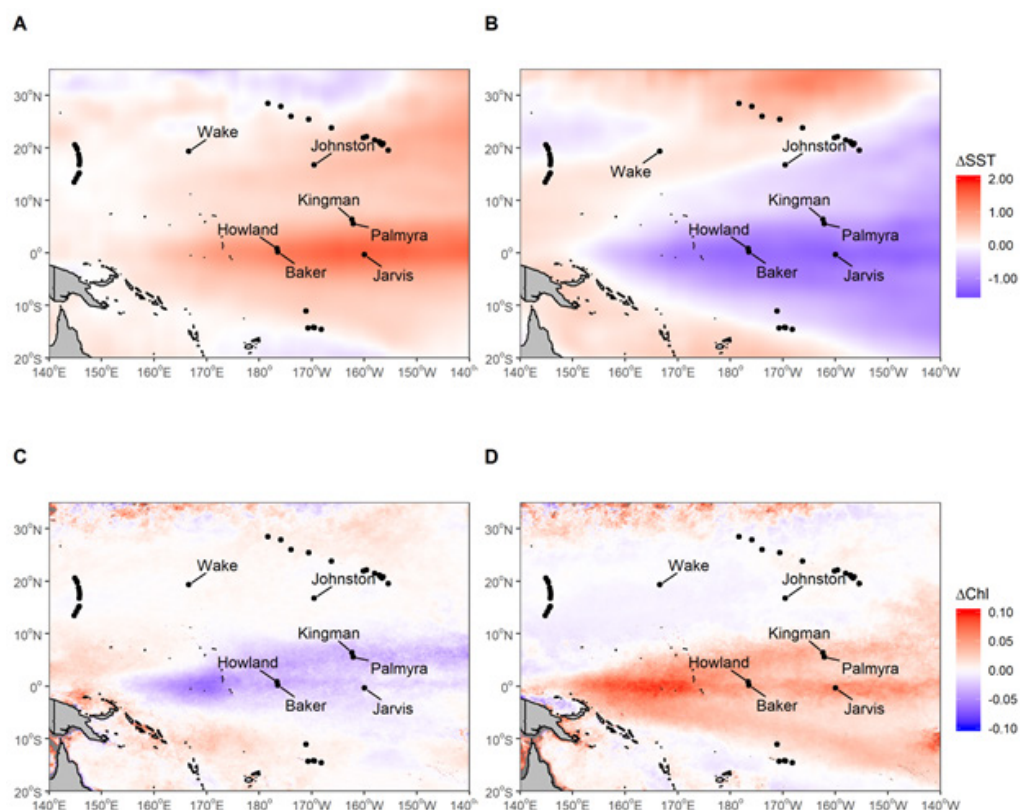


Figure 4. Sea surface temperature (SST, °C) and chlorophyll-a (Chl, mg m⁻³) anomalies (ΔSST and ΔChl) during a strong El Niño event from May 2015 to May 2016 ((A) and (C)) and a strong La Niña event from July 2010 to April 2012 ((B) and (D)). SST anomalies were calculated relative to the December 1981 to April 2018 climatology from the Optimum Interpolation SST (OISST) data set. Chlorophyll-a concentration anomalies were calculated from the July 2002 to July 2018 climatology from the Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua. Locations of all U.S. Pacific Islands are shown with PRIMNM islands labelled.

Calcium Carbonate Accretion

Net carbonate accretion rates were highly variable across the Pacific regions, ranging from 0.016 g CaCO₃ cm⁻² yr⁻¹ at Pearl and Hermes Atoll in the Northwestern Hawaiian Islands to 0.128 g CaCO₃ cm⁻² yr⁻¹ at Rose Atoll in American Samoa. The highest regional average rate of carbonate accretion in the U.S. Pacific Islands was measured in American Samoa (0.090 g CaCO₃ cm⁻² yr⁻¹) and the PRIMNM (0.058 g CaCO₃ cm⁻² yr⁻¹). The PRIMNM's northernmost oligotrophic islands had two of the lowest average carbonate accretion rates in the U.S. Pacific Islands, with values of 0.020 g CaCO₃ cm⁻² yr⁻¹ at Johnston and 0.017 g CaCO₃ cm⁻² yr⁻¹ at Wake. Regional averages for the Mariana Archipelago and the Northwestern Hawaiian Islands were 0.035 g CaCO₃ cm⁻² yr⁻¹ and 0.022 g CaCO₃ cm⁻² yr⁻¹, respectively. Much of the habitat provided by coral reefs comes from the structural complexity of their calcium carbonate foundations. Net carbonate accretion rates provide an indicator of the reef's growth over time; hence, the low rates observed, especially around the Northwestern Hawaiian Islands, could be cause for concern.

The distinctions seen in patterns of aragonite saturation state and CAU accretion rate (Figure 5) highlight the importance of tracking both environmental exposures to the seawater carbonate chemistry and ecological responses to that chemistry. There can be strong forcing of net accretion on CAUs by aragonite saturation state (e.g., in American Samoa both aragonite saturation state and accretion rate are high), but this relationship is likely modified by the relative high productivity in the equatorial islands and low productivity in the northern oligotrophic islands. For example, while the equatorial islands of Jarvis, Howland, and Baker were exposed to low aragonite saturation states largely due to their upwelling environment, they still exhibited high rates of net accretion (Figure 5). Conversely, coral reefs at Wake and Johnston Atolls showed similar in-situ aragonite saturation states to the equatorial islands, but had low rates of accretion.

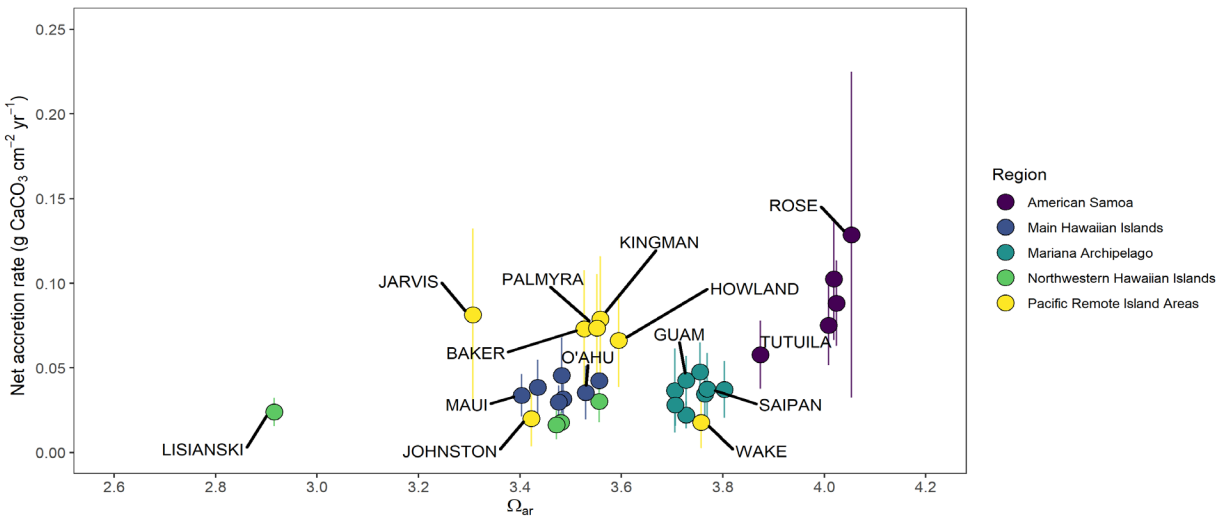
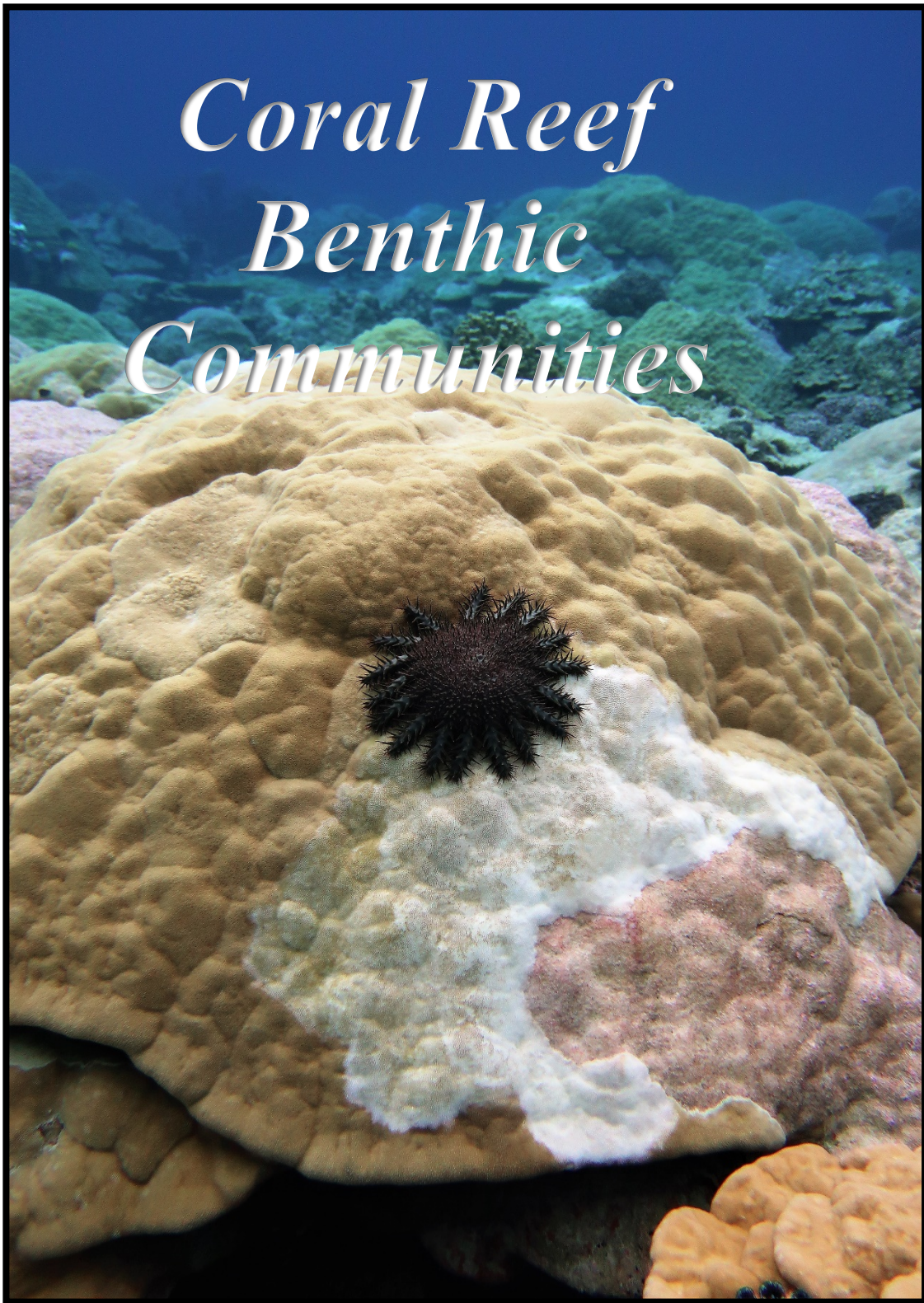


Figure 5. Average observed aragonite saturation state (Ω_A) across all sampling periods since 2010 plotted against average carbonate accretion rate (\pm SE) for all Pacific Islands. Island points are colored by region. PRIMNM islands and additional islands of interest are labelled.

Coral Reef Benthic Communities



*A crown of thorns sea star feeding on Porites at Kingman Reef.
Photo: Ariel Halperin, NOAA Fisheries.*

9.4 Coral Reef Benthic Communities



*Benthic community at Baker Island.
Photo: Benjamin Ruttenburg, Cal Poly, courtesy NOAA Fisheries.*

Temporal patterns in benthic cover for hard coral, macroalgae, and crustose coralline algae (CCA) are shown in Figure 5. The time series were constructed using the towed-diver survey data (TDS) from 2001 to 2012 and stratified random sampling (StRS) photoquad data surveys conducted from 2014 to 2018, as these two datasets provided the most robust data available on benthic community composition from mid-depth forereef habitats over the duration of RAMP surveys within the PRIMNM. However, because of this change in survey methodology in 2014, TDS data cannot be directly compared to the StRS photoquad data in a quantitative manner. Rather, we report temporal trends within each dataset rather than across the two datasets.

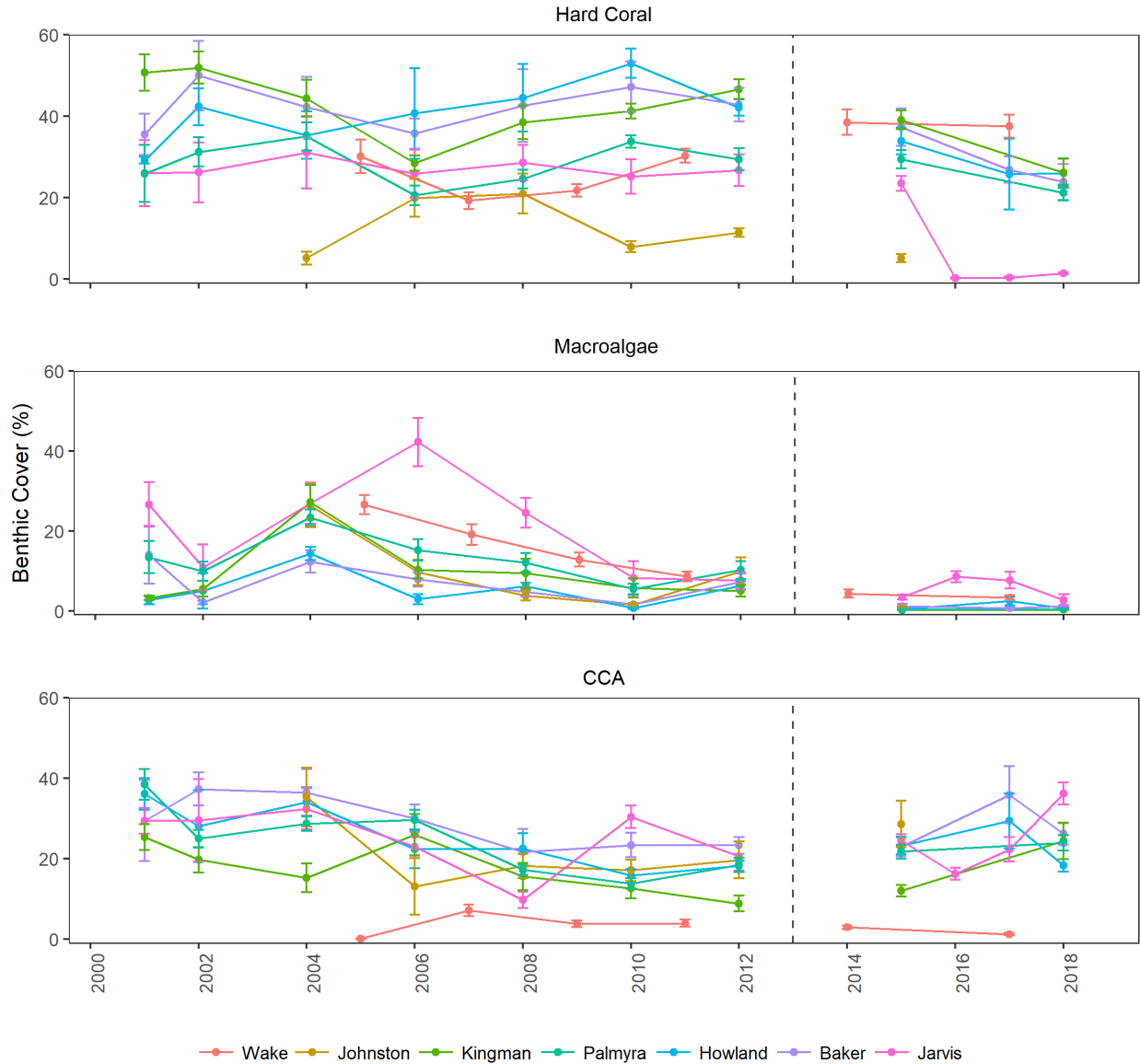


Figure 6. Time series of mean (± 1 SE) hard coral, macroalgae, and crustose coralline algae (CCA) cover (%) in the PRIMNM at the mid-depth (>6–18 m) forereefs from 2001 to 2018. The dashed line in 2014 demarks a change in methodology; data prior to 2014 are visual estimates from towed-diver surveys (TDS) while data from 2014 onward are estimates from photoquadrat surveys using stratified random sampling (StRS).

TDS observations and StRS photoquadrat estimates of coral cover remained high from 2001 through 2018 across most islands and atolls in the PRIMNM, though coral cover was consistently lower at Johnston Atoll than the other islands (Figure 6). Observed declines in coral cover were frequently followed by increases in percent cover by the next sampling period, suggesting these systems have the capacity to recover from disturbance and/or stress events. A notable exception was seen in the most recent survey year (StRS survey methodology), when Jarvis Island experienced a massive decline in coral cover in response to acute thermal stress associated with the 2015–2016 El Niño warming event; Jarvis has shown no substantial recovery in coral cover since. Coral cover at Baker Island and Kingman Reef also declined from 2015 to

2018, reaching covers of 24% at Baker and 26% at Kingman, reflecting a 13% decline over 3 years at both islands. These 2018 values are the lowest levels of coral cover observed across the entire duration of RAMP surveys at those reefs. Future surveys will be key for determining whether the recent patterns of decline observed in 2018 are followed by coral recovery.

Macroalgal cover in the PRIMNM was variable over time, particularly during the TDS surveys (2001–2012) for most islands and atolls. Macroalgal cover remained low in 2014–2018 StRS survey data, though this difference between datasets was further confounded by methodology as the TDS estimates of macroalgal cover included fleshy, calcified, and encrusting macroalgae and therefore tend to be greater than estimates acquired using the StRS photoquadrat methods that excluded calcified and encrusting macroalgae. Average CCA cover was high and highly variable among surveys throughout the PRIMNM with the exception of consistently low values observed at Wake Atoll in both TDS and StRS photoquad datasets. CCA cover has shown marked increases in 2018 at both Kingman Reef and Jarvis Island. No consistent temporal increases or decreases in CCA cover can be observed in the TDS or StRS photoquad data.

In a Pacific-wide context, the summed percent cover of calcifying organisms and active reef builders (hard corals and CCA) make up a large proportion of the benthos in American Samoa and the PRIMNM compared to the other regions surveyed (Figure 7). Calcifiers comprised approximately half of the benthos at Howland Island, Kingman Reef, and Baker Island. Despite a catastrophic decline in coral cover in 2016 (Figure 6), the recent proportion of calcifiers at Jarvis Island was high (~0.4; Figure 7), likely due to a marked increase in CCA cover observed in 2018 (Figure 6). Wake Atoll exhibited the lowest proportion of calcifying organisms reported in the PRIMNM in 2018, though Johnston Atoll was not surveyed in 2018 and therefore is not included in Figure 7.

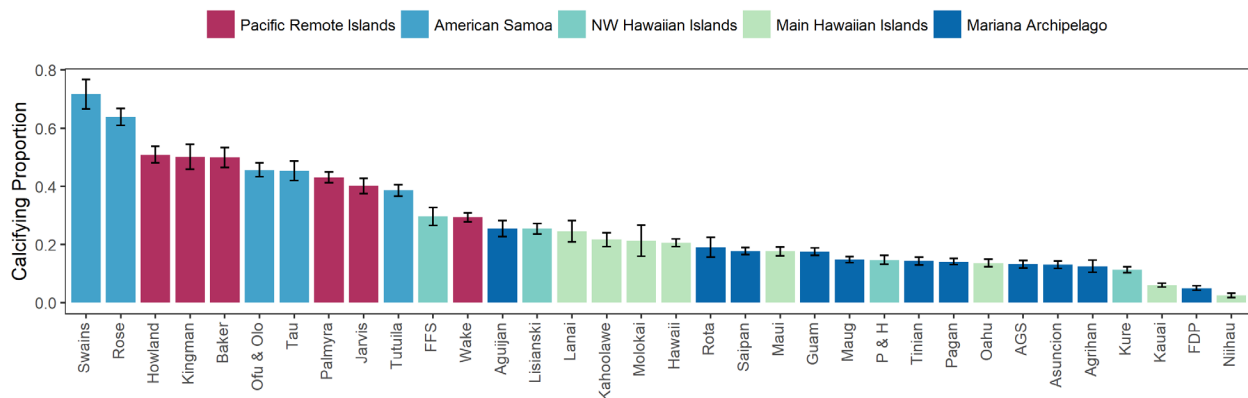


Figure 7. Mean (± 1 SE) proportion of calcifying benthic organisms (total % cover of hard corals and crustose coralline algae (CCA)) comprising benthic cover of forereef sites across all regions surveyed by Pacific RAMP. Data shown are from the most recent survey years (PRIMNM: 2018, American Samoa: 2018, Northwestern and main Hawaiian Islands: 2016, and Mariana Archipelago: 2017) and includes all forereef depth strata (0–30 m).

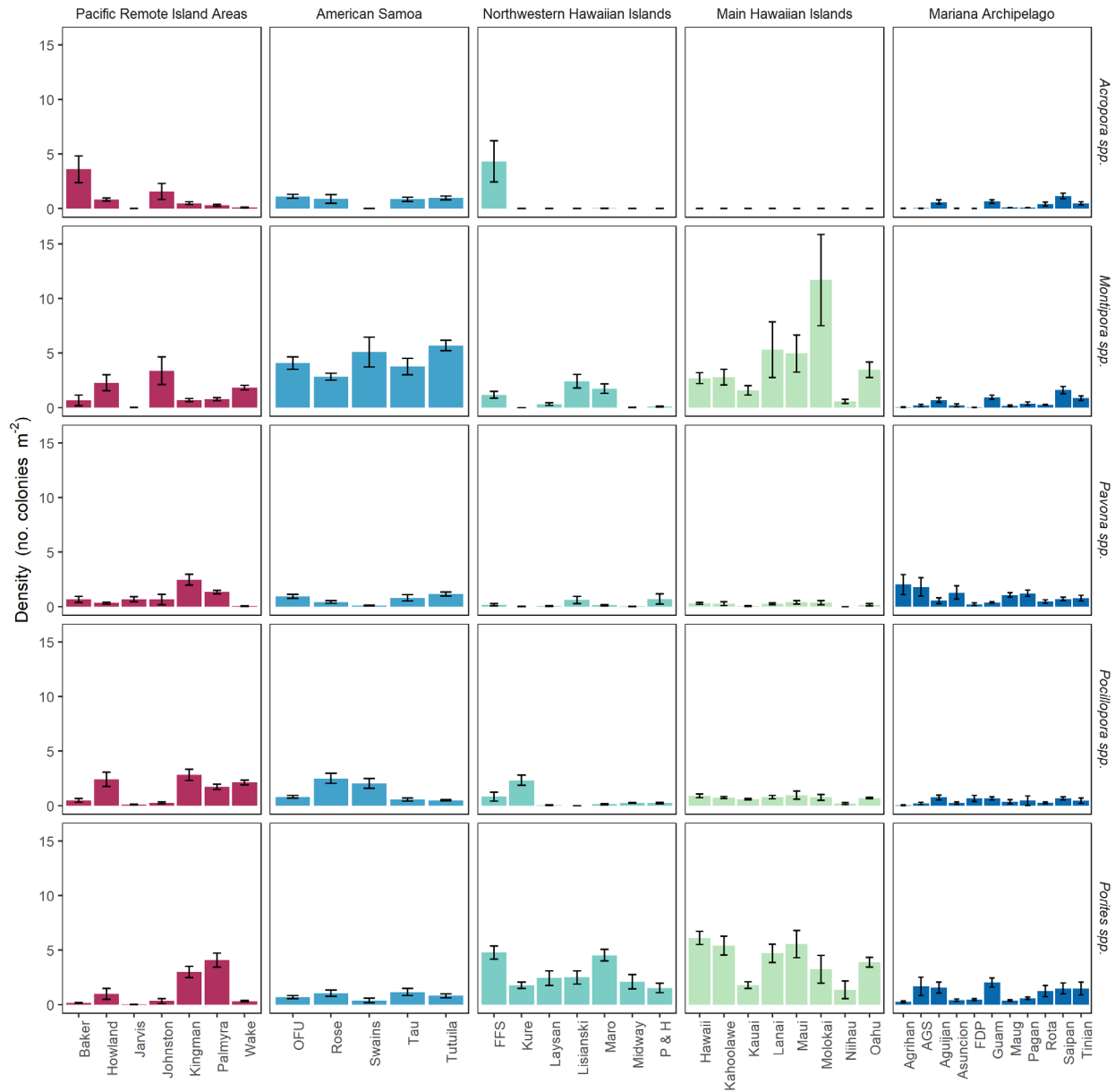


Figure 8. Mean (± 1 SE) adult colony density (no. colonies m^{-2}) in all five regions of RAMP operations from Rapid Ecological Assessment (REA) surveys of five typically abundant coral genera (*Acropora* spp., *Montipora* spp., *Pavona* spp., *Pocillopora* spp., and *Porites* spp.) to facilitate comparison among islands. Data shown are from the most recent survey years (PRIMNM: 2018, American Samoa: 2018, Northwestern and main Hawaiian Islands: 2016, and Mariana Archipelago: 2017) and includes all foreereef depth strata.

To facilitate comparison, colony density was examined among five coral genera typically abundant across the U.S. Pacific Island Region. No single coral taxon was numerically dominant across all seven areas of the PRIMNM (Figure 8). *Acropora* was most abundant at Baker Island; *Pocillopora* and *Montipora* at Howland Island; *Montipora* and *Acropora* at Johnston Atoll; *Porites*, *Pocillopora*, and *Pavona* at Palmyra Atoll and Kingman Reef; and *Pocillopora* and

Montipora at Wake Atoll. Relative densities of these five genera differed within the equatorial islands of Howland, Baker, and Jarvis, but were consistent between the central transition islands of Kingman and Palmyra. This disparate pattern may be attributed to factors, such as remoteness, larval dispersal mechanisms, benthic habitat availability across depths, and the specific oceanographic conditions particular to each island. In addition, the heterogeneity in coral composition within the PRIMNM contrasts with the other areas surveyed by Pacific RAMP, where one or two genera tended to be numerically dominant among reef systems within archipelagoes. For example, corals that dominated in terms of observed density in the other U.S. Pacific Islands were as follows: *Montipora* in American Samoa, *Montipora* and *Porites* in the main Hawaiian Islands, and *Porites* in the Northwestern Hawaiian Islands. No single coral taxon appeared to be numerically dominant in the Mariana Islands; nonetheless, *Porites* and *Pavona* appeared to be important community components.

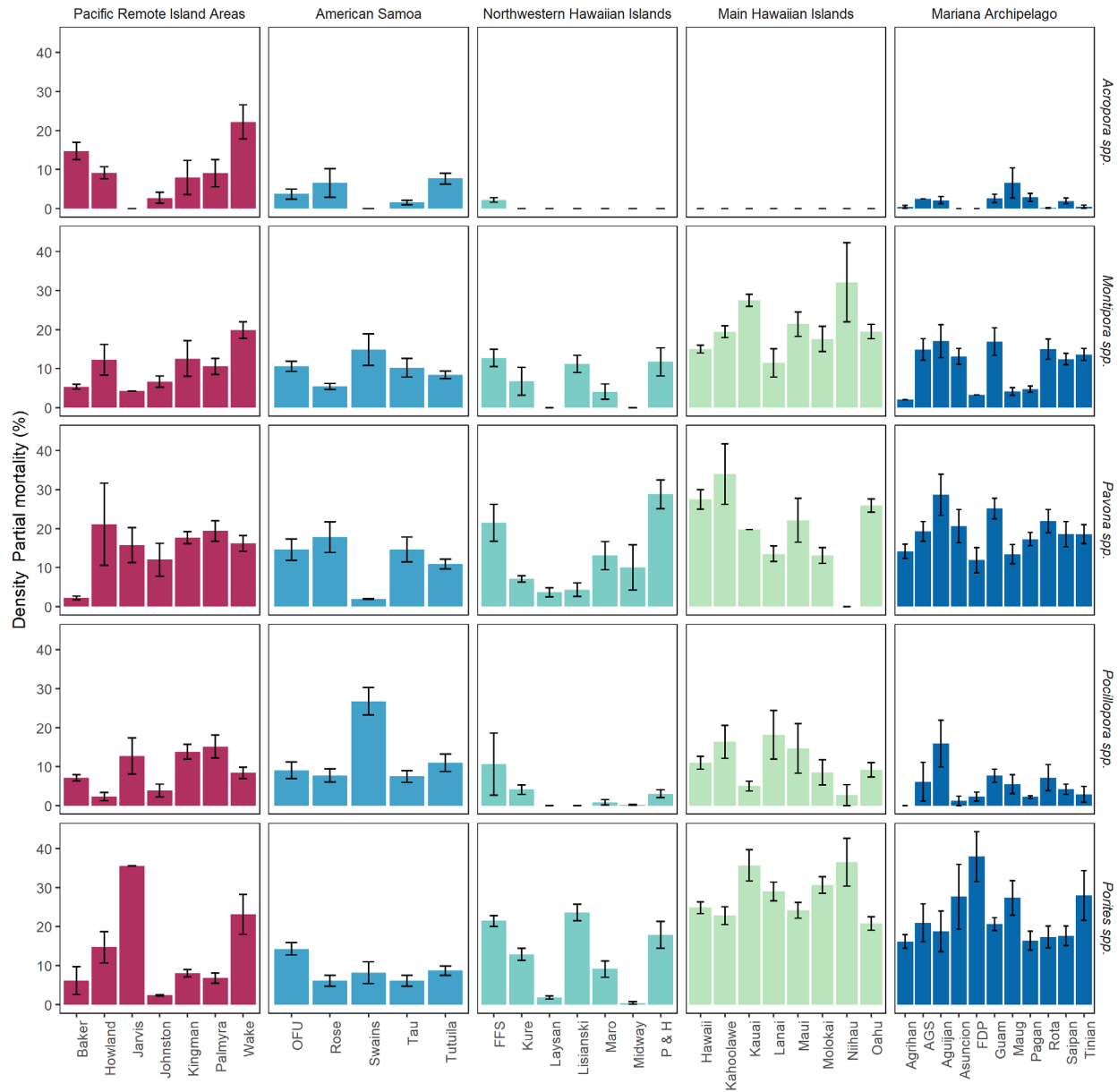


Figure 9. Mean (± 1 SE) adult colony partial mortality (%) in all five regions of RAMP operations from Rapid Ecological Assessment (REA) surveys of five typically abundant coral genera (*Acropora* spp., *Montipora* spp., *Pavona* spp., *Pocillopora* spp., and *Porites* spp.) to facilitate comparison among islands. Data shown are from the most recent survey years (PRIMNM: 2018, American Samoa: 2018, Northwestern and main Hawaiian Islands: 2016, and Mariana Archipelago: 2017) and includes all foreereef depth strata.

Average partial mortality of coral colonies observed across the five genera was also variable among taxa and among islands in the PRIMNM (Figure 8). No single taxa showed consistent levels of partial mortality among or within regions suggesting that drivers of partial mortality are island-specific (not regional) and have variable impacts on coral genera. Partial mortality was low across the majority of the PRIMNM for the genera shown; only *Porites* at Jarvis Island

exhibited an average partial mortality greater than 30%. Partial mortality was similarly low in all other regions except for the main Hawaiian Islands, with no genera having exceeded 30% mean partial mortality with the exception of *Porites* at Farallon de Pajaros in the Mariana Archipelago (mean partial mortality = 38%). Among the five survey regions, partial mortality was greatest in the main Hawaiian Islands with several genera exceeding 30% mean partial mortality, including *Porites* at Niihau and Kauai, *Montipora* at Niihau, and *Pavona* at Kohoolawe.

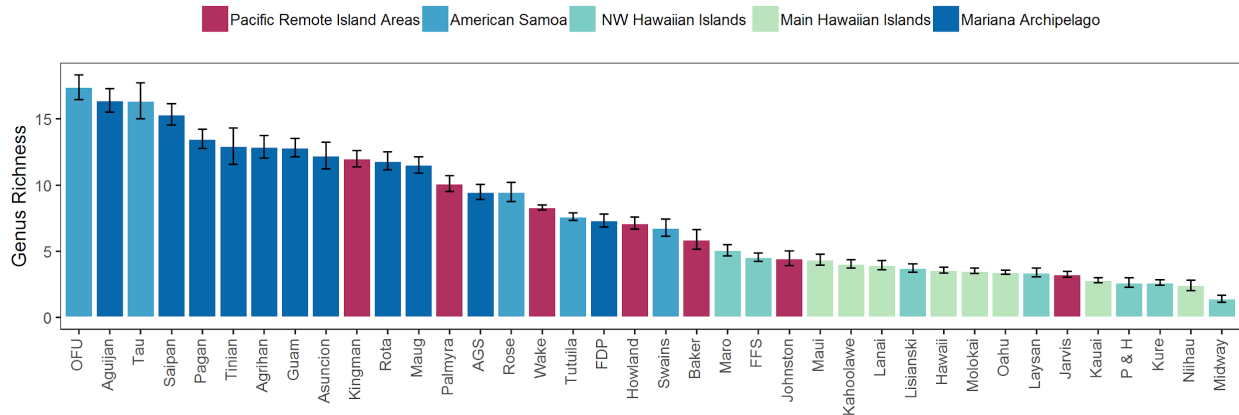


Figure 10. Mean (± 1 SE) generic richness of corals per site (calculated as cumulative richness observed in three benthic segments [7.5m²] per site). Data shown are from the most recent survey years (PRIMNM: 2018; American Samoa: 2018, Northwestern and main Hawaiian Islands: 2016, and Mariana Archipelago: 2017) and includes all foreereef depth strata (0–30m).

The mean richness of coral genera per site was variable among the islands of the PRIMNM (Figure 10). Kingman Reef and Palmyra Atoll were the most diverse, while Jarvis Island had the fewest genera (exacerbated by the large mortality event observed in 2015–2016). A table showing total generic richness of hard corals in the PRIMNM can be found in Appendix A. In the context of the wider-Pacific U.S. jurisdictions, the coral diversity observed across the PRIMNM was moderate. Islands within the American Samoa and Mariana Archipelago regions tended to have greater diversity of coral genera than the PRIMNM, while the Northwestern and main Hawaiian Islands tended to be less diverse. It is worth mentioning that mean generic richness observed in Tutuila in American Samoa (~7 genera per site) in 2018 was likely low due to inclement weather reducing the variety of habitats and number of sites surveyed that year (compared to ~12 genera per site observed in 2015). Bleaching-induced mortality may also have contributed to a reduction of diversity in 2018, and thus warrants more investigation.

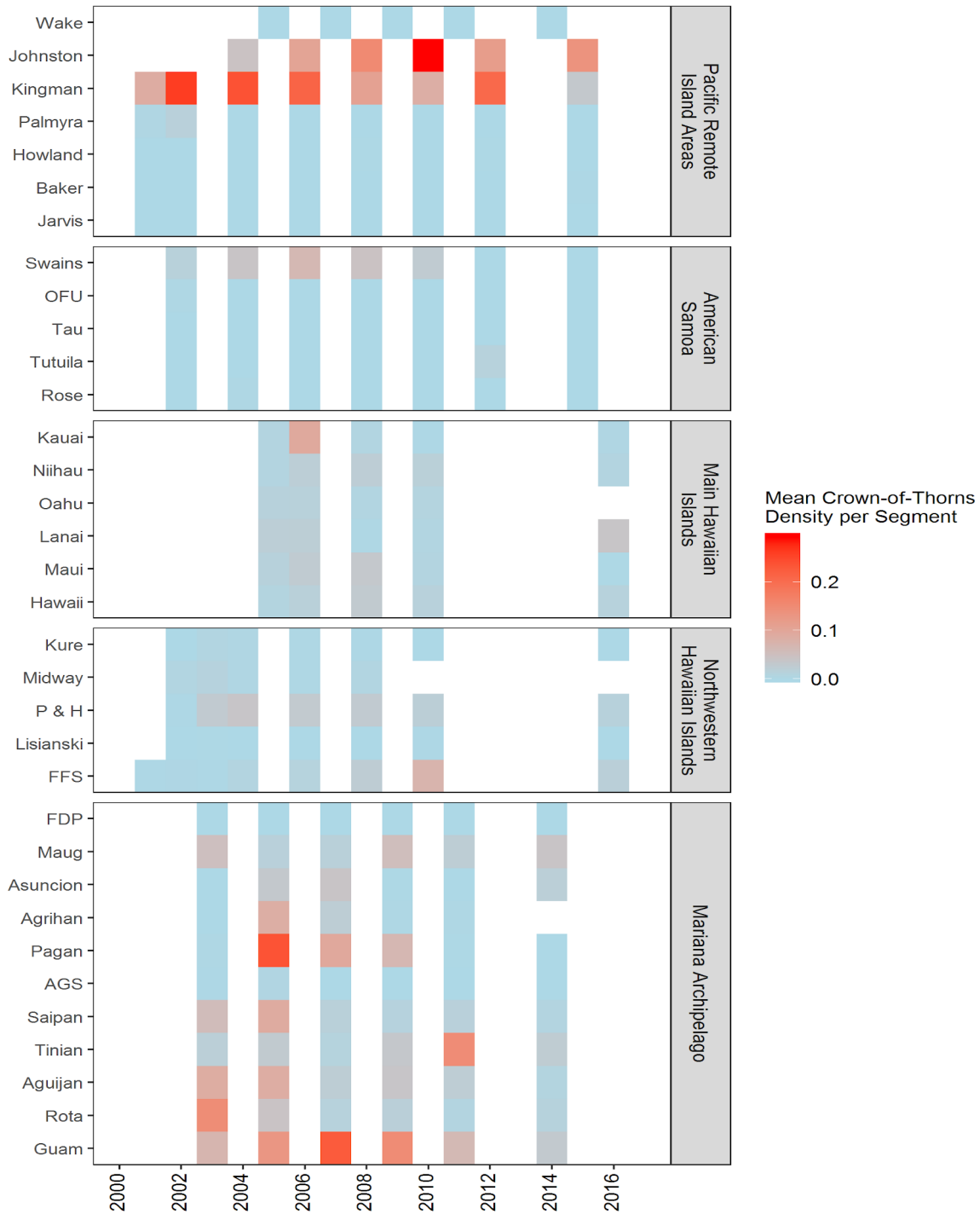


Figure 11. Mean density (individuals/100 m²) of the crown-of-thorns sea star (COTS) observed per segment from benthic towed-diver surveys (TDS) conducted throughout all depth strata (>0–30 m). Data are shown by survey year for all five regions of RAMP operations from 2001 to 2016.

Across the PRIMNM, crown-of-thorns sea star (*Acanthaster planci*, COTS) was consistently observed only at Kingman Reef and Johnston Atoll, though densities fluctuated across survey years (Figure 11). Sightings of COTS in the other islands of the PRIMNM have been sporadic

and always in small numbers. Throughout the U.S. Pacific jurisdictions, the presence of COTS was widespread over space and time. Densities in the Hawaiian Archipelago have been consistently low, while at some islands in the Mariana Archipelago, densities were similar to those observed in Kingman and Johnston. Periodic COTS outbreaks have been reported in American Samoa (Bucchianeri 2013; Barker 2018; Schumacher et al. 2018), yet were not captured by the Pacific RAMP surveys. Timmers et al. (2012) showed that localized outbreaks that occurred at similar times across central Pacific reefs appeared to be genetically independent rather than spread via the planktonic larvae released from a primary outbreak source. The authors concluded that synchronized sequential outbreaks were more likely driven by similar environmental conditions in the areas where outbreaks occurred.



*Periclimenes and Stichodactyla at Palmyra Atoll.
Photo: Megan Moews-Asher, NOAA Fisheries.*

Cryptofauna Biodiversity

9.5 Cryptofauna Biodiversity



A magnified image of a hairy crab found in an Autonomous Reef Monitoring Structure picked up from Palmyra Atoll.

Photo: Evan Barba, HIMB, courtesy NOAA Fisheries.

Much of the biomass and most of the biodiversity on a coral reef lies within the complex architecture of the reef matrix: the cryptobiota. Cryptobionts are the “insects of the sea” and are fundamental to nutrient recycling and the ability of reefs to thrive in oligotrophic oceans. Yet, this community is poorly understood in part due to their sheer diversity and the challenges in extracting them from the reef matrix. Using standardized sampling devices, such as Autonomous Reef Monitoring Structures (ARMS), across space and time, scientists are creating baselines of the cryptofauna community to understand what is present and abundant on our reefs today.

Biodiversity is one of the key factors that supports ecosystem resilience and, therefore, is an important variable for evaluating both the health of ecosystems and the success of management. A more diverse ecosystem has greater functional redundancy, which increases its probability of withstanding and recovering from impacts, such as disease and hurricane events. However, biodiversity is an extremely challenging variable to quantify given the inherent diversity that exists within coral reef ecosystems. The ARMS surveys in the PRIMNM provide the first standardized baseline of cryptofauna that recruited to this particular niche space.

ESD deployed and recovered 251 ARMS units from 91 sites between 2013 and 2018. Of these, 55 ARMS units from 19 sites were recovered in the PRIMNM. Family-level richness varied within the PRIMNM with Jarvis having the greatest richness of the 2 mm fauna and Wake having the lowest (Figure 12). Kingman additionally had the lowest abundance of 2 mm cryptofauna while Wake and Jarvis had the greatest. Compared to the rest of the U.S. Pacific regions, the PRIMNM had comparable overall richness with American Samoa but lower than the Hawaiian and Mariana Archipelagos.

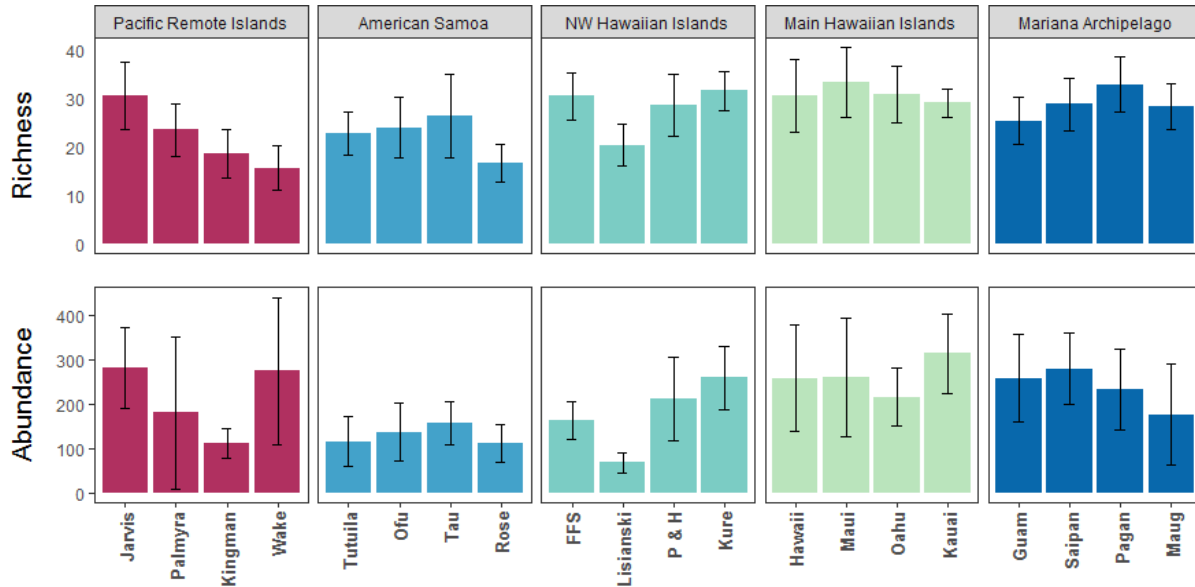


Figure 12. Mean richness and abundance of ≥ 2 mm cryptofauna per ARMS unit across islands in the U.S. Pacific.

From the 55 ARMS units in the PRIMNM, a total of 12,312 organisms were counted and identified to 112 families across seven phyla. The dominant phyla were Arthropoda, Mollusca, and Echinodermata with 9,142; 2,749; and 429 organisms, respectively, identified to 32, 52, and 21 families. When examining the top 15 families across all regions, the PRIMNM had the greatest number of Paguroidea (hermit crabs—detritivores) and Columbellidae (marine snails—omnivores). These 15 families represented 75% of the total organisms counted across all regions. The remaining 25% were split across 183 identified families. The proportional abundances of these dominant 15 families within the PRIMNM were similar to the main Hawaiian Islands (Figure 13).

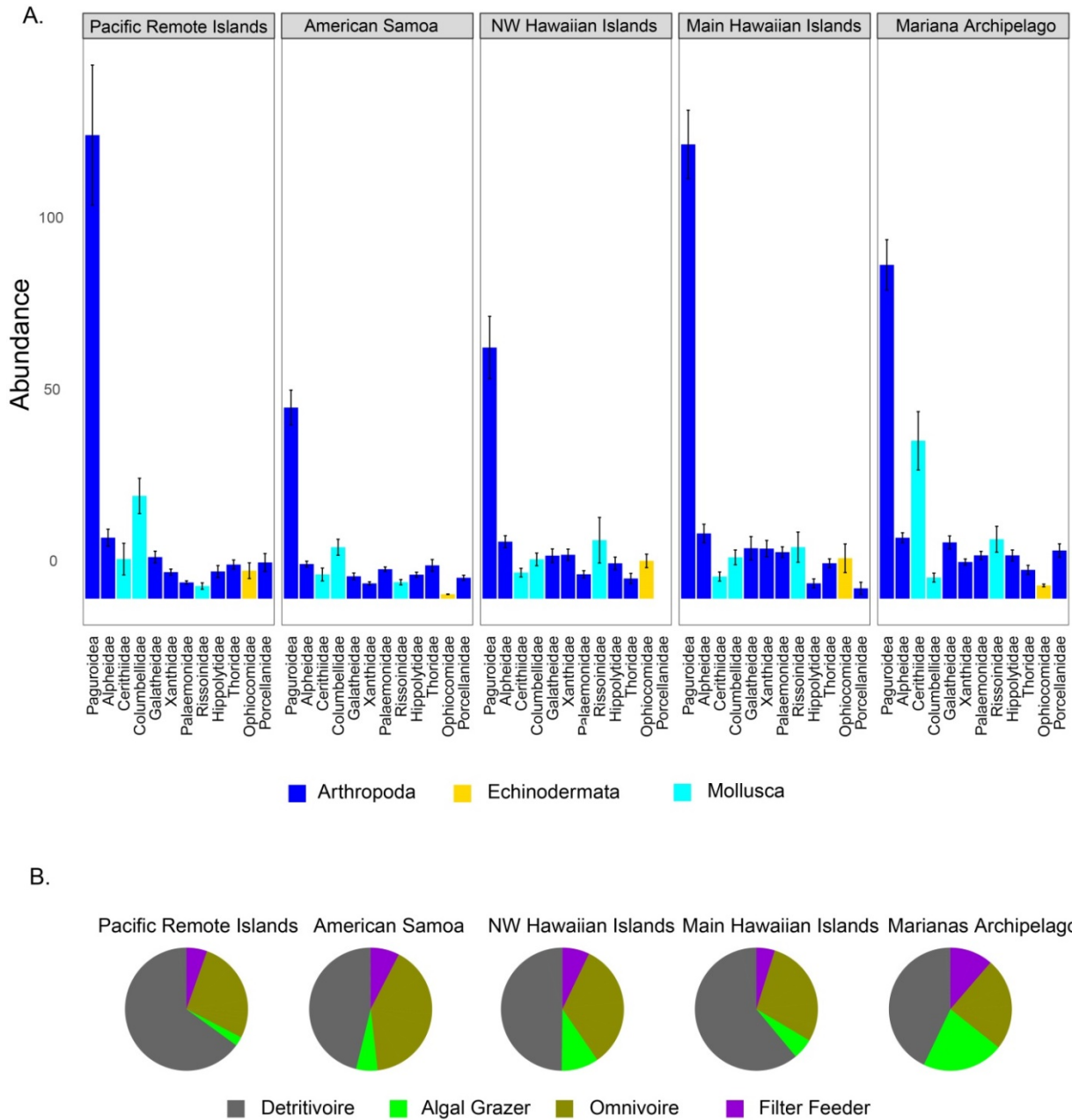


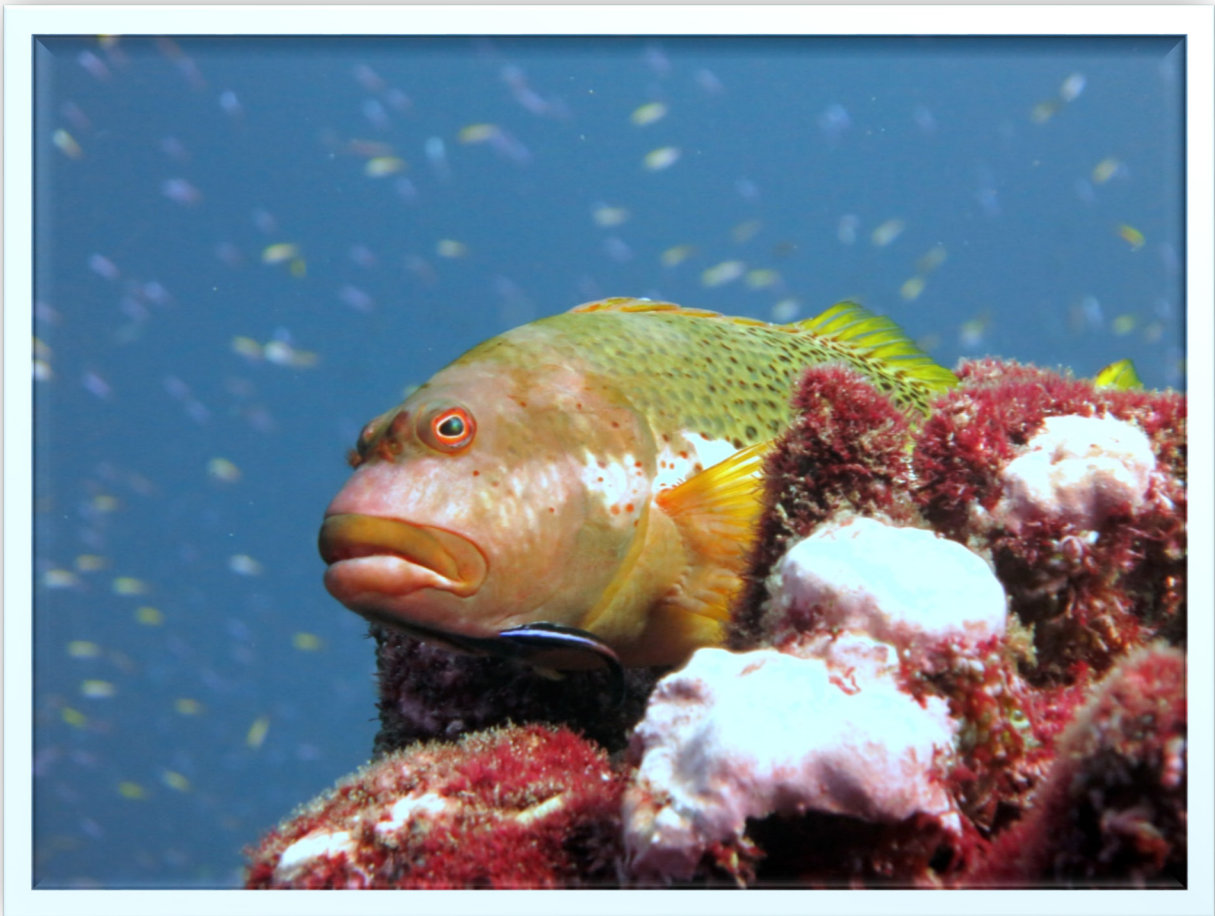
Figure 13. (A) Mean abundance of the dominant 15 families found on the ARMS units across all U.S. Pacific regions. (B) The relative trophic proportion of those 15 families across regions.



Dascyllus auripinnis and *Stichodactyla* at Palmyra Atoll.
Photo: Megan Moews-Asher, NOAA Fisheries.

Microbiota

9.6 Microbiota



Paracirrhites hemistictus and cleaner wrasse at Jarvis Island.
Photo: Andrew E. Gray, NOAA Fisheries.

The reef microbiota facilitate the cycling of essential nutrients by breaking down organic materials released by photosynthetic benthic macroorganisms. Reef water samples were collected from sites across all the U.S. Pacific Islands beginning in 2008, with the first PRIMNM samples measured in 2009 at Wake and Johnston Atolls and 2010 at Jarvis, Howland, and Baker Islands, Palmyra Atoll, and Kingman Reef. The assessment and monitoring of the reef microbiota paired with data collected on benthic and pelagic macro-biota across the entire U.S. Pacific allows for characterization of coral reefs from a molecular to an ecosystem scale.

Microbial biomass on reefs

Habitats dominated by reef-building organisms (e.g., stony corals and calcified algae) are often characterized by reduced microbial activity as energy and nutrients move through metazoan food webs. Non-calcifying benthic organisms like fleshy macroalgae and turf algae (observed in

higher abundances on human-impacted reef systems) release high amounts of bioavailable dissolved organic carbon (DOC) and support larger, fast-growing microbial communities that use these nutrient resources to sustain their greater metabolic demands. The associated changes in microbial community structure and biomass when benthic community composition shifts from corals to algae shunts much more of the energy produced by the system towards decomposition pathways with enhanced respiration of organic compounds to carbon dioxide. This phenomenon is referred to as microbialization. Correspondingly, islands with greater algal dominance and lower calcifier cover have higher microbial biomass (as observed on the main Hawaiian Islands; Figure 14), which exhibit up to an order of magnitude more microbial biomass in the overlying reef waters than the coral dominated reefs of Wake, Kingman, and Palmyra (i.e., Wake Atoll in 2009 = 12 mg m⁻³ and Oahu in 2008 = 153 mg m⁻³).

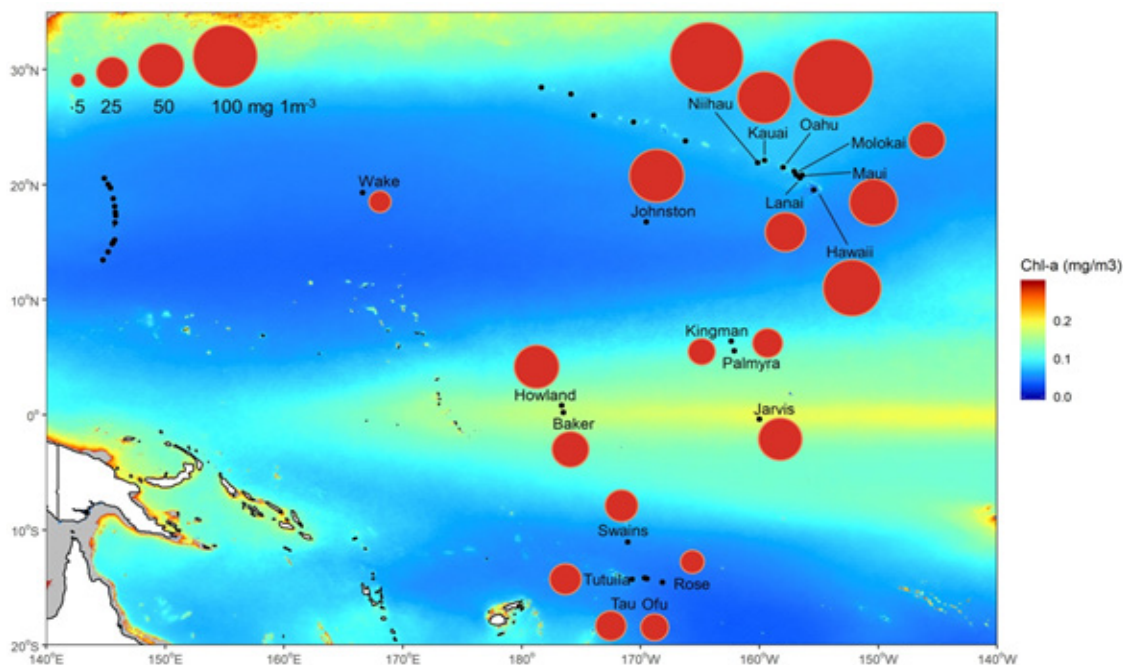


Figure 14. Microbial biomass (as cell volume; red circles) collected across the U.S. Pacific Islands from 2008 to 2010 (n = 150) across chl-a gradients. Cell volume was estimated based on measurements of cell length and width and cell abundances enumerated using epi-fluorescent microscopy. Biomass is reported as mg m⁻³. Data published in McDole et al. (2012).

Microbial Composition and Diversity

Microbial communities in reef waters were collected from 2012 to 2014, and extracted for shotgun sequence metagenomic libraries. Microbial community composition at uninhabited locations, including the PRIMNM, was characterized by higher community richness and evenness on average compared to other U.S. Pacific islands (Figure 15). The community structure of the microbes at inhabited sites was characterized by higher abundances of the dominant taxonomic groups, resulting in a loss of evenness and, therefore, lower Shannon Diversity (an index that accounts for both abundance and evenness of the species present and is commonly used to characterize diversity in a community).

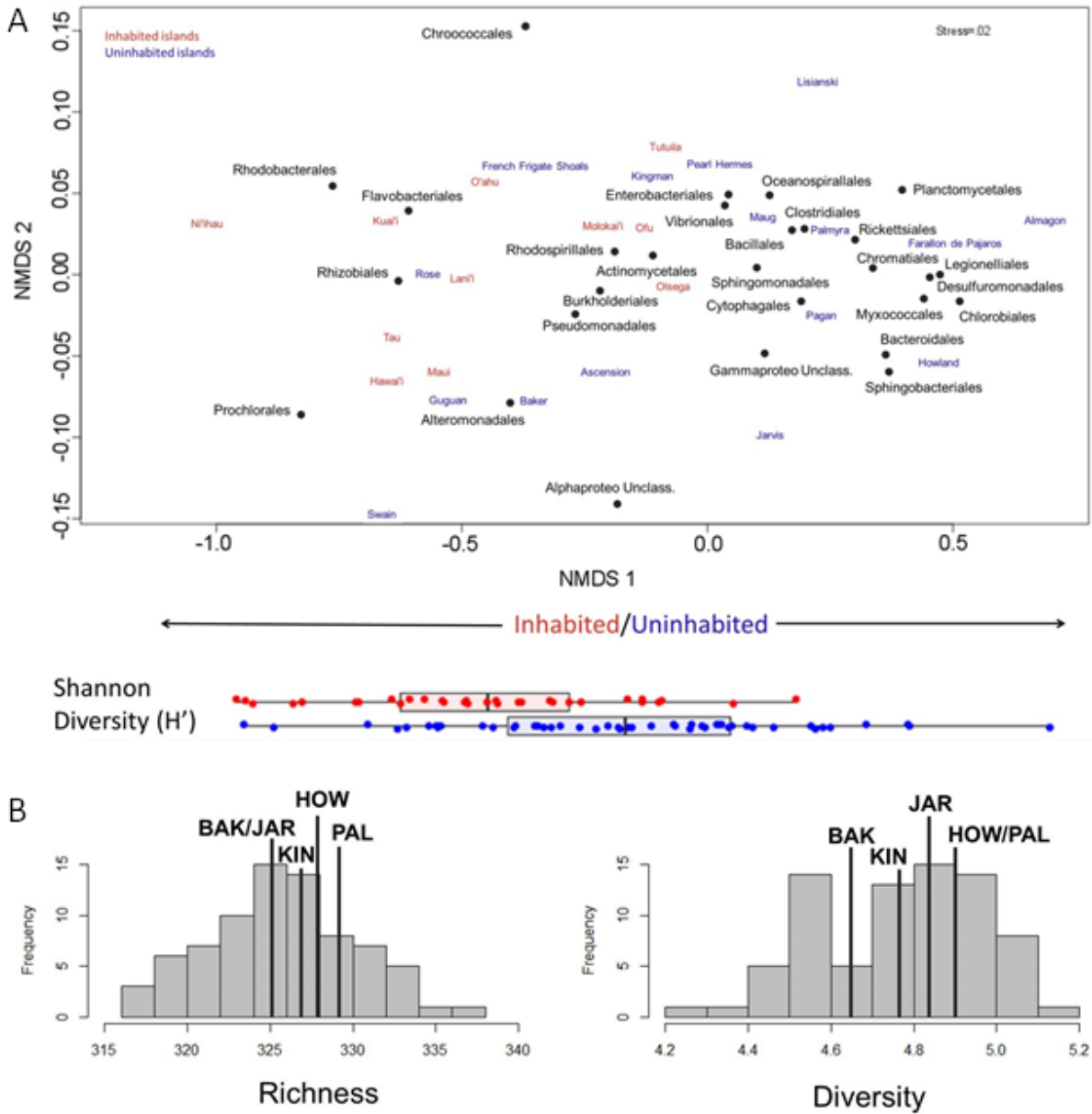


Figure 15. Pacific-wide microbial composition and diversity. (A) Ordination of microbial taxonomic groups shown at Order level, where uninhabited islands (blue) exhibit greater evenness across microbial taxa than inhabited islands (red). **(B)** Comparison of microbial diversity measured at Genus level on five areas of the PRIMNM overlaid on a histogram of all Community Richness and Shannon Diversity (H') observations across the U.S. Pacific islands collected between 2012 and 2014 ($n = 77$ reef sites). Note: height of black bars denoting PRIMNM locations are staggered for ease of labeling and are not representative of the frequency histogram.

Reef Fishes



*Parrotfish (Bolbometopon muricatum) at Wake Atoll.
Photo: Andrew E. Gray, NOAA Fisheries.*

9.7 Reef Fishes



*Jacks (Caranx sexfasciatus) at Wake Atoll.
Photo: Kevin Lino, NOAA Fisheries.*

Reef fish biomass

Mean total reef fish biomass varied by a factor of >15 among the islands surveyed for the Pacific RAMP (Figure 16). The equatorial upwelling and central transition islands of the PRIMNM were among the islands with the highest biomass, all greater than 150 g m^{-2} (Figure 16). Fish biomass was less than 100 g m^{-2} at all locations other than the equatorial islands and several of the Northwestern Hawaiian Islands, and generally less than 50 g m^{-2} at inhabited islands (Figure 16). Total fish biomass at the two other PRIMNM islands—Wake and Johnston Atolls—was generally comparable to remote and uninhabited islands in the Mariana Archipelago (Figure 16).

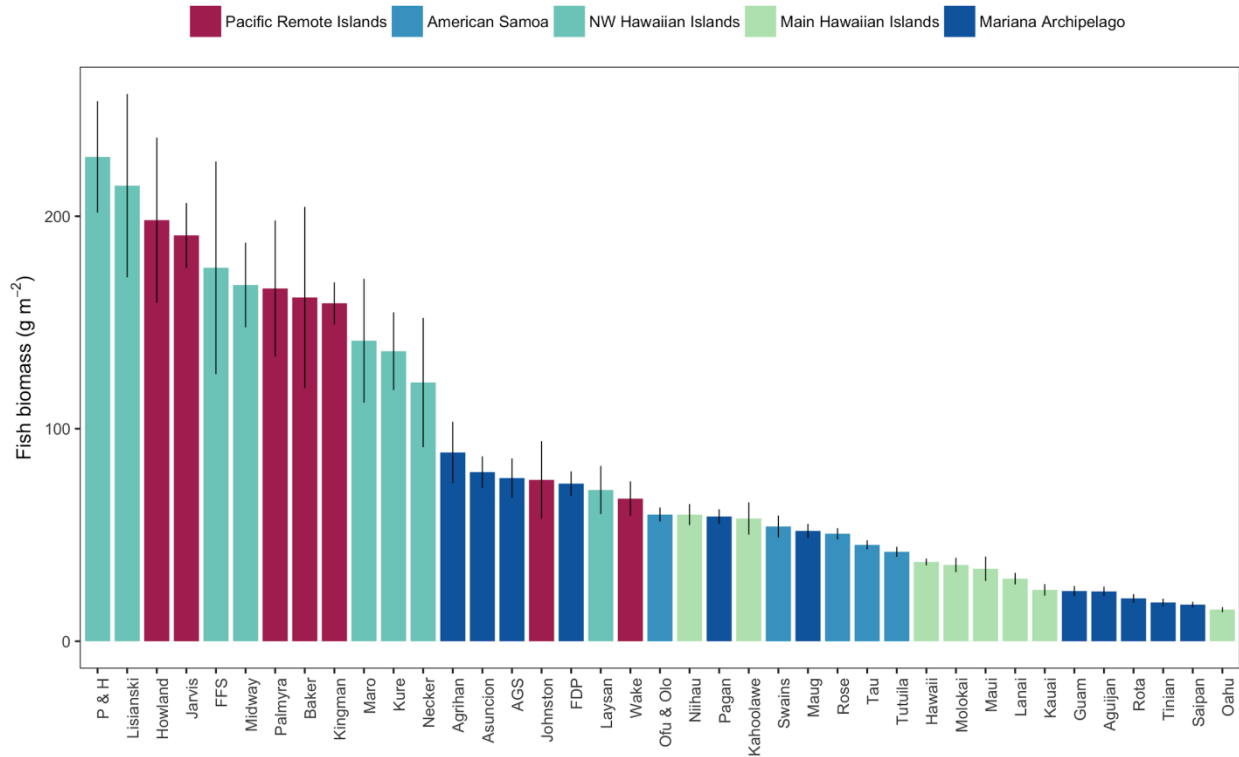


Figure 16. Mean total fish biomass (g m⁻² ± SE) by island surveyed for the Pacific RAMP. Data shown are from all surveys conducted in foreereef and protected slope habitats since the adoption of the stationary point count method and new survey design in 2010. All depth strata are included (0–30 m).

The high fish biomass observed in the equatorial upwelling and central transition islands of the PRIMNM and the Northwestern Hawaiian Islands was primarily a reflection of very high biomass of large-bodied (>50 cm TL) fishes in these two regions (Figure 17, Figure 16). Notably, Baker, Howland, and Jarvis Islands also had very high biomass of fishes in the smallest size class (<20 cm TL, Figure 17), due to superabundant small planktivores and relatively high biomass of small primary consumers.

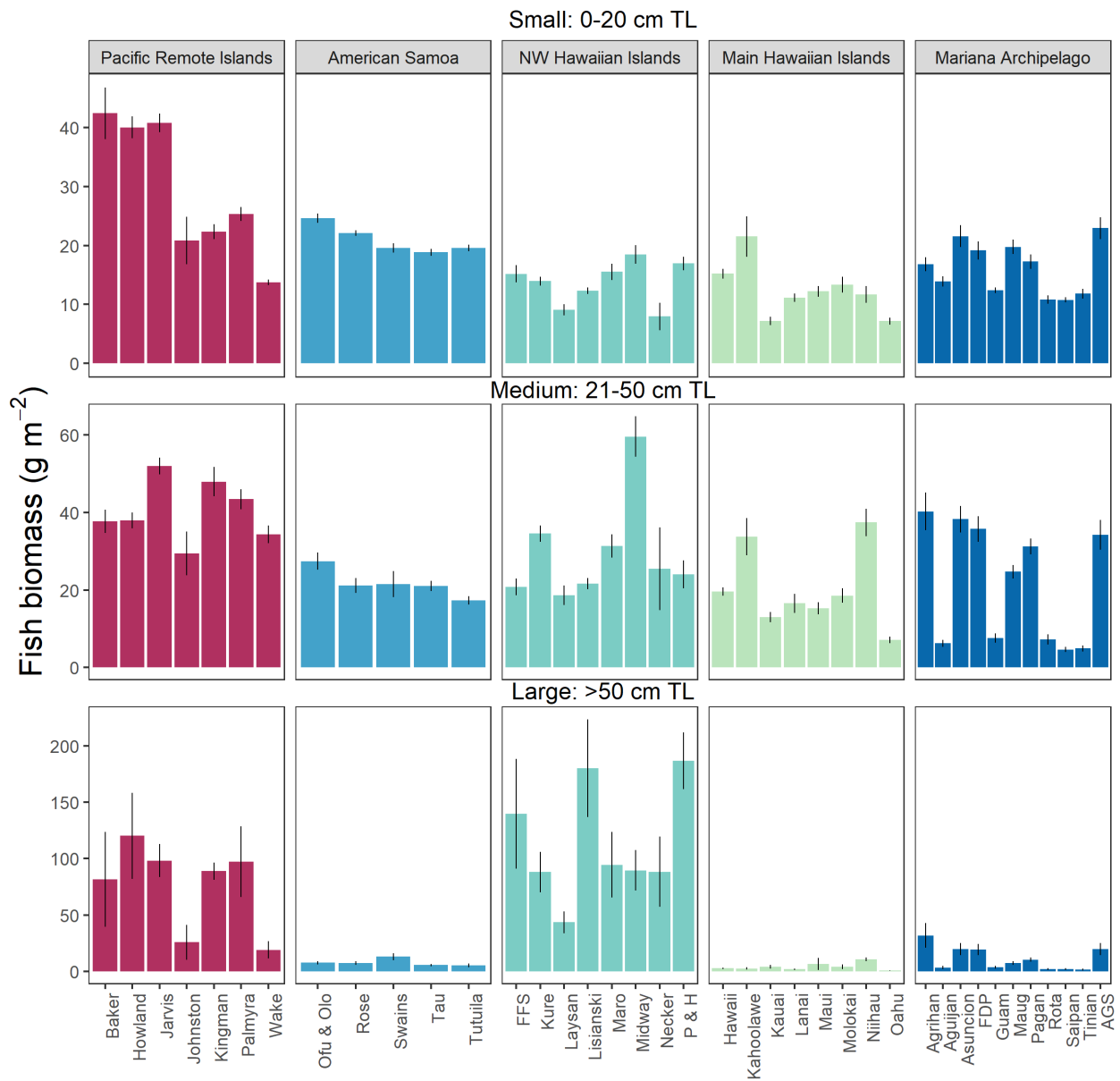


Figure 17. Mean total reef fish biomass (g m⁻² ± SE) by size class and island. Data shown are from all surveys conducted in foreereef and protected slope habitats since the adoption of the stationary point count method and new survey design in 2010. All depth strata are included (0–30 m).

Equatorial upwelling and central transition islands of the PRIMNM also had notably high biomass of piscivores and planktivores (Figure 18). In fact, Wake Atoll was the only of the PRIMNM islands that did not have high biomass of planktivores (Figure 18).

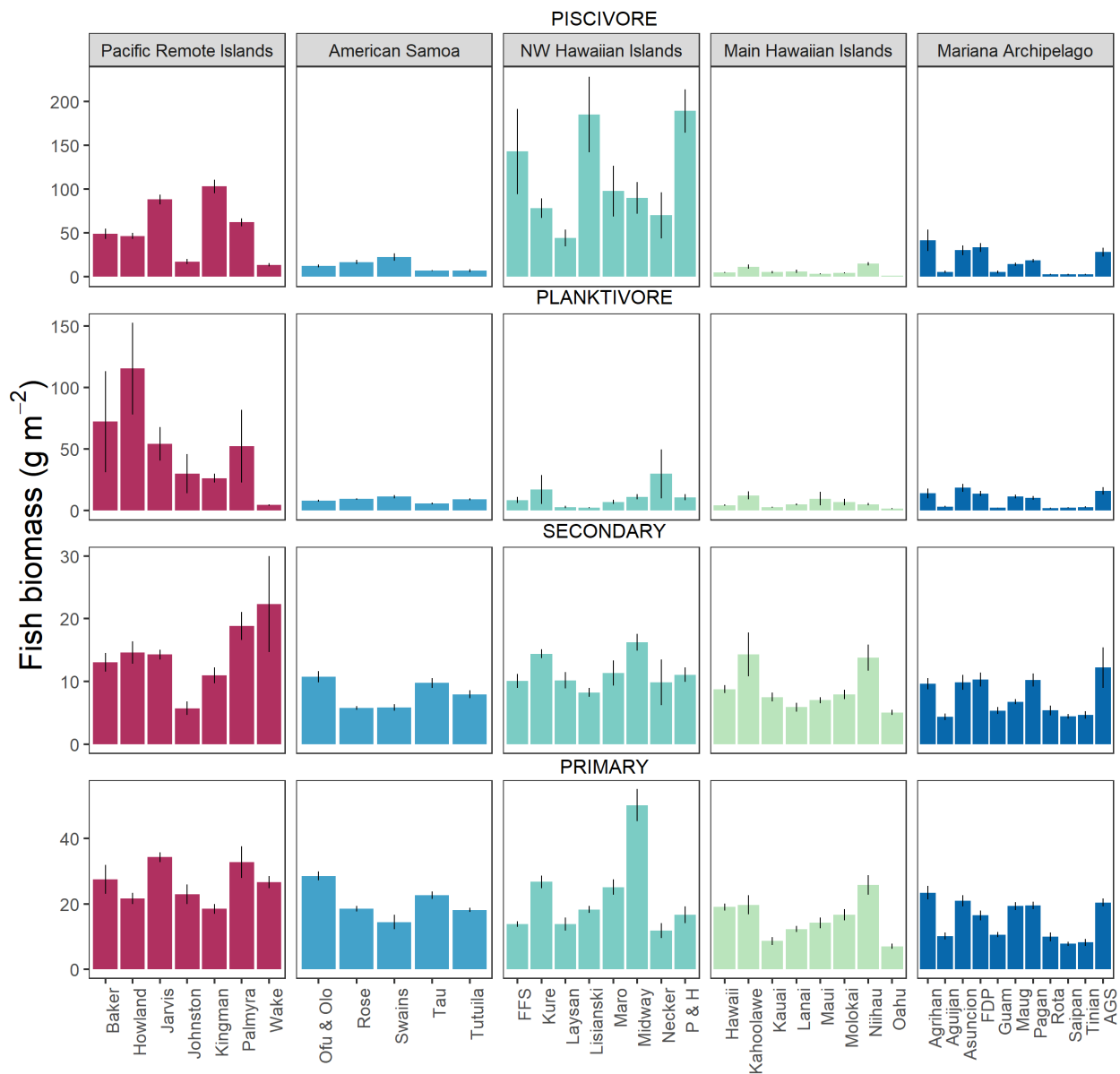


Figure 18. Mean total reef fish biomass ($\text{g m}^{-2} \pm \text{SE}$) by consumer group by island. Data shown are from all surveys conducted in foreereef and protected slope habitats since the adoption of the stationary point count method and new survey design in 2010 to the end of 2017. All depth strata are included (0–30 m).

Wake Atoll was notable for the high rate of sightings of bumphead parrotfishes (*Bolbometopon muricatum*), which were much more frequently observed there than at any other area surveyed for Pacific RAMP (Figure 19). High biomass of bumphead parrotfish also contributed to the high biomass of secondary consumers at Wake (Figure 18), as that species is classified as a corallivore (i.e., a secondary consumer), unlike all other parrotfishes that are classified as primary consumers.

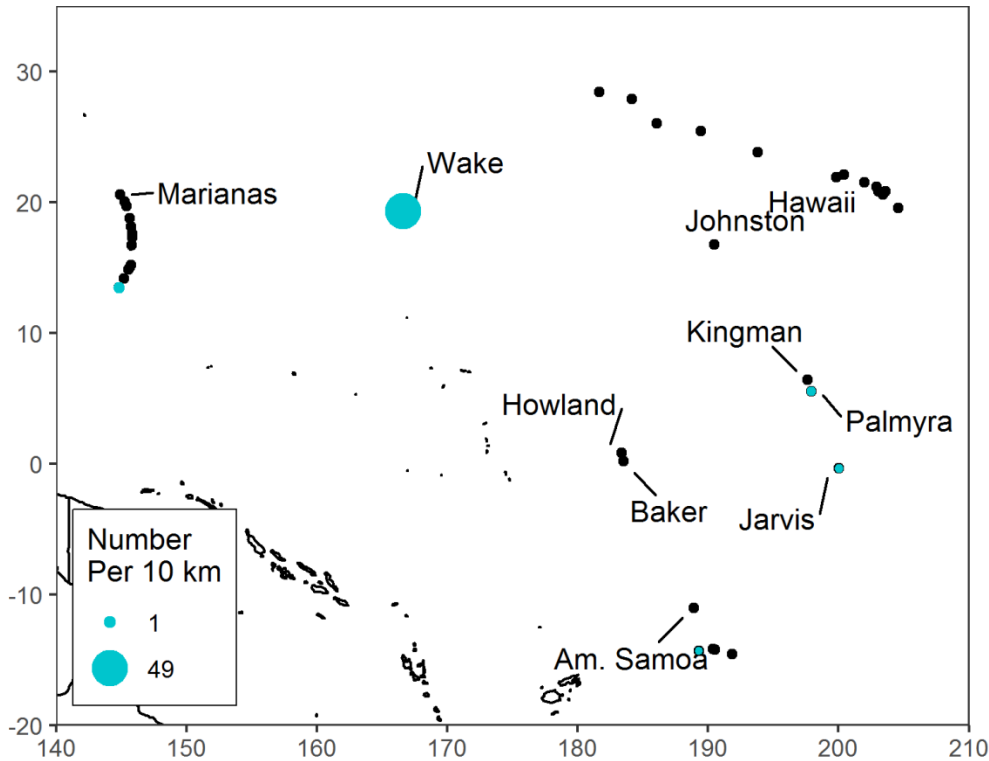


Figure 19. Cumulative sightings of bumphead parrotfishes per 10 km of distance towed, based on all towed divers surveys conducted from 2005 to 2017. Solid black circles denote where no bumphead parrotfish were observed.

Several of the species listed as threatened or vulnerable by the Endangered Species Act were seen in higher numbers in the PRIMNM than in other areas of the U.S. Pacific. Manta rays (*Mobula* spp.) were more frequently seen at the equatorial islands of the PRIMNM, along with scalloped hammerhead sharks (*Sphyrna lewini*) and various species of sea turtles (Figure 20, Figure 21). Wake and Palmyra Atolls had higher sightings of humphead wrasse, *Cheilinus undulatus* (Figure 20). A complete list of all fish species observed in the PRIMNM is provided in Appendix B.

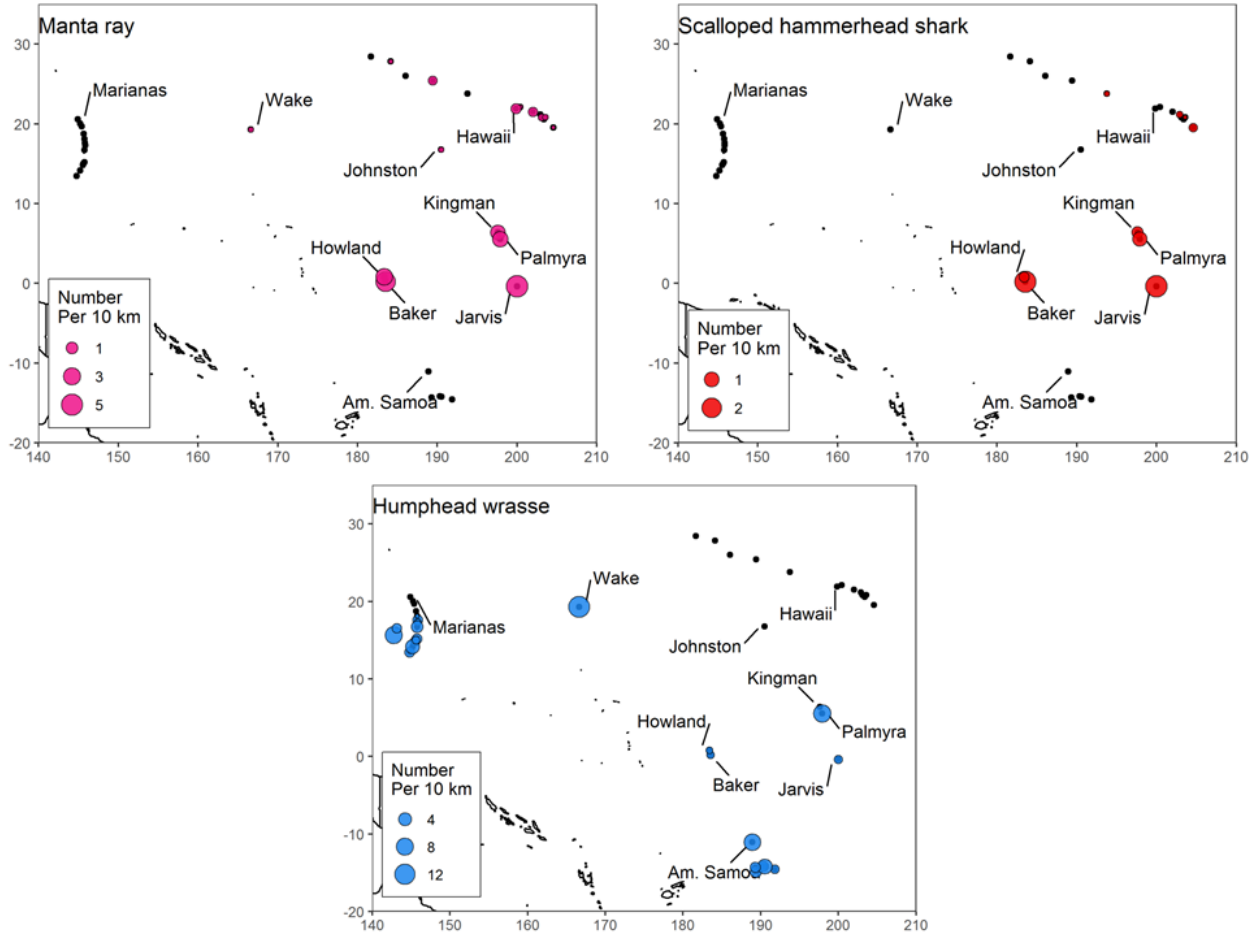


Figure 20. Cumulative sightings of Endangered Species Act-listed fish species per 10 km of distance towed, based on all towed divers surveys conducted from 2005 to 2017. Species shown are manta rays, scalloped hammerhead shark, and humphead wrasse.

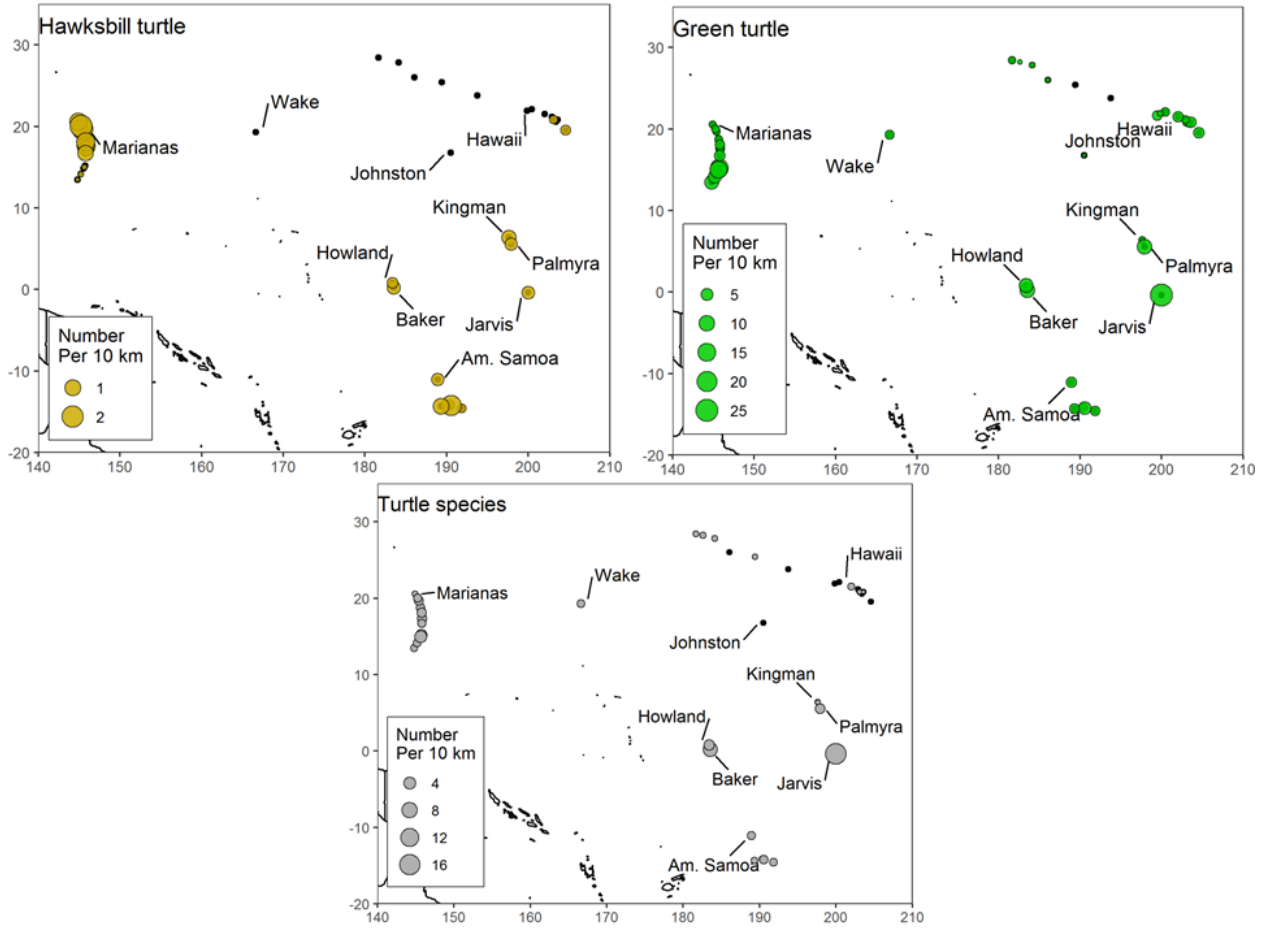


Figure 21. Cumulative sightings of Endangered Species Act-listed turtle species per 10 km of distance towed, based on all towed divers surveys conducted from 2005 to 2017. Taxa shown are hawksbill sea turtle, green sea turtle, and observations of turtles where divers were not able to identify the species (shown as “Turtle species”).



*Acanthurus triostegus at Wake Atoll.
Photo: Ron Hoeke, NOAA Fisheries.*

Ecosystem Integration

9.8 Ecosystem Integration



Top row, left to right: Chaetodon punctatofasciatus at Wake Atoll, Photo: Andrew E. Gray; reef at Johnston Atoll, Photo: Marc Nadon; NOAA divers taking water samples for microbiota analyses; Carcharhinus at Jarvis Island, Photo: Hatsue Bailey. Bottom row, left to right: Chlorurus microrhinos at Kingman Reef, towed diver at Howland Island, manta at Baker Island, and Epinephelus polyphkadion at Kingman Reef, Photos: Kevin Lino; benthic community including anthias, Pseudanthias bartlettorum, Plectroglyphidodon dickii, jack, and damselfish, Photo: Andrew E. Gray. All photos courtesy NOAA Fisheries.

Across the PRIMNM, there are variations in oceanographic and environmental drivers that largely reflect the positioning of each island relative to the equator and oceanic currents. Despite these oceanographic differences, coral cover remained relatively high across the PRIMNM, with low coral partial mortality at most islands and atolls across survey years which suggests that these reefs have historically been capable of recovering from disturbances, such as thermal events (e.g., Barkley et al. 2018) and hurricanes. Underlying such recovery may be the high mean rate of carbonate accretion measured across the PRIMNM, which was the highest among regions (along with American Samoa) in the U.S. Pacific. This overall rate likely reflects the nutrient-rich conditions that characterize the central transition and equatorial upwelling islands of the PRIMNM that are located near the equator.

In addition to oceanographic and environmental drivers, human activity greatly influences and shapes coral-reef communities. Across the U.S. Pacific Islands, biomass of reef fishes is consistently and substantially lower at human-populated versus remote locations—i.e., locations that are situated 200 km or more from the nearest human population (Williams et al. 2015, Figure 22). All of the islands and atolls of the PRIMNM, other than Wake Atoll, are considered remote (note that although Palmyra has a small year round presence of researchers, managers, and support staff, extractive fishing of reef fishes is not permitted there). Reef fish biomass at several islands of the PRIMNM was among the highest recorded by the RAMP survey program, comparable only to some of the islands in the Papahānaumokuākea Marine National Monument in the Northwestern Hawaiian Islands (Figure 22). The PRIMNM has also been notable for supporting larger abundances of species listed under the Endangered Species Act (ESA),

including the greatest densities of the green sea turtle (*Chelonia mydas*) observed in the U.S. Pacific, with numbers of sightings remaining stable through time (Becker et al. 2019). ESA-listed corals, such as *Acropora retusa*, *Isopora crateriformis*, and *Pavona cf. diffluens*, have been sighted in the PRIMNM (Kenyon et al. 2010).

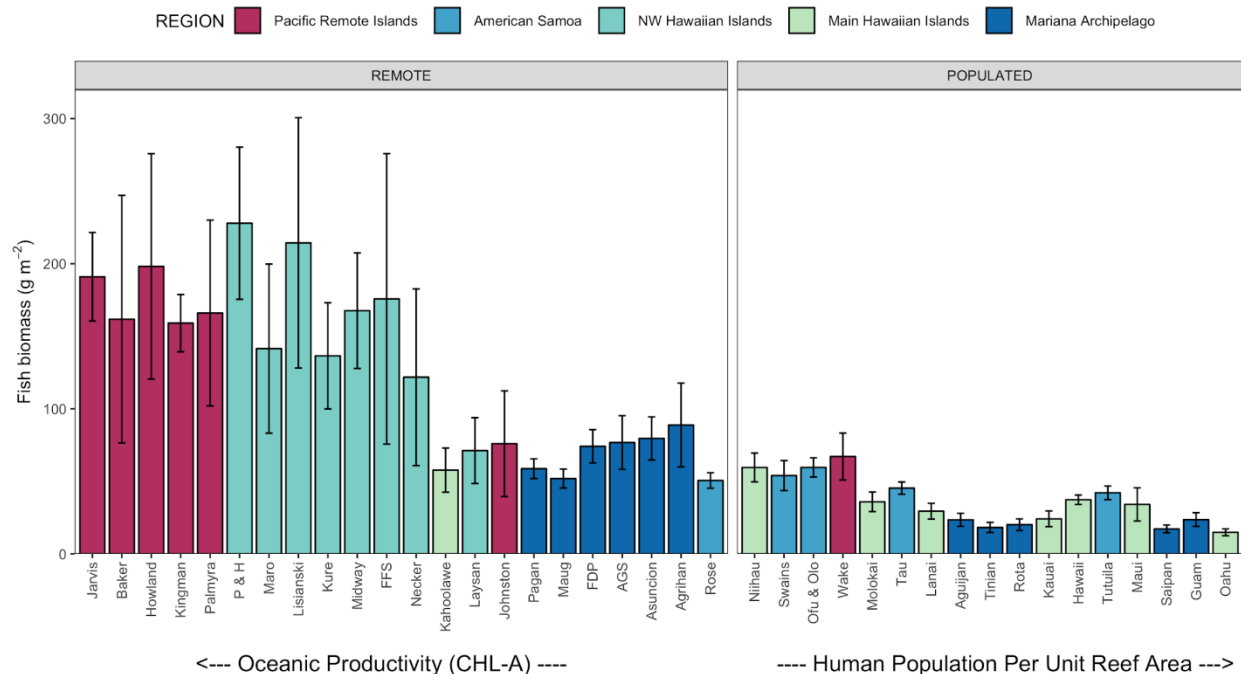


Figure 22. Mean fish biomass (± 1 SEM) at remote (left panel) and populated (right panel) islands of the U.S. Pacific. Remote islands are positioned from left to right in order of decreasing values of oceanic productivity (measured as chlorophyll-a), whereas populated islands are positioned from left to right in order of increasing human population (per unit reef area). These data are therefore indicative of a positive relationship between fish biomass and oceanic productivity, and a negative relationship with human population density, as has been previously shown for these locations (Williams et al. 2015).

Typical of remote locations, the PRIMNM also exhibited greater diversity of reef microbiota, which broadly is essential for coral reefs in facilitating nutrient cycling. Furthermore, microbialization—an indicator of shifting energy flow in a system as a result of major community shifts—was low across the PRIMNM (Figure 23); again, likely reflective of minimal reef degradation or fish depletion resulting from low human impacts (McDole et al. 2012). Johnston Atoll was an exception, with a microbialization score comparable to other U.S. Pacific Islands with the greatest magnitudes of human impact (Figure 23), perhaps due to the long history of military use at Johnston. Indeed, within the PRIMNM, cover of hard coral tended to be the lowest at Johnston, and cover of CCA was lowest at Wake Atoll, resulting in lower proportions of benthic calcifiers at these atolls compared to the rest of the PRIMNM. These patterns may reflect the oligotrophic conditions or reduced rates of carbonate accretion observed at Johnston and Wake, which were also the lowest mean rates observed across the U.S. Pacific. Johnston’s reefs may have further been influenced by the COTS, which were consistently sighted across all survey years within the PRIMNM only at Johnston and Kingman Reef. Spatial variance in the presence of this corallivorous sea star across the PRIMNM was consistent with

genetic studies (Timmers et al. 2012) that indicate COTS populations in the U.S. Central Pacific are genetically independent and do not exhibit high connectivity via larval dispersal.

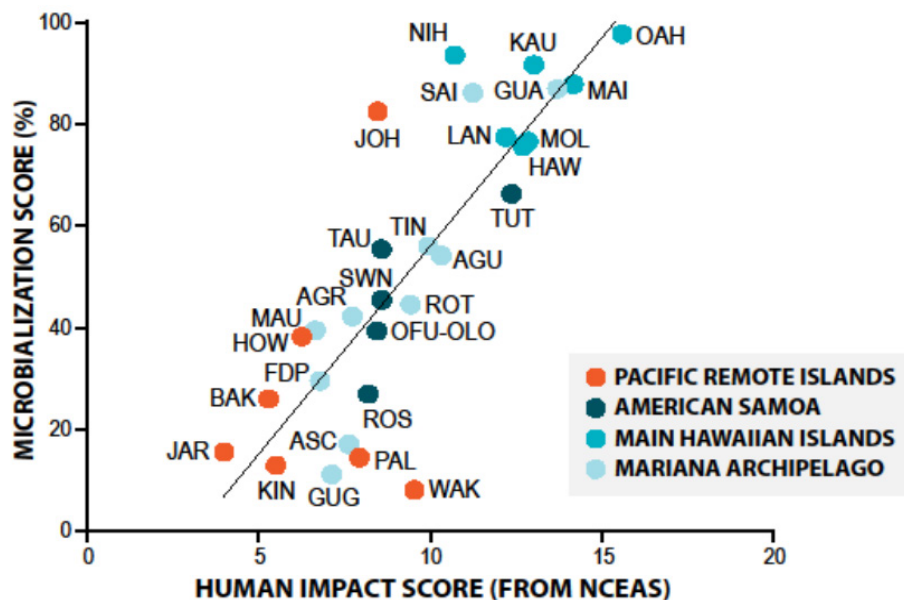


Figure 23. Proportion of total reef metabolic rate composed of microbial metabolic rate (i.e., microbialization score) versus the cumulative human impact scores on coral reefs (scores provided by NCEAS) of the U.S. Pacific Islands. A higher microbialization score may indicate enhanced vulnerability of an ecosystem to phase shifts from coral- to macroalgal-dominated states. The positive relationship between human impact and microbialization is indicated by the solid line (linear regression: 95% CI of slope = 5.994 to 10.39). Individual islands are labeled with the first three letters of their name, and U.S. jurisdictional regions are indicated by color.

Given their locations relatively far north of the equator, the northernmost oligotrophic islands are largely removed from the influences of equatorial currents and ENSO. Therefore, Johnston and Wake Atolls were less likely to experience substantial periods of thermal anomalies typically linked with El Niño events. However, these atolls lacked periodic nutrient enrichment via equatorial or topographic upwelling and were the only places in the PRIMNM located directly in the path of hurricanes. This combination of conditions likely influenced the overall composition of benthic and fish communities. In particular, the positive relationship between primary productivity and fish biomass in the U.S. Pacific (Figure 22) is already well-understood (Williams et al. 2015); within the PRIMNM, fish biomass was the lowest in the relatively oligotrophic waters of Johnston and Wake. These atolls also did not appear to support the ESA-listed hawksbill sea turtle (*Eretmochelys imbricata*), which were sighted at all other islands of the PRIMNM. Despite the relatively low productivity at Wake, the highest family-level richness of cryptofauna within the PRIMNM was observed at this atoll (along with Jarvis Island), as well as the greatest number of sightings of the bumphead parrotfish (*Bolbometopon muricatum*) and humphead wrasse (*Cheilinus undulatus*; along with Palmyra Atoll) across the U.S. Pacific.

In contrast with the northernmost islands of the PRIMNM, the equatorial upwelling and central transition islands experienced the greatest interannual variability in oceanographic conditions, with equatorial and topographic upwelling that varied widely in strength and intensity with ENSO cycles. During La Niña conditions, enhanced upwelling resulted in anomalously cool,

nutrient-rich surface waters fueling high productivity. This productivity likely supported fish biomass, which was highest throughout the equatorial upwelling and transition islands. Large-bodied species comprised a substantial portion of reef fish biomass at all of these locations, with the equatorial islands also having notably high biomass of small planktivores and other smaller-sized trophic groups (e.g., primary consumers). ESA-listed species were also frequently observed at the equatorial islands of the PRIMNM, including manta rays (*Mobula* spp.), scalloped hammerhead shark (*Sphyrna lewini*), and green sea turtle (*Chelonia mydas*).

Across the U.S. Pacific Islands, levels of primary productivity were highest at Jarvis Island due to the combination of strong topographic upwelling in addition to equatorial upwelling. As noted earlier, elevated nutrient levels likely sustained greater fish biomass and potentially supported the local cryptobiont community which consisted of the greatest family-level richness and abundance within the PRIMNM. Becker et al. (2019) also hypothesized that the high chlorophyll-a concentrations measured at Jarvis may have contributed to the corresponding high densities of the green sea turtle, potentially in combination with optimal SSTs and the lowest level of human impact of all the U.S. Pacific Islands. In contrast, the fewest number of coral genera were observed at Jarvis, possibly due to limited larval connectivity with other U.S. Pacific Islands or highly diverse source regions, such as the Coral Triangle.

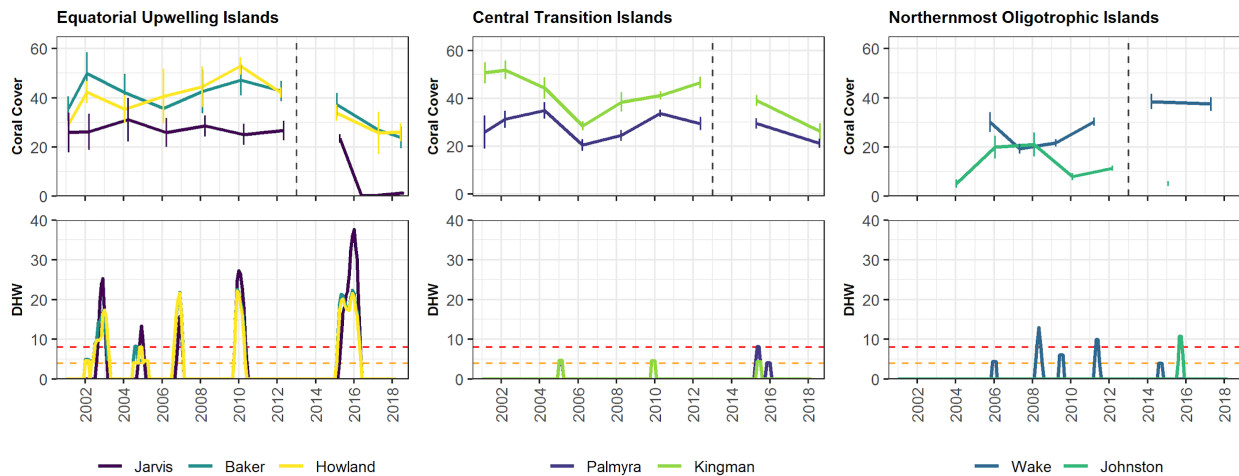


Figure 24. Time series of mean coral cover (± 1 SEM, top row) and degree-heating weeks (DHW, bottom row) at the equatorial upwelling Islands (left), central transition islands (middle), and northernmost oligotrophic islands of the PRIMNM. In plots of DHW, horizontal dashed lines indicate threshold levels in which moderate coral bleaching is expected (DHW = 4, orange line) and severe coral bleaching and mortality is expected (DHW = 8, red line). Vertical dashed lines in plots of coral cover indicate when the sampling method shifted from towed-diver surveys (TDS) survey data (pre-2013) to benthic Rapid Ecological Assessment (REA) survey data (post-2013). All cover data shown, irrespective of method, are from the mid-depth forereef. Note: the time series of DHW extends to April 2018.

During El Niño events, the weakening of upwelling resulted in warmer, more oligotrophic surface waters at the equatorial upwelling islands, which in turn experienced the greatest thermal stress through time in both frequency and magnitude within the PRIMNM (Figure 24). Thermal stress was reduced in comparison at all other remaining islands of the PRIMNM, with the likelihood of detectable levels further varying by the longitudinal positioning of each island and

whether a given El Niño event occurred in the Central versus Eastern Pacific. While some of the islands' temporal patterns in coral cover suggest a corresponding relationship with thermal stress, Jarvis Island provides the clearest example, whereby a massive decline in coral cover followed the unprecedented extent of thermal stress measured during the 2015–2016 El Niño event. Subsequent surveys indicated the benthic community has continued to shift (e.g., cover of CCA had increased by 2018, Vargas-Ángel et al. 2019), which emphasizes the need for continued monitoring to assess the extent of rebound and recovery of the benthic community versus potential phase shifts that may ultimately lead to reef degradation.

The transition islands are located further north from the equator and tended to experience more moderate levels of thermal stress and nutrient enrichment relative to the conditions that characterized the equatorial upwelling islands. In addition, Kingman and Palmyra are the only locations in the PRIMNM supplied via the North Equatorial Countercurrent with water sourced from more biologically-diverse reefs further west (Kenyon et al. 2010), which may have contributed to the most species-rich coral assemblage observed within the PRIMNM. The cryptobiont communities at Kingman and Palmyra, however, consisted of the lowest family-level richness and abundance of the PRIMNM.

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9.10 Appendices

APPENDIX A

Table A1. List of total generic richness of hard corals for the PRIMNM reef systems based on surveys conducted from 2010 to 2018. Presence of fire coral *Millepora* and blue coral *Heliopora* are included in this list.

Genus	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Acanthastrea</i>					X	X	X
<i>Acropora</i>	X	X	X	X	X	X	X
<i>Astrea</i>							X
<i>Astreopora</i>					X	X	X
<i>Caulastrea</i>					X		
<i>Coscinaraea</i>			X	X	X	X	
<i>Cycloseris</i>	X	X		X	X	X	X
<i>Cyphastrea</i>	X	X		X	X	X	X
<i>Echinophyllia</i>					X		X
<i>Echinopora</i>					X	X	X
<i>Favia</i>	X	X	X	X	X	X	X
<i>Favites</i>	X	X	X		X	X	X
<i>Fungia</i>	X	X	X	X	X	X	X
<i>Gardineroseris</i>		X			X	X	
<i>Goniastrea</i>	X	X	X		X	X	X
<i>Halomitra</i>					X	X	
<i>Heliopora</i>							X
<i>Herpolitha</i>	X				X	X	
<i>Hydnophora</i>	X	X	X		X	X	X
<i>Isopora</i>	X	X	X				X
<i>Leptastrea</i>	X	X	X	X	X	X	X
<i>Leptoria</i>						X	
<i>Leptoseris</i>	X	X	X	X	X	X	
<i>Lobophyllia</i>					X	X	
<i>Merulina</i>					X		
<i>Millepora</i>		X	X	X	X		X
<i>Montastraea</i>	X	X			X	X	X
<i>Montipora</i>	X	X	X	X	X	X	X
<i>Oulophyllia</i>					X		X
<i>Pachyseris</i>		X					

Genus	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Parascolymia</i>					X		
<i>Pavona</i>	X	X	X	X	X	X	X
<i>Phymastrea</i>							X
<i>Platygyra</i>	X				X	X	X
<i>Plerogyra</i>					X		
<i>Plesiastrea</i>							X
<i>Pocillopora</i>	X	X	X	X	X	X	X
<i>Podabacia</i>	X						
<i>Polyphyllia</i>					X		
<i>Porites</i>	X	X	X	X	X	X	X
<i>Psammocora</i>	X	X	X	X	X	X	
<i>Sandalolitha</i>						X	
<i>Scapophyllia</i>							X
<i>Stylocoeniella</i>							X
<i>Stylophora</i>					X	X	X
<i>Symphyllia</i>						X	X
<i>Tubastraea</i>	X	X	X			X	
<i>Turbinaria</i>	X	X			X	X	
Total	22	22	17	14	35	31	30

APPENDIX B

Table B1. Encounter Frequency of species seen on reef fish stationary point count (SPC) surveys from 2013 onwards. Only data from 2012 onwards are used for encounter frequency as additional presence observations were added to the survey method at that time. Where species have been observed by divers at a location, but only on SPC, a “P” is added to indicate that the species is present at the island or atoll (even if never recorded during SPC surveys).

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
Acanthuridae							
<i>Acanthurus achilles</i>	8%	9%	23%	55%	10%	13%	47%
<i>Acanthurus</i> hybrid = <i>rackliffei</i>	-	-	2%	-	P	-	-
<i>Acanthurus albipectoralis</i>	-	-	3%	-	P	-	-
<i>Acanthurus blochii</i>	3%	P	2%	32%	P	24%	7%
<i>Acanthurus dussumieri</i>	6%	-	8%	3%	-	1%	1%
<i>Acanthurus guttatus</i>	-	9%	2%	-	-	P	4%
<i>Acanthurus leucocheilus</i>	22%	P	31%	-	33%	27%	-
<i>Acanthurus leucopareius</i>	-	-	-	-	P	P	P
<i>Acanthurus lineatus</i>	25%	20%	38%	-	P	9%	-
<i>Acanthurus maculiceps</i>	25%	29%	7%	-	4%	31%	-
<i>Acanthurus mata</i>	11%	26%	18%	-	P	P	-
<i>Acanthurus nigricans</i>	97%	97%	99%	6%	98%	94%	10%
<i>Acanthurus nigricauda</i>	P	P	4%	P	P	17%	9%
<i>Acanthurus nigrofuscus</i>	3%	6%	8%	10%	20%	29%	74%
<i>Acanthurus nigroris</i>	3%	11%	9%	94%	10%	8%	58%
<i>Acanthurus nubilus</i>	-	-	-	-	-	-	3%
<i>Acanthurus olivaceus</i>	33%	11%	35%	68%	37%	28%	3%
<i>Acanthurus pyroferus</i>	3%	26%	-	-	4%	1%	-
<i>Acanthurus thompsoni</i>	25%	34%	17%	16%	39%	33%	31%
<i>Acanthurus triostegus</i>	11%	17%	13%	42%	8%	15%	27%
<i>Acanthurus xanthopterus</i>	6%	9%	7%	10%	2%	37%	-
<i>Ctenochaetus binotatus</i>	11%	11%	-	-	2%	13%	-
<i>Ctenochaetus cyanocheilus</i>	75%	71%	33%	-	86%	71%	77%
<i>Ctenochaetus flavicauda</i>	25%	9%	31%	-	4%	P	-
<i>Ctenochaetus hawaiiensis</i>	6%	20%	38%	32%	10%	27%	39%
<i>Ctenochaetus marginatus</i>	97%	89%	98%	-	78%	83%	-
<i>Ctenochaetus striatus</i>	17%	6%	26%	-	33%	31%	58%
<i>Ctenochaetus strigosus</i>	-	-	-	84%	-	-	-

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Naso annulatus</i>	3%	P	1%	P	P	1%	-
<i>Naso brevirostris</i>	P	6%	13%	6%	8%	22%	22%
<i>Naso caesius</i>	P	P	P	P	P	P	-
<i>Naso hexacanthus</i>	39%	54%	39%	16%	33%	15%	4%
<i>Naso lituratus</i>	39%	57%	27%	87%	35%	22%	70%
<i>Naso tonganus</i>	-	-	P	-	P	P	-
<i>Naso unicornis</i>	6%	P	-	10%	6%	13%	10%
<i>Naso vlamingii</i>	25%	34%	17%	-	45%	21%	4%
<i>Paracanthurus hepatus</i>	8%	6%	-	-	2%	-	-
<i>Zebrasoma flavescens</i>	-	-	-	77%	P	-	67%
<i>Zebrasoma rostratum</i>	11%	14%	48%	-	16%	5%	-
<i>Zebrasoma scopas</i>	33%	46%	4%	-	8%	6%	-
<i>Zebrasoma veliferum</i>	P	P	-	10%	2%	1%	12%
Apogonidae							
<i>Apogon angustatus</i>	P	P	2%	-	P	P	-
<i>Apogon apogonoides</i>	P	P	12%	-	-	-	-
Apogonidae	P	9%	2%	P	2%	1%	-
<i>Cheilodipterus macrodon</i>	-	-	-	-	-	-	P
<i>Cheilodipterus quinquelineatus</i>	-	-	-	-	6%	-	P
<i>Cheilodipterus</i> sp.	-	-	-	P	-	-	-
Aulostomidae							
<i>Aulostomus chinensis</i>	14%	6%	1%	29%	P	P	2%
Balaenopteridae							
<i>Megaptera novaeangliae</i>	-	-	-	P	-	-	-
Balistidae							
<i>Balistapus undulatus</i>	89%	94%	77%	-	78%	79%	-
<i>Balistidae</i>	P	P	P	-	-	P	1%
<i>Balistoides conspicillum</i>	-	P	-	-	-	-	-
<i>Balistoides viridescens</i>	8%	17%	3%	-	P	14%	1%
<i>Melichthys niger</i>	58%	54%	72%	71%	82%	53%	46%
<i>Melichthys vidua</i>	94%	100%	84%	29%	73%	69%	96%
<i>Odonus niger</i>	36%	29%	12%	-	-	1%	-
<i>Pseudobalistes flavimarginatus</i>	3%	3%	13%	-	4%	21%	-
<i>Rhinecanthus aculeatus</i>	P	-	-	13%	-	1%	5%
<i>Rhinecanthus rectangulus</i>	19%	14%	16%	-	P	15%	23%

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Sufflamen bursa</i>	31%	37%	47%	58%	8%	14%	48%
<i>Sufflamen chrysopteron</i>	11%	14%	5%	-	8%	8%	-
<i>Sufflamen fraenatum</i>	6%	3%	-	3%	6%	1%	-
<i>Xanthichthys auromarginatus</i>	-	9%	2%	16%	-	-	-
<i>Xanthichthys caeruleolineatus</i>	11%	9%	9%	-	-	1%	-
<i>Xanthichthys mento</i>	-	-	-	-	-	-	16%
Belonidae							
<i>Tylosurus crocodilus</i>	-	-	1%	-	P	P	1%
Blenniidae							
Blenniidae	6%	9%	63%	-	16%	17%	15%
<i>Cirripectes polyzona</i>	P	P	3%	-	-	-	1%
<i>Cirripectes</i> sp.	P	P	2%	-	P	P	P
<i>Cirripectes vanderbilti</i>	P	-	-	P	-	-	-
<i>Cirripectes variolosus</i>	8%	9%	17%	3%	6%	4%	16%
<i>Ecsenius bicolor</i>	25%	17%	-	-	-	-	-
<i>Ecsenius midas</i>	P	P	1%	-	-	P	-
<i>Exallias brevis</i>	P	P	1%	P	-	P	-
<i>Meiacanthus atrodorsalis</i>	-	P	-	-	-	-	-
<i>Plagiotremus rhinorhynchos</i>	3%	P	7%	-	-	P	-
<i>Plagiotremus tapeinosoma</i>	3%	P	8%	-	P	P	1%
Bothidae							
<i>Bothus mancus</i>	6%	3%	6%	P	-	-	3%
Caesionidae							
<i>Caesio teres</i>	33%	37%	9%	-	35%	9%	-
<i>Pterocaesio marri</i>	-	-	-	-	P	4%	-
<i>Pterocaesio tile</i>	3%	17%	8%	-	10%	5%	-
Callionymidae							
<i>Callionymidae</i>	P	P	-	-	-	-	-
Caracanthidae							
<i>Caracanthus maculatus</i>	P	P	2%	-	-	P	1%
<i>Caracanthus typicus</i>	-	-	-	3%	-	-	-
Carangidae							
<i>Alectis ciliaris</i>	-	-	-	-	-	-	P
<i>Carangoides ferdau</i>	P	14%	2%	P	P	P	2%
<i>Carangoides orthogrammus</i>	28%	66%	23%	48%	4%	4%	11%

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Caranx ignobilis</i>	8%	9%	3%	P	4%	15%	-
<i>Caranx lugubris</i>	44%	49%	52%	3%	4%	P	39%
<i>Caranx melampygus</i>	86%	97%	61%	55%	18%	62%	87%
<i>Caranx sexfasciatus</i>	-	3%	1%	P	4%	P	3%
<i>Decapterus macarellus</i>	P	3%	7%	P	P	5%	2%
<i>Elagatis bipinnulata</i>	P	11%	21%	6%	4%	5%	13%
<i>Scomberoides lysan</i>	-	3%	1%	13%	2%	9%	30%
<i>Selar crumenophthalmus</i>	-	-	-	P	-	-	P
<i>Seriola dumerili</i>	-	-	-	3%	-	-	16%
<i>Trachinotus baillonii</i>	-	-	1%	-	-	-	3%
<i>Trachinotus blochii</i>	-	-	1%	-	-	-	-
Carcharhinidae							
<i>Carcharhinus albimarginatus</i>	-	-	-	-	P	-	-
<i>Carcharhinus amblyrhynchos</i>	53%	66%	55%	13%	78%	31%	17%
<i>Carcharhinus galapagensis</i>	-	P	P	3%	-	-	-
<i>Carcharhinus melanopterus</i>	6%	14%	17%	-	P	58%	1%
<i>Galeocerdo cuvier</i>	-	-	-	P	P	P	-
<i>Triaenodon obesus</i>	22%	9%	24%	-	49%	9%	P
Chaetodontidae							
<i>Chaetodon auriga</i>	25%	9%	23%	77%	61%	42%	44%
<i>Chaetodon bennetti</i>	P	3%	-	-	12%	9%	-
<i>Chaetodon citrinellus</i>	3%	P	-	P	P	-	-
<i>Chaetodon ephippium</i>	-	-	2%	10%	6%	26%	15%
<i>Chaetodon fremblii</i>	3%	-	-	-	-	-	-
<i>Chaetodon kleinii</i>	6%	P	-	10%	39%	4%	-
<i>Chaetodon lineolatus</i>	-	3%	-	-	-	1%	-
<i>Chaetodon lunula</i>	36%	34%	40%	P	10%	65%	40%
<i>Chaetodon lunulatus</i>	3%	-	-	32%	18%	63%	-
<i>Chaetodon mertensii</i>	-	-	-	-	P	P	-
<i>Chaetodon meyeri</i>	61%	74%	24%	-	2%	17%	-
<i>Chaetodon miliaris</i>	3%	-	-	3%	-	-	-
<i>Chaetodon multicinctus</i>	-	-	-	52%	-	-	-
<i>Chaetodon ornatissimus</i>	14%	31%	23%	16%	82%	62%	69%
<i>Chaetodon pelewensis</i>	-	-	-	-	P	4%	-
<i>Chaetodon punctatofasciatus</i>	-	-	-	-	53%	23%	64%

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Chaetodon quadrimaculatus</i>	11%	6%	15%	42%	57%	38%	53%
<i>Chaetodon reticulatus</i>	3%	9%	P	3%	61%	26%	19%
<i>Chaetodon semeion</i>	-	-	-	-	-	P	P
<i>Chaetodon trifascialis</i>	28%	6%	-	45%	29%	24%	1%
<i>Chaetodon ulietensis</i>	-	-	-	-	8%	27%	27%
<i>Chaetodon unimaculatus</i>	-	-	P	19%	39%	21%	14%
<i>Chaetodon vagabundus</i>	6%	6%	-	-	-	6%	-
<i>Forcipiger flavissimus</i>	36%	43%	31%	39%	37%	14%	26%
<i>Forcipiger longirostris</i>	8%	9%	-	-	P	1%	17%
<i>Hemitaurichthys thompsoni</i>	P	-	3%	23%	8%	-	20%
<i>Heniochus acuminatus</i>	3%	-	-	-	-	-	-
<i>Heniochus monoceros</i>	P	P	-	-	-	-	-
<i>Heniochus varius</i>	P	P	-	-	-	-	-
Chanidae							
<i>Chanos chanos</i>	8%	3%	12%	-	2%	18%	2%
Cheloniidae							
<i>Chelonia mydas</i>	P	P	P	P	P	P	P
Unidentified turtle	P	P	4%	P	P	P	1%
<i>Eretmochelys imbricata</i>	P	P	P	-	P	P	-
Cirrhitidae							
<i>Cirrhitichthys oxycephalus</i>	36%	54%	41%	-	2%	6%	-
<i>Cirrhitops fasciatus</i>	-	-	-	3%	-	-	-
<i>Cirrhitops hubbardi</i>	19%	17%	34%	-	-	1%	-
<i>Cirrhites pinnulatus</i>	11%	11%	13%	13%	-	P	6%
<i>Neocirrhites armatus</i>	-	3%	P	-	-	-	55%
<i>Paracirrhites arcatus</i>	64%	71%	38%	32%	69%	68%	88%
<i>Paracirrhites forsteri</i>	56%	66%	46%	19%	41%	33%	72%
<i>Paracirrhites hemistictus</i>	64%	80%	69%	-	35%	29%	66%
<i>Paracirrhites xanthus</i>	P	-	5%	-	2%	-	-
Congridae							
<i>Congridae</i>	P	-	-	-	-	-	-
Dasyatidae							
<i>Dasyatidae</i>	-	-	P	-	-	-	-
Delphinidae							
<i>Delphinidae</i>	-	P	2%	-	P	-	-

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TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Tursiops truncatus</i>	-	-	P	-	-	-	-
Diodontidae							
<i>Diodon hystrix</i>	11%	3%	1%	P	P	-	5%
Echeneidae							
<i>Echeneis naucrates</i>	P	3%	1%	-	-	-	-
Ephippidae							
<i>Ephippidae</i>	-	-	P	-	-	-	-
<i>Platax orbicularis</i>	-	3%	-	-	P	1%	-
<i>Platax teira</i>	3%	P	-	-	-	-	-
Fistulariidae							
<i>Fistularia commersonii</i>	P	P	1%	3%	4%	1%	15%
Gobiidae							
<i>Amblyeleotris</i> sp.	-	-	-	P	-	-	-
<i>Amblygobius phalaena</i>	-	-	-	-	-	-	P
<i>Coryphopterus</i> sp.	-	-	-	P	-	-	P
<i>Gnatholepis</i> sp.	-	-	-	-	P	-	-
<i>Unid Gobiidae</i>	3%	9%	-	P	P	-	4%
<i>Valenciennesa strigata</i>	P	3%	2%	-	P	P	-
Holocentridae							
<i>Unid Holocentridae</i>	P	3%	P	-	P	P	-
<i>Myripristinae</i>	6%	6%	12%	P	6%	13%	6%
<i>Myripristis adusta</i>	-	-	P	-	-	13%	P
<i>Myripristis amaena</i>	28%	29%	16%	10%	27%	6%	5%
<i>Myripristis berndti</i>	31%	51%	33%	23%	37%	28%	14%
<i>Myripristis earlei</i>	25%	23%	23%	-	6%	5%	-
<i>Myripristis kuntee</i>	11%	17%	1%	10%	33%	23%	1%
<i>Myripristis murdjan</i>	-	-	P	-	2%	-	-
<i>Myripristis vittata</i>	6%	9%	-	-	-	-	-
<i>Myripristis woodsi</i>	P	P	-	-	P	P	-
<i>Neoniphon opercularis</i>	P	P	-	-	12%	1%	-
<i>Neoniphon sammara</i>	-	-	-	P	6%	4%	3%
<i>Neoniphon</i> sp.	-	P	1%	-	P	P	P
<i>Sargocentron caudimaculatum</i>	8%	31%	12%	-	12%	19%	-
<i>Sargocentron diadema</i>	-	3%	-	-	P	P	-
<i>Sargocentron microstoma</i>	-	P	1%	-	-	P	P

# Sites after 2012	36	35	120	31	49	78	98
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<i>Sargocentron</i> sp.	-	-	P	-	P	-	3%
<i>Sargocentron spiniferum</i>	3%	3%	2%	23%	8%	18%	23%
<i>Sargocentron tiere</i>	67%	66%	62%	3%	27%	27%	30%
Kyphosidae							
<i>Kyphosus cinerascens</i>	P	P	1%	P	P	P	P
<i>Kyphosus pacificus</i>	P	-	-	P	P	-	P
<i>Kyphosus</i> sp.	17%	20%	12%	13%	P	1%	88%
<i>Kyphosus vaigiensis</i>	P	-	P	P	-	P	P
<i>Sectator ocyurus</i>	-	P	1%	-	-	-	-
Labridae							
<i>Anampses caeruleopunctatus</i>	25%	31%	65%	-	2%	8%	34%
<i>Anampses cuvier</i>	6%	-	-	-	-	-	-
<i>Anampses melanurus</i>	3%	3%	8%	-	P	3%	2%
<i>Anampses meleagrides</i>	22%	17%	9%	-	P	4%	-
<i>Anampses</i> sp.	P	-	1%	-	P	-	-
<i>Anampses twistii</i>	3%	3%	-	-	59%	29%	-
<i>Bodianus anthioides</i>	-	-	-	-	-	-	1%
<i>Bodianus axillaris</i>	8%	11%	4%	-	31%	37%	-
<i>Bodianus bilunulatus</i>	-	-	-	35%	-	-	-
<i>Bodianus diana</i>	25%	37%	-	-	-	-	-
<i>Bodianus loxozonus</i>	-	-	4%	-	96%	37%	-
<i>Bodianus mesothorax</i>	3%	-	-	-	-	-	-
<i>Bodianus prognathus</i>	P	6%	36%	-	-	P	-
<i>Cheilinus chlorourus</i>	-	-	-	-	-	-	17%
<i>Cheilinus fasciatus</i>	-	-	-	-	-	-	10%
<i>Cheilinus oxycephalus</i>	19%	14%	-	-	14%	10%	-
<i>Cheilinus</i> sp.	-	-	-	-	-	P	-
<i>Cheilinus trilobatus</i>	33%	P	34%	-	41%	79%	53%
<i>Cheilinus undulatus</i>	3%	P	6%	-	P	27%	21%
<i>Cheilio inermis</i>	-	-	-	P	-	-	-
<i>Cirrhilabrus exquisitus</i>	28%	14%	1%	-	10%	17%	-
<i>Cirrhilabrus katherinae</i>	3%	-	-	-	2%	-	-
<i>Cirrhilabrus</i> sp.	-	-	1%	-	P	P	-
<i>Coris aygula</i>	33%	17%	75%	-	27%	23%	73%
<i>Coris centralis</i>	22%	11%	17%	-	4%	3%	-

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TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Coris gaimard</i>	33%	34%	40%	39%	27%	17%	-
<i>Epibulus insidiator</i>	8%	-	2%	65%	41%	82%	36%
<i>Gomphosus varius</i>	89%	83%	98%	55%	82%	78%	91%
<i>Halichoeres biocellatus</i>	-	-	-	-	-	-	34%
<i>Halichoeres chrysus</i>	3%	-	-	-	-	-	-
<i>Halichoeres hortulanus</i>	89%	80%	73%	-	71%	67%	-
<i>Halichoeres margaritaceus</i>	P	9%	18%	-	4%	3%	14%
<i>Halichoeres melasmapomus</i>	3%	17%	12%	-	2%	5%	-
<i>Halichoeres ornatissimus</i>	78%	77%	33%	45%	47%	49%	61%
<i>Halichoeres pallidus</i>	-	-	P	-	-	-	-
<i>Halichoeres sp.</i>	-	-	1%	3%	P	-	23%
<i>Halichoeres trimaculatus</i>	-	P	2%	-	-	-	P
<i>Hemigymnus fasciatus</i>	61%	60%	82%	-	53%	28%	46%
<i>Hologymnosus annulatus</i>	-	-	P	-	P	-	-
<i>Hologymnosus doliatus</i>	6%	-	2%	-	6%	-	-
<i>Iniistius aneitensis</i>	-	-	-	P	-	-	-
<i>Labrichthys unilineatus</i>	P	-	-	-	4%	P	-
<i>Labroides bicolor</i>	53%	54%	27%	-	43%	28%	27%
<i>Labroides dimidiatus</i>	75%	71%	64%	-	88%	65%	8%
<i>Labroides pectoralis</i>	3%	-	-	-	-	P	1%
<i>Labroides phthirophagus</i>	-	-	-	35%	-	-	-
<i>Labroides rubrolabiatus</i>	78%	77%	60%	-	43%	45%	71%
<i>Labropsis xanthonota</i>	8%	11%	2%	-	2%	1%	-
<i>Macropharyngodon geoffroy</i>	P	-	-	10%	-	-	-
<i>Macropharyngodon meleagris</i>	11%	6%	14%	-	35%	26%	-
<i>Novaculichthys taeniourus</i>	8%	P	6%	P	4%	3%	9%
<i>Oxycheilinus bimaculatus</i>	P	-	-	-	-	-	-
<i>Oxycheilinus digramma</i>	-	-	-	-	4%	3%	15%
<i>Oxycheilinus sp.</i>	P	-	-	-	-	-	P
<i>Oxycheilinus unifasciatus</i>	33%	-	5%	61%	71%	51%	77%
<i>Pseudocheilinus evanidus</i>	3%	P	-	P	P	8%	-
<i>Pseudocheilinus hexataenia</i>	39%	14%	42%	-	45%	58%	22%
<i>Pseudocheilinus ocellatus</i>	-	-	-	-	-	-	3%
<i>Pseudocheilinus octotaenia</i>	42%	60%	47%	48%	57%	62%	60%
<i>Pseudocheilinus tetrataenia</i>	36%	51%	17%	10%	10%	12%	18%

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Pseudocoris aurantiofasciata</i>	-	P	-	-	-	-	5%
<i>Pseudocoris heteroptera</i>	6%	11%	2%	-	4%	P	-
<i>Pseudocoris yamashiroi</i>	-	-	-	-	P	P	-
<i>Pseudodax moluccanus</i>	25%	17%	8%	-	24%	17%	-
<i>Pseudojuloides atavai</i>	-	-	-	-	-	-	18%
<i>Pseudojuloides cerasinus</i>	3%	-	-	10%	P	P	-
<i>Pseudojuloides sp.</i>	-	3%	P	P	-	-	-
<i>Stethojulis balteata</i>	P	-	-	55%	-	-	-
<i>Stethojulis bandanensis</i>	14%	6%	20%	-	P	3%	10%
<i>Thalassoma amblycephalum</i>	75%	77%	79%	-	71%	79%	-
<i>Thalassoma ballieui</i>	-	-	-	3%	-	-	-
<i>Thalassoma duperrey</i>	-	-	-	74%	-	-	-
<i>Thalassoma dup/lut hybrid</i>	-	-	-	P	-	-	-
<i>Thalassoma hardwicke</i>	P	-	2%	-	4%	4%	-
<i>Thalassoma lunare</i>	-	3%	-	-	18%	6%	-
<i>Thalassoma lutescens</i>	25%	14%	5%	39%	55%	33%	92%
<i>Thalassoma purpureum</i>	3%	20%	19%	-	-	1%	5%
<i>Thalassoma quinquevittatum</i>	61%	69%	87%	42%	65%	81%	55%
<i>Thalassoma sp.</i>	-	-	2%	P	-	-	4%
<i>Thalassoma trilobatum</i>	28%	23%	13%	P	P	P	15%
Lethrinidae							
<i>Gnathodentex aureolineatus</i>	6%	P	P	-	4%	3%	-
<i>Lethrinus harak</i>	-	-	-	-	2%	-	-
<i>Lethrinus obsoletus</i>	-	-	-	-	12%	-	21%
<i>Lethrinus olivaceus</i>	8%	6%	3%	-	P	17%	1%
<i>Lethrinus rubrioperculatus</i>	-	-	-	-	6%	-	3%
<i>Lethrinus sp.</i>	P	-	-	-	10%	P	5%
<i>Lethrinus xanthochilus</i>	P	-	-	-	P	32%	11%
<i>Monotaxis grandoculis</i>	17%	6%	15%	P	63%	51%	47%
Lutjanidae							
<i>Aphareus furca</i>	72%	80%	67%	65%	57%	41%	52%
<i>Aprion virescens</i>	6%	6%	-	55%	18%	13%	2%
<i>Lutjanus bohar</i>	89%	86%	89%	-	100%	94%	-
<i>Lutjanus fulvus</i>	8%	14%	-	-	2%	15%	43%
<i>Lutjanus gibbus</i>	17%	23%	P	-	67%	78%	-

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Lutjanus kasmira</i>	3%	P	16%	-	-	-	-
<i>Lutjanus monostigma</i>	19%	31%	8%	-	-	13%	16%
<i>Lutjanus semicinctus</i>	-	11%	-	-	-	-	-
<i>Macolor macularis</i>	P	-	-	-	-	-	2%
<i>Macolor niger</i>	6%	P	P	-	-	-	P
<i>Macolor sp.</i>	P	P	-	-	P	-	P
Malacanthidae							
<i>Malacanthus brevirostris</i>	3%	-	-	P	-	-	P
<i>Malacanthus latovittatus</i>	P	-	1%	-	P	P	-
Microdesmidae							
<i>Gunnellichthys curiosus</i>	P	P	-	-	-	-	-
<i>Nemateleotris magnifica</i>	-	P	-	16%	2%	4%	1%
Mobulidae							
<i>Mobula sp.</i>	11%	23%	17%	3%	2%	5%	P
Monacanthidae							
<i>Aluterus scriptus</i>	22%	26%	11%	19%	20%	22%	15%
<i>Amanes scopas</i>	17%	14%	-	-	P	P	-
<i>Cantherhines dumerilii</i>	25%	29%	33%	6%	14%	23%	4%
<i>Cantherhines pardalis</i>	P	6%	9%	-	10%	9%	-
<i>Cantherhines sandwichiensis</i>	3%	-	-	32%	-	-	-
<i>Pervagor aspricaudus</i>	-	-	-	45%	2%	-	-
<i>Pervagor janthinosoma</i>	-	-	2%	-	6%	-	-
<i>Pervagor marginalis</i>	-	-	6%	-	2%	P	-
<i>Pervagor sp.</i>	-	-	-	3%	2%	-	-
<i>Pervagor spilosoma</i>	-	-	-	P	-	-	-
Mullidae							
<i>Mulloidichthys flavolineatus</i>	P	P	2%	19%	2%	P	2%
<i>Mulloidichthys mimicus</i>	P	P	P	-	P	P	-
<i>Mulloidichthys vanicolensis</i>	8%	3%	2%	13%	6%	1%	4%
<i>Parupeneus barberinus</i>	-	-	-	-	-	5%	11%
<i>Parupeneus chrysonemus</i>	-	-	-	-	2%	-	-
<i>Parupeneus cyclostomus</i>	11%	3%	34%	48%	8%	12%	12%
<i>Parupeneus insularis</i>	67%	66%	76%	77%	14%	41%	51%
<i>Parupeneus multifasciatus</i>	39%	43%	43%	87%	39%	41%	45%
<i>Parupeneus pleurostigma</i>	-	-	-	29%	P	-	P

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TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
Muraenidae							
<i>Echidna nebulosa</i>	-	P	-	-	-	-	-
<i>Enchelycore pardalis</i>	-	-	1%	-	-	-	-
<i>Gymnomuraena zebra</i>	-	P	-	-	-	-	-
<i>Gymnothorax breedeni</i>	11%	11%	16%	-	2%	-	-
<i>Gymnothorax flavimarginatus</i>	8%	14%	8%	6%	4%	1%	1%
<i>Gymnothorax javanicus</i>	-	3%	1%	P	2%	4%	16%
<i>Gymnothorax meleagris</i>	3%	3%	2%	13%	2%	3%	-
<i>Gymnothorax</i> sp.	8%	9%	2%	3%	P	1%	1%
<i>Gymnothorax undulatus</i>	P	-	-	-	-	P	3%
Myliobatidae							
<i>Aetobatus narinari</i>	11%	3%	P	6%	P	4%	12%
Ophichthidae							
<i>Myrichthys magnificus</i>	-	-	-	3%	-	-	-
Oplegnathidae							
<i>Oplegnathus fasciatus</i>	-	-	-	-	-	-	P
<i>Oplegnathus punctatus</i>	-	-	-	P	-	-	2%
Ostraciidae							
Ostraciidae	P	P	P	P	P	P	-
<i>Ostracion cubicus</i>	-	-	-	-	-	-	2%
<i>Ostracion meleagris</i>	6%	14%	13%	23%	2%	-	8%
<i>Ostracion whitleyi</i>	3%	-	-	16%	-	-	-
Pempheridae							
<i>Pempheridae</i>	P	-	-	-	-	P	-
<i>Pempheris oualensis</i>	31%	14%	10%	-	10%	17%	P
Pinguipedidae							
<i>Parapercis schauinslandii</i>	-	-	-	6%	-	-	-
<i>Parapercis</i> sp.	3%	-	-	P	P	P	-
Pomacanthidae							
<i>Apolemichthys griffisi</i>	6%	9%	22%	-	2%	-	-
<i>Apolemichthys xanthopunctatus</i>	39%	60%	53%	-	6%	27%	-
<i>Centropyge bicolor</i>	3%	3%	-	-	-	-	-
<i>Centropyge bispinosa</i>	-	3%	-	-	-	-	-
<i>Centropyge fisheri</i>	-	-	-	-	-	P	-

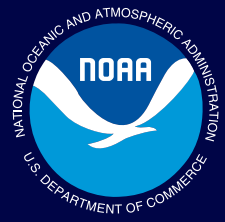
# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Centropyge flavissima</i>	92%	97%	88%	-	96%	90%	93%
<i>Centropyge loricula</i>	69%	89%	50%	68%	33%	27%	71%
<i>Centropyge multicolor</i>	-	-	-	-	-	-	P
<i>Centropyge multifasciata</i>	-	P	-	-	-	-	-
<i>Centropyge potteri</i>	-	-	-	19%	-	-	-
<i>Centropyge vrolikii</i>	P	11%	-	-	-	-	-
<i>Pomacanthus imperator</i>	61%	69%	78%	-	2%	17%	-
<i>Pygoplites diacanthus</i>	31%	49%	-	-	P	-	-
Pomacentridae							
<i>Abudefduf abdominalis</i>	11%	-	-	P	-	-	-
<i>Abudefduf notatus</i>	-	-	P	-	-	-	-
<i>Abudefduf septemfasciatus</i>	P	-	-	-	-	-	-
<i>Abudefduf sordidus</i>	-	P	8%	P	-	P	2%
<i>Abudefduf vaigiensis</i>	11%	14%	4%	P	-	3%	1%
<i>Amphiprion chrysopterus</i>	11%	P	-	-	-	-	-
<i>Amphiprion perideraion</i>	6%	P	-	-	-	-	-
<i>Chromis acares</i>	11%	17%	34%	48%	29%	29%	79%
<i>Chromis agilis</i>	P	-	8%	23%	2%	P	72%
<i>Chromis alpha</i>	P	-	-	-	-	-	-
<i>Chromis amboinensis</i>	-	-	P	-	P	-	-
<i>Chromis caudalis</i>	P	P	-	-	-	-	-
<i>Chromis hanui</i>	-	-	-	P	-	-	-
<i>Chromis lepidolepis</i>	-	-	-	-	2%	P	-
<i>Chromis margaritifer</i>	83%	86%	75%	-	84%	74%	-
<i>Chromis ternatensis</i>	3%	-	-	-	P	-	-
<i>Chromis vanderbilti</i>	72%	54%	73%	6%	61%	86%	35%
<i>Chromis verater</i>	-	-	-	23%	-	-	-
<i>Chromis viridis</i>	-	-	-	-	-	1%	-
<i>Chromis xanthura</i>	42%	63%	2%	-	71%	74%	-
<i>Chrysiptera brownriggii</i>	14%	11%	-	-	-	-	P
<i>Chrysiptera cyanea</i>	-	-	12%	-	4%	5%	-
<i>Chrysiptera taupou</i>	-	-	-	-	2%	-	-
<i>Dascyllus albisella</i>	-	-	-	55%	P	-	-
<i>Dascyllus aruanus</i>	-	-	-	-	2%	1%	P
<i>Dascyllus auripinnis</i>	31%	20%	-	-	61%	9%	-

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Dascyllus reticulatus</i>	3%	P	-	-	-	-	-
<i>Dascyllus trimaculatus</i>	-	-	-	-	P	-	-
<i>Lepidozygus tapeinosoma</i>	28%	46%	54%	-	4%	3%	-
<i>Plectroglyphidodon dickii</i>	86%	91%	94%	-	63%	76%	34%
<i>P. imparipennis</i>	14%	14%	17%	19%	4%	5%	30%
<i>P. johnstonianus</i>	61%	74%	35%	35%	80%	79%	82%
<i>P. lacrymatus</i>	11%	20%	-	-	-	-	3%
<i>P. phoenixensis</i>	17%	17%	23%	P	P	17%	23%
unid Pomacentridae	8%	9%	2%	P	P	P	1%
<i>Pomacentrus brachialis</i>	-	-	-	-	6%	3%	-
<i>Pomacentrus coelestis</i>	P	3%	4%	-	8%	18%	-
<i>Pomacentrus philippinus</i>	-	-	-	-	P	-	-
<i>Stegastes albifasciatus</i>	3%	3%	-	-	-	3%	1%
<i>Stegastes aureus</i>	69%	80%	85%	-	49%	58%	-
<i>Stegastes fasciolatus</i>	36%	29%	18%	-	2%	21%	69%
<i>Stegastes lividus</i>	-	-	-	-	-	4%	-
<i>Stegastes nigricans</i>	P	-	7%	-	2%	P	26%
Priacanthidae							
<i>Heteropriacanthus cruentatus</i>	3%	P	-	-	4%	1%	-
<i>Priacanthus hamrur</i>	-	-	-	-	P	-	-
<i>Priacanthus meeki</i>	-	-	-	-	4%	-	-
<i>Priacanthus sp.</i>	-	-	1%	-	2%	-	-
Ptereleotridae							
<i>Ptereleotris evides</i>	-	-	5%	-	4%	1%	1%
<i>Ptereleotris heteroptera</i>	-	-	-	-	P	1%	-
<i>Ptereleotris zebra</i>	3%	9%	2%	-	P	1%	-
Scaridae							
<i>Bolbometopon muricatum</i>	-	-	P	-	-	P	13%
<i>Calotomus carolinus</i>	11%	P	22%	16%	33%	6%	3%
<i>Calotomus zonarchus</i>	P	-	-	3%	P	-	-
<i>Chlorurus frontalis</i>	-	3%	2%	-	P	8%	38%
<i>Chlorurus microrhinos</i>	6%	3%	3%	-	86%	44%	13%
<i>Chlorurus perspicillatus</i>	-	-	-	61%	-	-	-
<i>Chlorurus sordidus</i>	8%	6%	4%	81%	43%	95%	87%
<i>Hipposcarus longiceps</i>	-	-	2%	-	-	4%	1%

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
unid Scaridae	8%	P	9%	6%	2%	8%	2%
<i>Scarus altipinnis</i>	P	3%	6%	-	2%	4%	7%
<i>Scarus dubius</i>	-	-	-	19%	-	-	-
<i>Scarus festivus</i>	14%	-	2%	-	6%	P	-
<i>Scarus forsteni</i>	-	-	32%	-	31%	18%	90%
<i>Scarus frenatus</i>	47%	17%	83%	-	71%	54%	-
<i>Scarus ghobban</i>	-	-	-	-	2%	23%	7%
<i>Scarus globiceps</i>	-	-	-	-	2%	13%	8%
<i>Scarus niger</i>	3%	3%	2%	-	2%	1%	-
<i>Scarus oviceps</i>	P	P	4%	-	4%	38%	16%
<i>Scarus psittacus</i>	P	-	7%	45%	6%	6%	23%
<i>Scarus rubroviolaceus</i>	92%	89%	92%	32%	71%	54%	2%
<i>Scarus schlegeli</i>	-	-	-	-	-	1%	-
<i>Scarus</i> sp.	P	P	P	3%	P	P	1%
<i>Scarus spinus</i>	11%	-	-	-	2%	10%	-
<i>Scarus tricolor</i>	67%	40%	54%	-	59%	55%	-
Scombridae							
<i>Acanthocybium solandri</i>	-	-	P	-	P	P	1%
<i>Euthynnus affinis</i>	P	P	13%	-	2%	-	-
<i>Gymnosarda unicolor</i>	6%	11%	2%	-	P	-	P
<i>Katsuwonus pelamis</i>	P	-	-	-	-	-	-
unid Scombridae	3%	3%	2%	-	-	-	-
<i>Thunnus albacares</i>	-	-	1%	-	2%	-	-
Scorpaenidae							
<i>Pterois antennata</i>	-	P	-	-	P	1%	2%
<i>Pterois</i> sp.	-	P	-	-	-	-	P
<i>Pterois volitans</i>	P	-	P	-	-	-	-
<i>Scorpaenopsis diabolus</i>	3%	-	-	-	-	-	-
<i>Scorpaenopsis</i> sp.	P	3%	2%	-	-	-	-
<i>Sebastapistes cyanostigma</i>	6%	3%	1%	-	P	P	-
Serranidae							
<i>Aethaloperca rogae</i>	14%	26%	-	-	-	-	-
<i>Anthias</i> sp.	P	P	P	-	-	P	-
<i>Cephalopholis argus</i>	81%	91%	94%	-	98%	97%	91%
<i>Cephalopholis leopardus</i>	8%	17%	9%	-	2%	4%	-

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Cephalopholis miniata</i>	50%	66%	50%	-	P	4%	-
<i>Cephalopholis sexmaculata</i>	11%	3%	6%	-	-	P	-
<i>Cephalopholis sonnerati</i>	-	P	-	-	-	-	-
<i>Cephalopholis</i> sp.	P	P	-	-	P	-	-
<i>Cephalopholis spiloparaea</i>	3%	3%	-	-	-	-	12%
<i>Cephalopholis urodeta</i>	75%	89%	98%	-	76%	64%	8%
<i>Epinephelus fasciatus</i>	33%	14%	16%	-	8%	4%	18%
<i>Epinephelus hexagonatus</i>	P	14%	6%	-	P	3%	8%
<i>Epinephelus howlandi</i>	3%	3%	1%	-	P	4%	2%
<i>Epinephelus lanceolatus</i>	-	-	2%	-	P	-	-
<i>Epinephelus macrospilos</i>	8%	14%	P	-	-	8%	-
<i>Epinephelus melanostigma</i>	11%	26%	13%	-	P	1%	-
<i>Epinephelus merra</i>	P	P	P	-	P	3%	1%
<i>Epinephelus polyphkadion</i>	-	-	-	-	18%	10%	19%
<i>Epinephelus retouti</i>	17%	14%	15%	-	-	P	-
<i>Epinephelus socialis</i>	-	-	-	-	-	1%	-
<i>Epinephelus</i> sp.	3%	11%	8%	-	2%	12%	7%
<i>Epinephelus spilotoceps</i>	6%	14%	13%	-	P	5%	14%
<i>Epinephelus tauvina</i>	P	P	10%	-	2%	4%	20%
<i>Gracila albomarginata</i>	25%	43%	26%	-	2%	14%	-
<i>Luzonichthys</i> sp.	-	-	P	-	-	-	-
<i>Luzonichthys whitleyi</i>	39%	54%	36%	-	P	P	-
<i>Plectropomus laevis</i>	-	P	P	-	P	-	-
<i>Pogonoperca punctata</i>	-	-	2%	-	-	-	-
<i>Pseudanthias bartlettorum</i>	56%	69%	64%	-	2%	10%	-
<i>Pseudanthias cooperi</i>	-	3%	-	-	P	P	-
<i>Pseudanthias dispar</i>	3%	-	3%	-	-	P	-
<i>Pseudanthias olivaceus</i>	58%	77%	70%	-	29%	49%	-
<i>Pseudanthias pascalus</i>	6%	6%	-	-	-	-	49%
<i>Variola louti</i>	28%	31%	38%	-	20%	56%	1%
Sphyraenidae							
<i>Sphyraena barracuda</i>	8%	P	3%	P	12%	5%	10%
<i>Sphyraena helleri</i>	-	P	2%	-	P	P	2%
<i>Sphyraena qenie</i>	6%	14%	7%	-	4%	6%	-
Sphyrnidae							

# Sites after 2012	36	35	120	31	49	78	98
TAXON NAME	Baker	Howland	Jarvis	Johnston	Kingman	Palmyra	Wake
<i>Sphyrna lewini</i>	P	P	7%	-	P	8%	-
<i>Sphyrna mokarran</i>	-	-	P	-	-	P	-
Synodontidae							
unid Synodontidae	P	P	P	13%	P	P	-
<i>Synodus binotatus</i>	-	-	-	-	P	-	-
<i>Synodus variegatus</i>	-	-	-	-	-	1%	-
Tetraodontidae							
<i>Arothron hispidus</i>	P	P	1%	P	-	P	7%
<i>Arothron mappa</i>	-	P	-	-	-	-	-
<i>Arothron meleagris</i>	14%	23%	9%	6%	4%	6%	26%
<i>Arothron nigropunctatus</i>	6%	3%	-	-	-	-	1%
<i>Arothron stellatus</i>	-	-	-	-	-	P	-
<i>Canthigaster amboinensis</i>	11%	P	9%	-	P	P	15%
<i>Canthigaster jactator</i>	-	-	-	29%	-	-	-
<i>Canthigaster janthinoptera</i>	3%	6%	-	-	-	P	2%
<i>Canthigaster solandri</i>	-	3%	-	-	-	P	7%
<i>Canthigaster valentini</i>	-	-	-	-	P	-	-
Tripterygiidae							
<i>Helcogramma striatum</i>	-	-	-	-	P	P	-
Zanclidae							
<i>Zanclus cornutus</i>	81%	71%	23%	45%	69%	38%	11%



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