Pacific National Coral Reef Monitoring Program 2024—Reef Fishes of Hawai‘i

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Pacific National Coral Reef Monitoring Program 2024 — Reef Fishes of Hawai‘i

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About this report

The Pacific Islands Fisheries Science Center (PIFSC) uses the PIFSC Data Report series to distribute scientific and technical information that has been scientifically reviewed and edited. Documents within this series reflect sound professional work and may be referenced in the formal scientific and technical literature. This report outlines a portion of the National Coral Reef Monitoring Program surveys conducted by the National Oceanic and Atmospheric Administration (NOAA) PIFSC Archipelagic Research Program (ARP) of the Ecosystem Sciences Division (ESD) in 2024 in Hawai‘i.

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Cover photo: Ulua follow a diver at Manawai. Photo Credit: NOAA Fisheries. Photographer: Ari Halperin.

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Introduction

Background

The Archipelagic Research Program (ARP) leads the U.S. Pacific National Coral Reef Monitoring Program (NCRMP; Figure 1), formerly known as the Pacific Reef Assessment and Monitoring Program (RAMP). ARP provides scientific information that supports ecosystem approaches to the management and conservation of coral reefs.

From 2000–2011, the Pacific RAMP surveyed each region on a biennial basis to establish baseline ecosystem assessments and conduct long-term monitoring that integrates biological observations with water quality and oceanographic data. In 2011, the NOAA Coral Reef Conservation Program (CRCP) established the NCRMP, and the Pacific RAMP was integrated into this broader objective to monitor the status and trends of all U.S. coral-reef ecosystems, including the Atlantic, Caribbean, and Puerto Rico (NOAA CRCP, 2014). Starting in 2012, the Pacific NCRMP transitioned to monitoring each region on a triennial cycle.

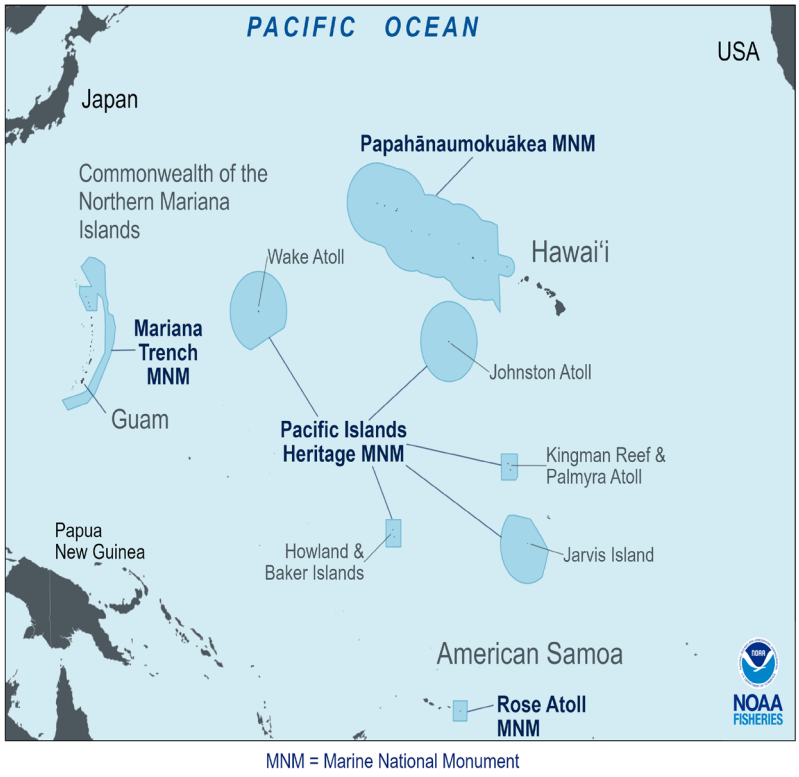

Figure 1. Coral-reef areas surveyed for the Pacific NCRMP. Shading indicates marine national monuments.

As an interdisciplinary monitoring program, the NCRMP has three main themes: biological, climate, and socioeconomic monitoring. The Pacific NCRMP executes the biological and climate components of hard-bottomed reef habitats in the 0–30 m depth range. Under the biological monitoring theme, the Pacific NCRMP collects the following reef-fish data for every observed species, including key fish taxa:

- Abundance
- Size structure
- Diversity
- Distribution

Partnership and cooperation with other federal and jurisdictional management groups is a core principle of the NCRMP. For example, the University of Guam's Long-Term Coral Reef Monitoring Program (GLTMP) conducts reef fish monitoring surveys around Guam using similar survey designs and methods. Therefore, data gathered by the GLTMP is readily merged with NCRMP data resulting in an increased survey domain for local research efforts.

This report focuses on the data collected using the stationary point count (SPC) method to survey the fish assemblage (Methods). Note that the Pacific NCRMP also collects benthic data via benthic transects in the same locations as SPC surveys, which are not included in this report (for more information access the NOAA Coral Program [2021]).

Monitoring scope of the NCRMP

CRCP's NCRMP includes the following biological monitoring goals:

- Develop and implement consistent and comparable methods and standard operating procedures that detail specific field, laboratory, and/or analytical procedures and best practices for all indicators (with periodic updates to reflect new technologies or logistical considerations)
- Develop and maintain strong partnerships with federal, state/territory, and academic partners
- Collect scientifically sound, geographically comprehensive data in U.S. coral reef areas
- Deliver high-quality data, data products, and tools to the coral reef conservation community
- Provide context for interpreting the results of localized monitoring
- Provide periodic assessments of the status and trends of the nation's coral reef ecosystems

- Contribute to local capacity-building through its engagement of jurisdictional entities and private-public partnerships involved in NCRMP data collection

These goals are based on the key monitoring questions for the CRCP and NCRMP support for baseline observations and monitoring (NOAA Coral Reef Conservation Program, 2009; NOAA CRCP, 2014; NOAA Coral Program, 2021).

The Pacific NCRMP involves monitoring over very large spatial scales: ~40 islands and atolls spread over thousands of kilometers. The target for fish monitoring is to provide periodic snapshot assessments of coral-reef assemblages at U.S.-affiliated islands in the Pacific, with the core reporting unit being at the island scale (or sub-island scale for large islands). As such, the survey design and effort are optimized to generate data at the spatial scale of islands and atolls. Therefore, the NCRMP is explicitly a "wide-but-thin" survey program, with the aim of generating large-scale, regional status and trend information of the nation's shallow (0–30 m) coral-reef ecosystems, to provide a broad-scale context and perspective for management and conservation.

Report structure

This report summarizes the reef-fish survey data collected in Hawai'i during the Pacific NCRMP survey mission in 2024. This report incorporates reef fish data collected by the Papahānaumokuākea Marine National Sanctuary monitoring team, who use the same reef fish survey methods as the NCRMP. The status of reef-fish assemblages is described at the island scale and for larger islands at the sector scale. By collecting data using the same methods over time, we are able to provide time series that begin in 2009, when ARP started to consistently use SPC fish surveys.

All data used in this report are available through NCRMP's online data visualization tool, CRCP's digital corals page, or through NOAA's InPort data system for 2009–2012, and 2014 on. For all remaining data requests or inquiries, please contact Andrew.Shantz@noaa.gov.

Methods

Sampling domain and survey design

The target sampling domain is hard-bottom habitat in water shallower than 30 m (Table 1). All islands/atolls within the regions are stratified by reef zone (backreef, forereef, lagoon, protected slope) and depth zone: shallow (>0–6 m), mid (>6–18 m), and deep (>18–30 m). Within the Main Hawaiian Islands, sampling is exclusively conducted in forereef habitats and each island is further stratified into sectors based on broad differences in oceanographic exposure, reef structure, and local human population density. In contrast, the Papahānaumokuākea Marine National Monument encompasses a broader range of habitats. Monitoring at Hōlanikū (Kure), Manawai (Pearl & Hermes), and Midway includes backreef and lagoon habitats in addition to forereefs, while the design at Lalo (French Frigate Shoals) incorporates all four primary reef zones, including protected slope.

Table 1. Sampling terms and definitions.

Term	Definition
Sampling domain	Hard-bottom habitat in water less than 30 m depth.
Reporting unit	A collection of sample sites, typically an island or atoll and in some cases, small island groups or sectors of larger islands.
Sectors	Management units and stretches of coastline with broadly similar habitat attributes and local human population density
Reef zone	Backreef, forereef, lagoon, or protected slope
Depth zone	Shallow >0*–6 m; mid >6–18 m; deep >18–30 m
Strata	Combination of sectors, reef zone and depth zone—the pooling level for site estimates by reef area
Sample site data	The average values of estimated observed quantities from the SPC surveys conducted at each site. These are typically derived from a single pair of simultaneous surveys. Sites are tied to geographic coordinates.

*For practical reasons, sites in which the center point of the survey cylinder is shallower than 1.5 m are not surveyed.

The number of sites to be surveyed per stratum is based on a weighting factor calculated from the proportional area per stratum per reporting unit (e.g., island) and the variance of the target output metrics (e.g., consumer group biomass and total fish biomass; Fish groupings), in combination with the ship time allotted per island or atoll.

The resulting target number of sites is then randomly distributed across each stratum. Details on the sampling effort across survey cruises are provided in Appendix A.

Site selection

Prior to each survey mission, sample site locations (latitude and longitude) are randomly drawn from geographic information system (GIS) habitat and strata maps of the entire sampling domain (Figure 2).

Maps used in the site selection procedure were created using information from the NOAA National Centers for Coastal Ocean Science, reef zones (e.g., forereef) digitized from IKONOS satellite imagery or nautical charts, bathymetric data from the Pacific Islands Fisheries Science Center (PIFSC)-affiliated Pacific Islands Benthic Habitat Mapping Center at the University of Hawai‘i at Mānoa, and prior knowledge gained from previous visits to survey locations.

Although the Pacific NCRMP aims to survey around the entirety of each island or atoll, the achieved monitoring effort is ultimately determined by field logistics and weather conditions encountered during field operations on each research cruise. If a site is not suitable (e.g., soft- as opposed to hard-bottomed habitat) or accessible (e.g., due to inclement sea conditions), the dive is aborted and an alternate (backup) site is picked from the randomized list. In some cases, the spatial coverage of sampling sites around the entire area of the target sampling domain is incomplete. As such, any inferences about coral-reef fish assemblages and habitat made at the island scale are only representative of the areas sufficiently surveyed (Appendix B). For further details on the methods and maps used to select sites, go to (Ayotte et al. 2015 and Williams et al. 2011).

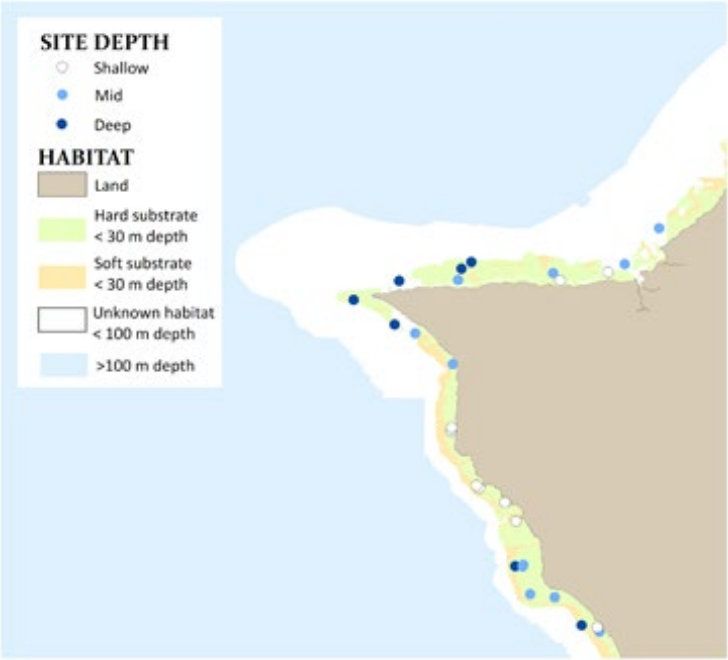

Figure 2. An example of the benthic habitat and depth strata information used in the site-selection process. Each circle identifies a site that falls on hard substrata (green) in the three depth strata (see map legend; shallow, <6 m; mid, >6–18 m; and deep, >18–30 m).

Sampling Methods

At each survey site, divers record the counts and sizes of observed fish assemblages. The SPC protocol closely follows that used by Ault et. al. (2006) and involves a pair of divers conducting simultaneous counts in adjacent, visually estimated 15 m diameter cylindrical plots extending from the substrate to the limits of vertical visibility (Figure 3).

Prior to beginning each SPC, a 30 m line is laid across the substratum. Markings at 7.5 m, 15 m, and 22.5 m enable survey divers to locate the midpoint (7.5 m or 22.5 m) and two edges (0 m and 15 m or 15 m and 30 m) of their survey plots. Each count consists of two components.

The first is a 5-minute species enumeration period in which the diver records the taxa of all species observed within their cylinder. At the end of the 5-minute period, divers begin the tallying portion of the count, where they systematically work through their species list and record the number and estimated size (total length [TL] to the nearest centimeter) of each individual fish.

The tallying portion is conducted as a series of rapid visual sweeps of the plot, with one species-grouping counted per sweep. To the extent possible, divers remain at the

center of their cylinders throughout the count. However, small, generally site-attached and semi-cryptic species—which tend to be under-represented in counts made by an observer remaining in the center of a 7.5-m radius cylinder—are left to the end of the tally period, at which time the observer swims through their plot area carefully searching for those species. In cases where a species is observed during the enumeration period but is not present in the cylinder during the tallying period, divers record their best estimates of size and number observed in the first encounter during the enumeration period and mark the data record as “non-instantaneous.”

Beginning in 2012, divers also recorded observations of fishes that were first seen inside the cylinders at some point between 5 and 30 minutes into the survey. However, for consistency across time periods, those additional observations were not used in this report. Surveys are not conducted if horizontal visibility is less than 7.5 m, that is, when observers cannot distinguish the edges of their cylinder (Ayotte et al., 2015).

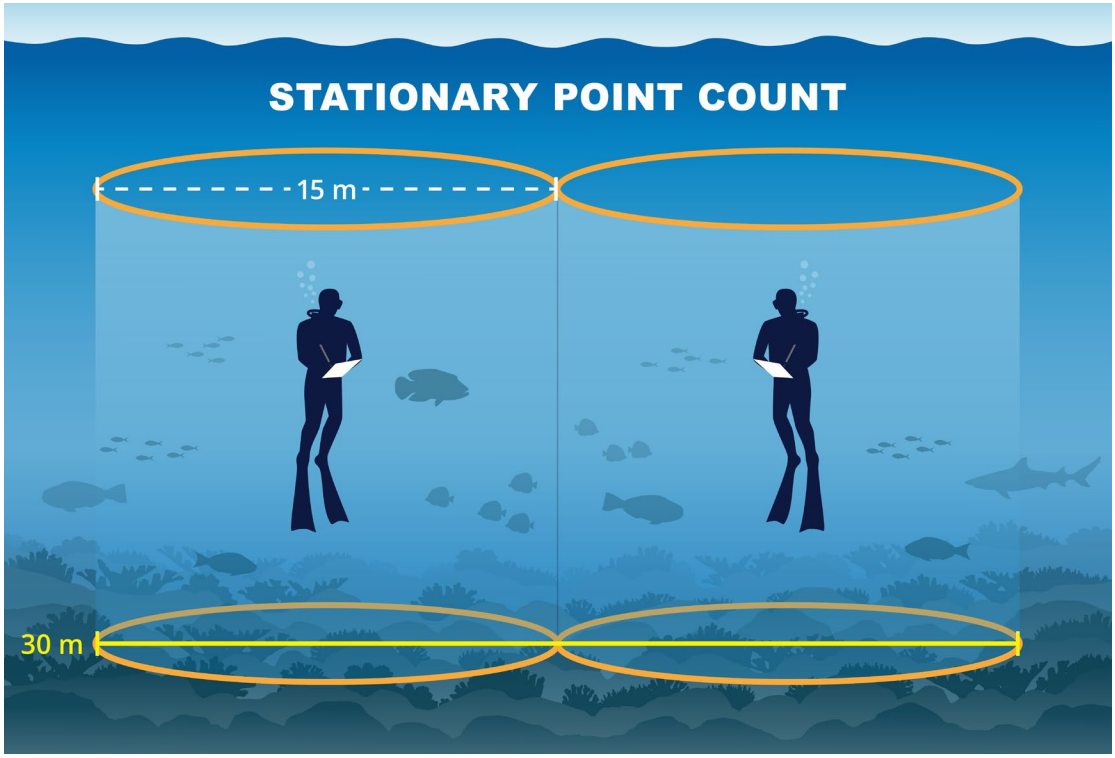

Figure 3. Side view of the stationary point count method. A pair of divers count and size the fishes within adjacent cylinders measuring 15 m in diameter.

Data entry and storage

Data are entered into a custom data entry application built with Oracle Application Express and stored in an Oracle mission-specific database. Upon completion of each monitoring cruise, all data are migrated to an existing master Oracle database that is stored on a server at the PIFSC.

Data quality control

Data quality control is implemented at three main stages:

- Prior to conducting fish surveys for the Pacific NCRMP, each observer must take the full training course. In between field data collections, observers practice survey methods and take fish identification tests (Figure 4: Pre-field).
- Checking for errors at the data entry stage (Figure 4: In the field) occurs on the cruise when observers check the data entered by their dive partner against their datasheet for typing and potential sizing errors. At the end of the cruise, a series of error checking scripts are run prior to migrating from the mission Oracle database to the master Oracle database (Figure 4: Post-field).

Examining diver estimation accuracy occurs during and after the monitoring cruise when diver estimates are compared between dive partner pairs (Figure 4: In the field). Observer comparisons from the regions surveyed in 2024 are in Appendix C.

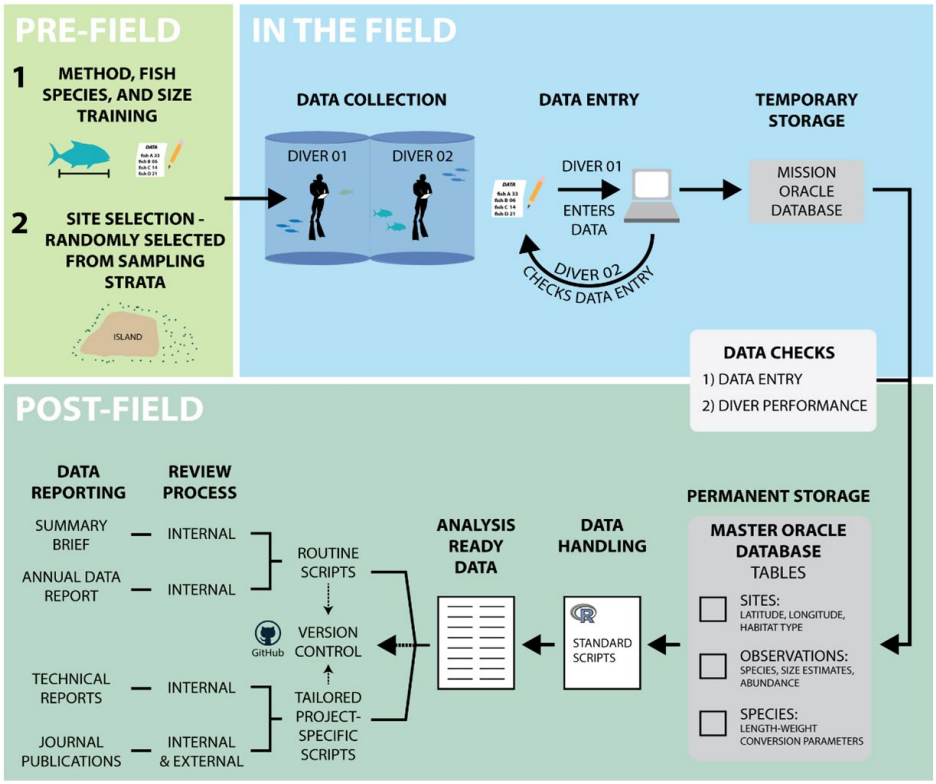

Figure 4. The training, data collection, data processing, and reporting workflow for the Pacific NCRMP SPC surveys.

Data handling

Calculating fish biomass per site

Using the count and size data collected per observer in each replicate survey, the body weight of each individual fish is calculated using length-to-weight (LW) conversion parameters and, where necessary, length-length (LL) parameters (for example, to convert TL to fork length [FL] for species with LW parameters based on FL). LW and LL conversion parameters were taken from FishBase (Froese & Pauly, 2010; Kulbicki et al., 2005). Biomass per fish is calculated using the standard length-weight equation. Herein, the term "biomass" refers to the aggregate body weight of a group of fishes per unit area (g m^{-2}). Site is the base sample unit, and the estimated biomass of fishes per site is calculated by taking the mean value from the paired SPC surveys.

Fish groupings

In this report, species data are summarized at several different levels: consumer group, total fish biomass ("all fishes"), parrotfish biomass, and average total length. Consumer groups are: "primary consumers" (herbivores and detritivores); "secondary consumers"

(omnivores and benthic invertivores); “planktivores;” and “piscivores,” with classifications based on diet information taken largely from FishBase (Froese & Pauly, 2010). For parrotfish, data are presented for two size classes: 10–30 cm and greater than 30 cm TL, as 30 cm is the legal minimum size for fishing on all islands.

Generating island-scale estimates from the stratified design

Summary statistics (e.g., mean and variance) of survey metrics (e.g., biomass) are calculated by first averaging values within each stratum before calculating the reporting unit values. A weighted-average method to calculate summary statistics is used because survey strata vary in size within each reporting unit.

Estimates of the mean and variance for each survey quantity considered are calculated based on the observed values at sampled sites within each stratum. Then, aggregate estimates of the quantities across all strata are calculated using these formulas:

(1) Pooled mean biomass (*X*) across S strata:

$$X = \Sigma_1^S (X_i * w_i)$$

(2) Pooled mean variance of mean biomass (*VAR*) across S strata:

$$VAR = \Sigma_1^S (VAR_i * w_i^2)$$

where X_i is the estimate of mean biomass within stratum *i*, VAR_i is the estimated variance of X_i and w_i is the stratum-weighting factor. Strata weighting factors were based on the size of strata, that is, if a stratum is 50% of the total habitat area surveyed at an island, its weighting factor will be 0.5, and the total of all weighting factors in an island sums to 1 (Smith et al., 2011).

In this report, only data from sites surveyed under the stratified sampling design are used (i.e., data collected from 2009 onward; Appendix D). In the rare cases where fewer than two sites were surveyed in a stratum during a reporting period, they were removed from the island-scale parameter estimates for that period.

Island-scale values for total fish biomass (i.e., all fishes, fishes by size class) and biomass per consumer group, parrotfish size class, and species of interest (mean and variance) are calculated by year (Island status and trends).

All data handling and analyses were performed using raw site data extracted from the NOAA PIFSC Oracle database, processed using a set of routine processing scripts written in R (R Development Core Team, 2011; Figure 4: Post-field), and visualized using the ggplot2 package (Wickham, 2016). The site-level data used to generate all figures and summary statistics are available upon request.

Island status and trends

This section summarizes SPC data collected at each island in Hawai‘i between 2010 and 2024, when comparable methods were used. For each island within a region—if there was sufficient sampling for the year—the maps illustrate the SPC site-level data and a standard set of graphs. The graphs show summary information about the fish community at the island and reef zone (forereef, lagoon, protected slope) scale.

On each fish biomass graph for the forereef habitat, a reference line indicates the region-wide mean estimate across all surveyed years (2010–2024), which is provided as a relevant regional comparison for island-level estimates. Fish biomass estimates are shown for each year of all fish combined, all fish in two size classes, parrotfish in two size classes, families of interest, and by consumer group. All fish, consumer group, and parrotfish biomass are core NCRMP indicators (NOAA CRCP 2014). Large parrotfishes are important grazers, so parrotfish biomass is separately reported for two size groups: large (>30 cm TL) and small (10–30 cm TL) fishes.

Mean fish size (cm TL) per island and year is also reported, as it can be a useful indicator of fishing pressure; fishes smaller than 10 cm TL are excluded to reduce noise from variable levels of recent fish recruitment. Biomass for jacks and all shark species are also shown.

Main Hawaiian Islands

Hawai‘i

Table 2. Year surveyed and the number of sites.

Year	2010	2013	2015	2016	2019	2024
Sites	43	58	97	59	73	47

Hawai‘i is further broken down into geographic sectors due to its large size. Sectors are indicated by different colors on the map, and summary data are shown at the island level and the sector level. Not all sectors were surveyed each year.

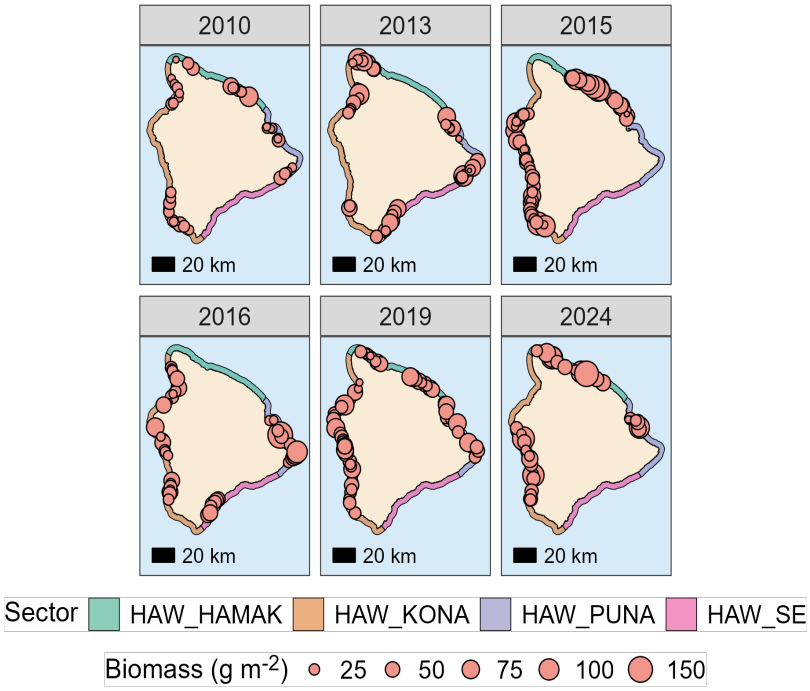

Figure 5. Hawai‘i Island site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

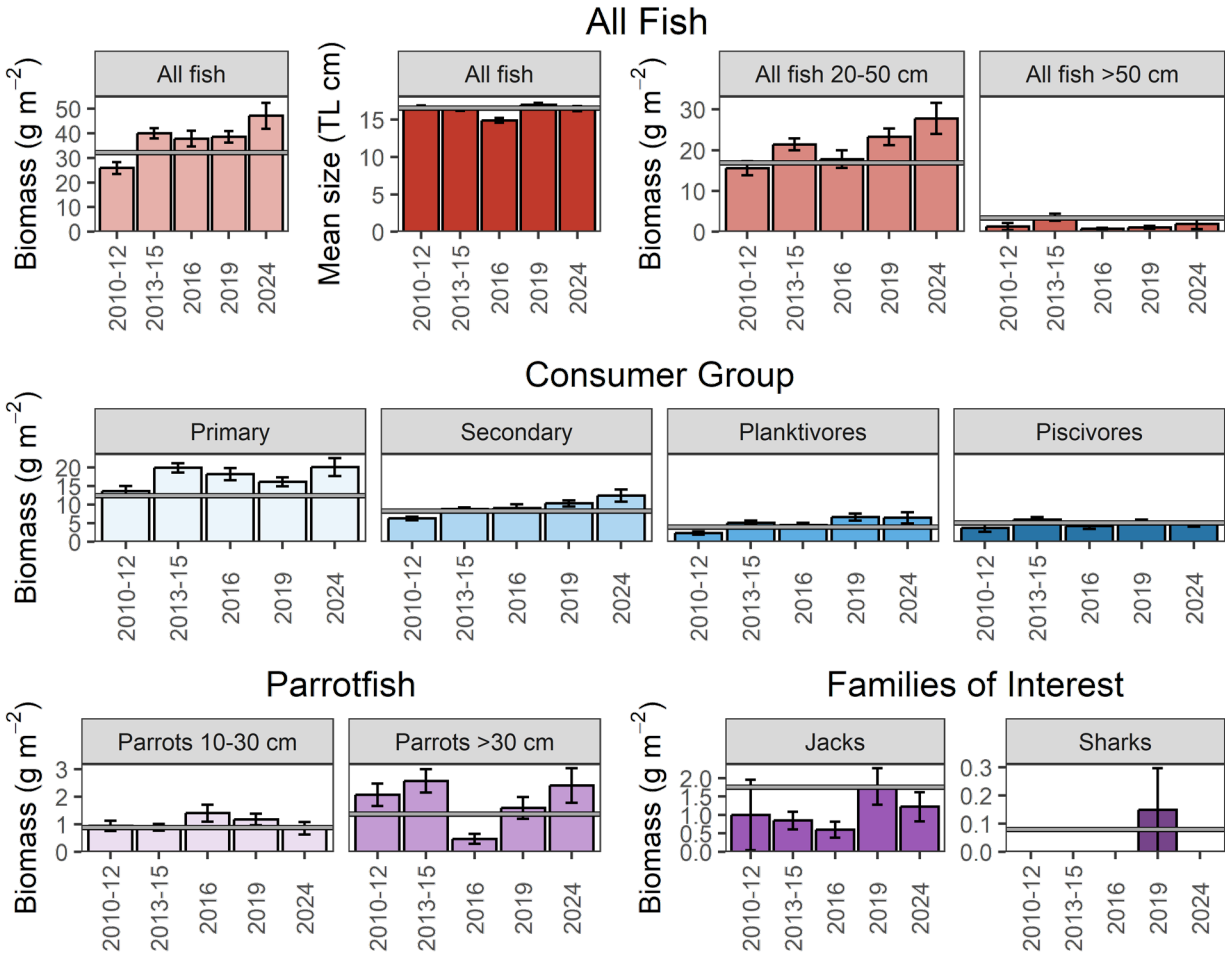

Figure 6. Hawai‘i Island fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Hawai'i's Hamakua Sector, indicated by green (Figure 5).

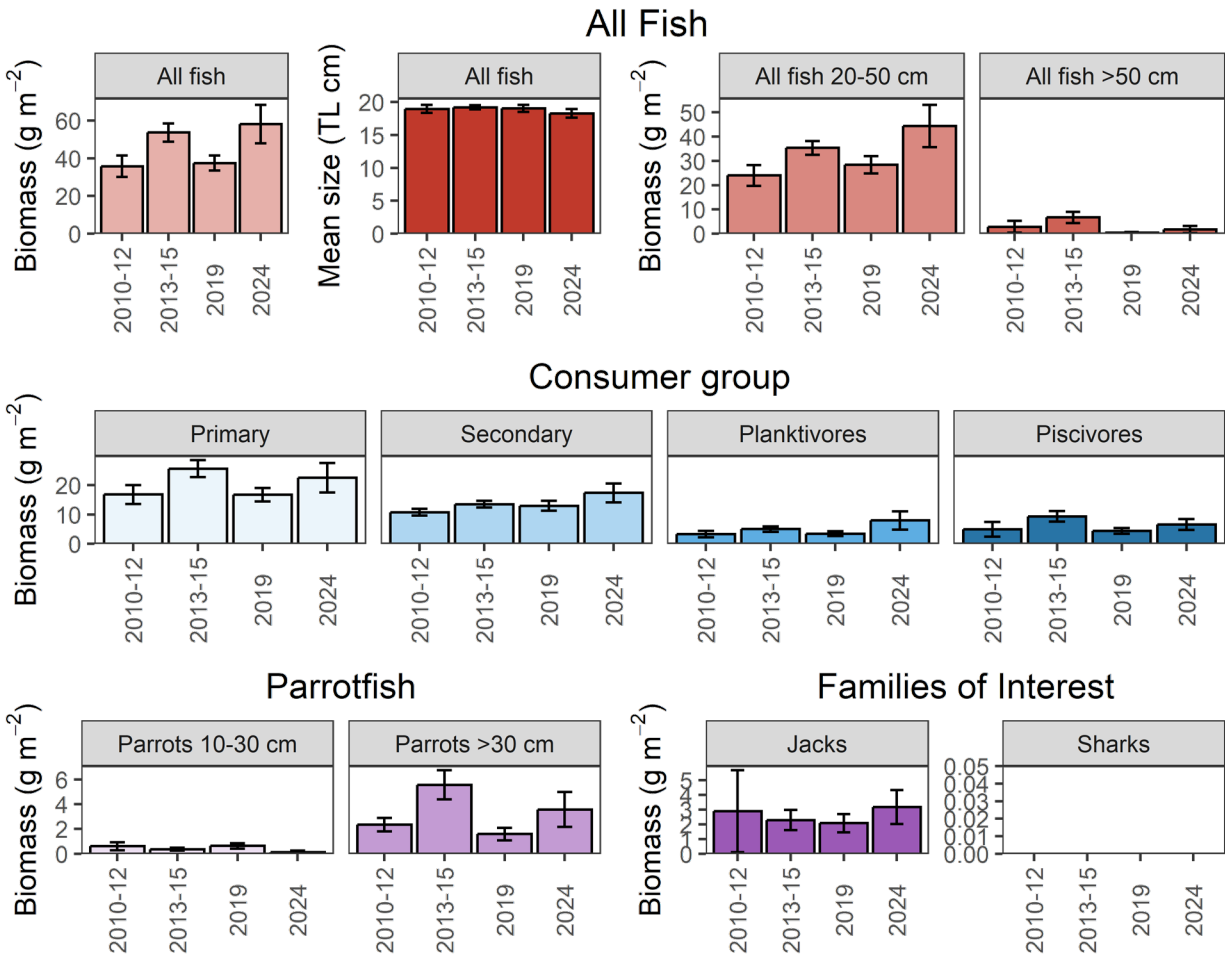

Figure 7. Hawai'i Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Hawai'i's Kona Sector, indicated by orange (Figure 5).

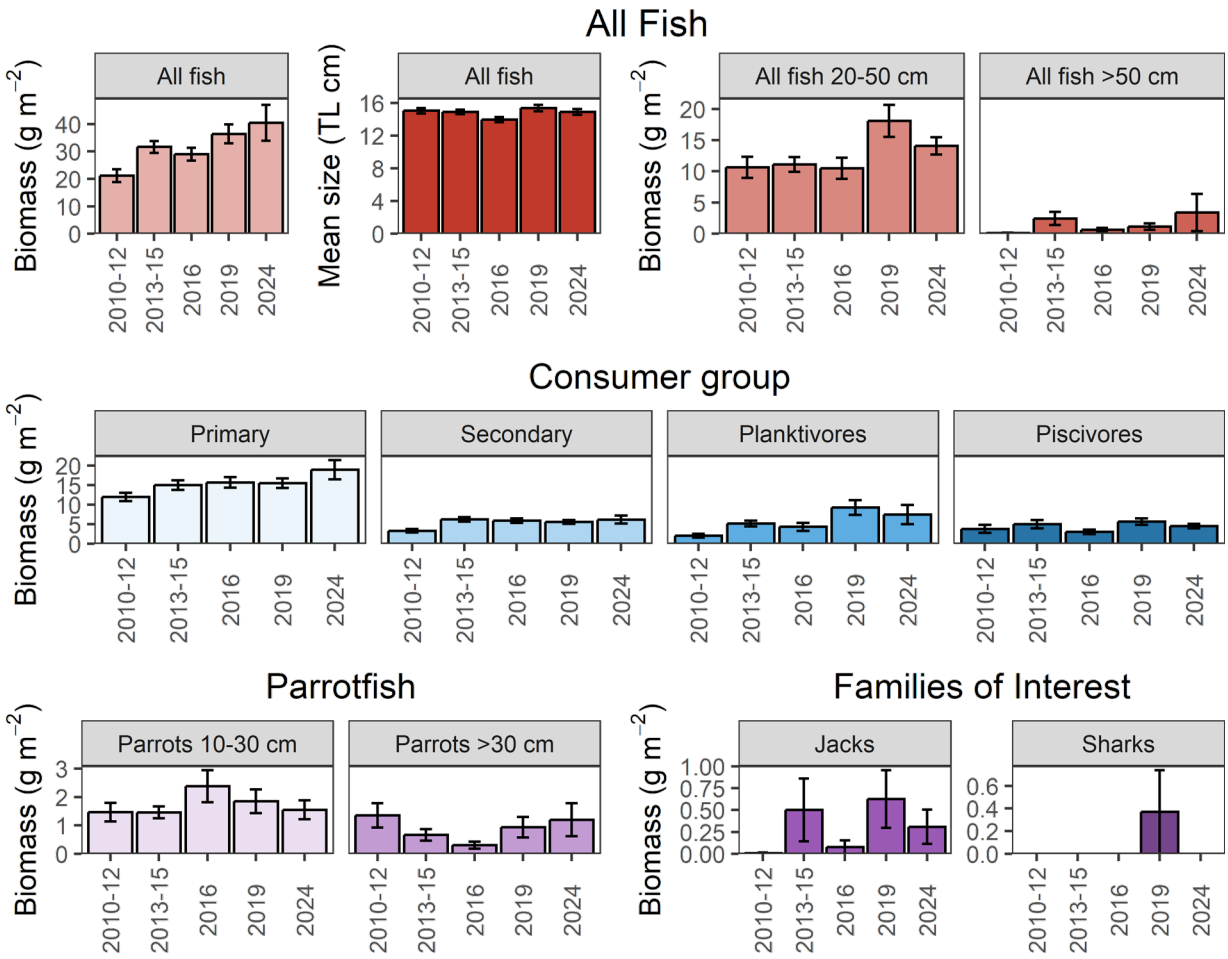

Figure 8. Hawai'i Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Hawai‘i’s Puna Sector, indicated by purple (Figure 5).

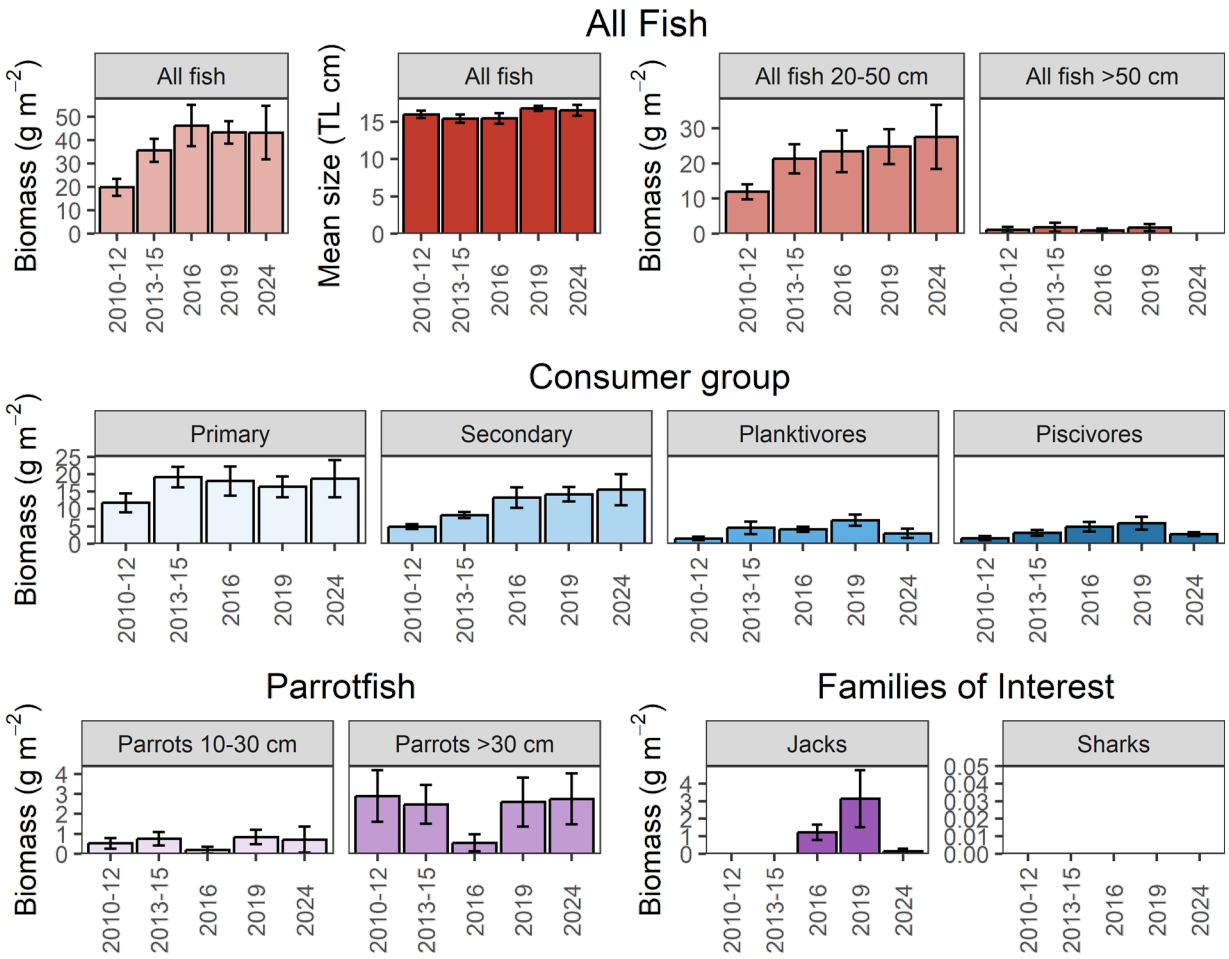

Figure 9. Hawai‘i Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Hawai'i's Southeast Sector, indicated by pink (Figure 5).

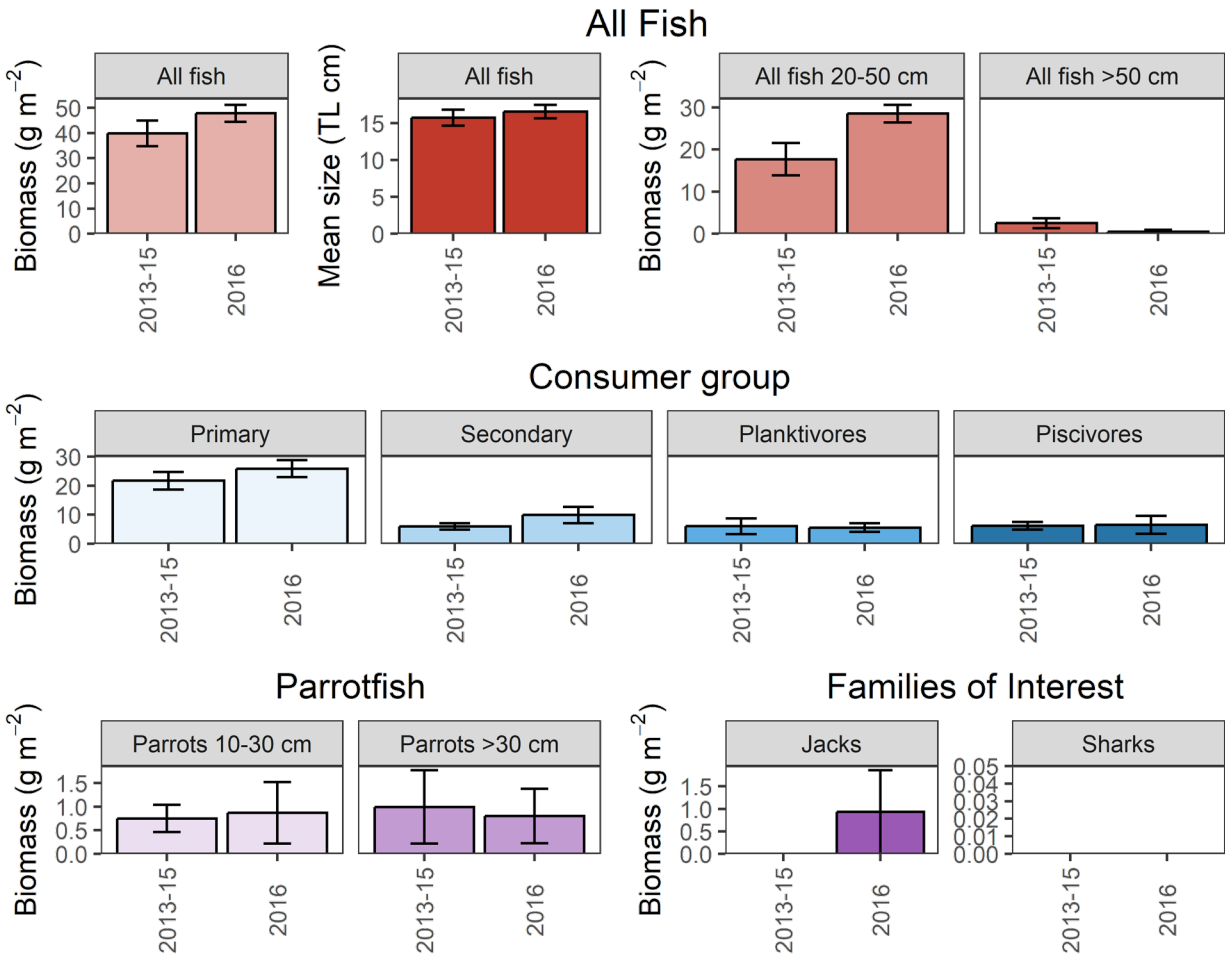

Figure 10. Hawai'i Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Kauai

Table 3. Year surveyed and the number of sites.

Year	2010	2013	2015	2016	2019	2024
Sites	26	37	20	30	22	15

Kauai is further broken down into geographic sectors due to its large size. Sectors are indicated by different colors on the map, and summary data are shown at the island level and the sector level. Not all sectors were surveyed each year.

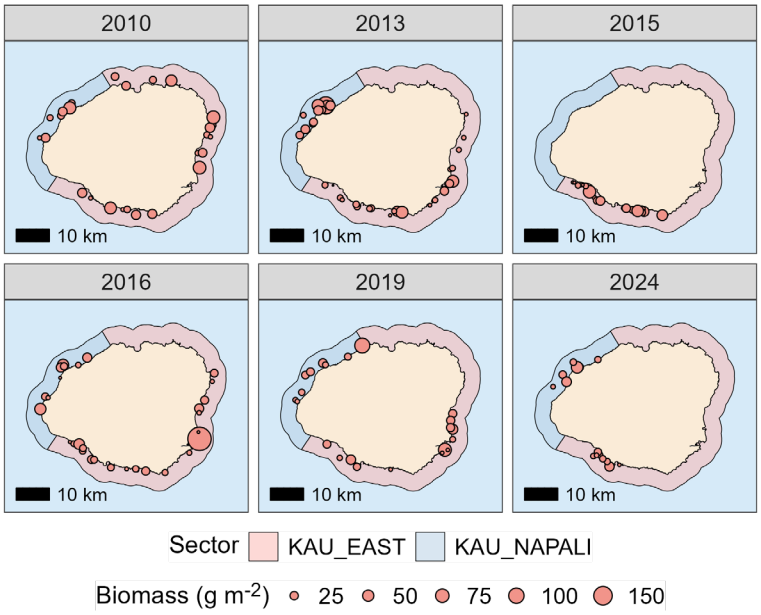

Figure 11. Kauai Island site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

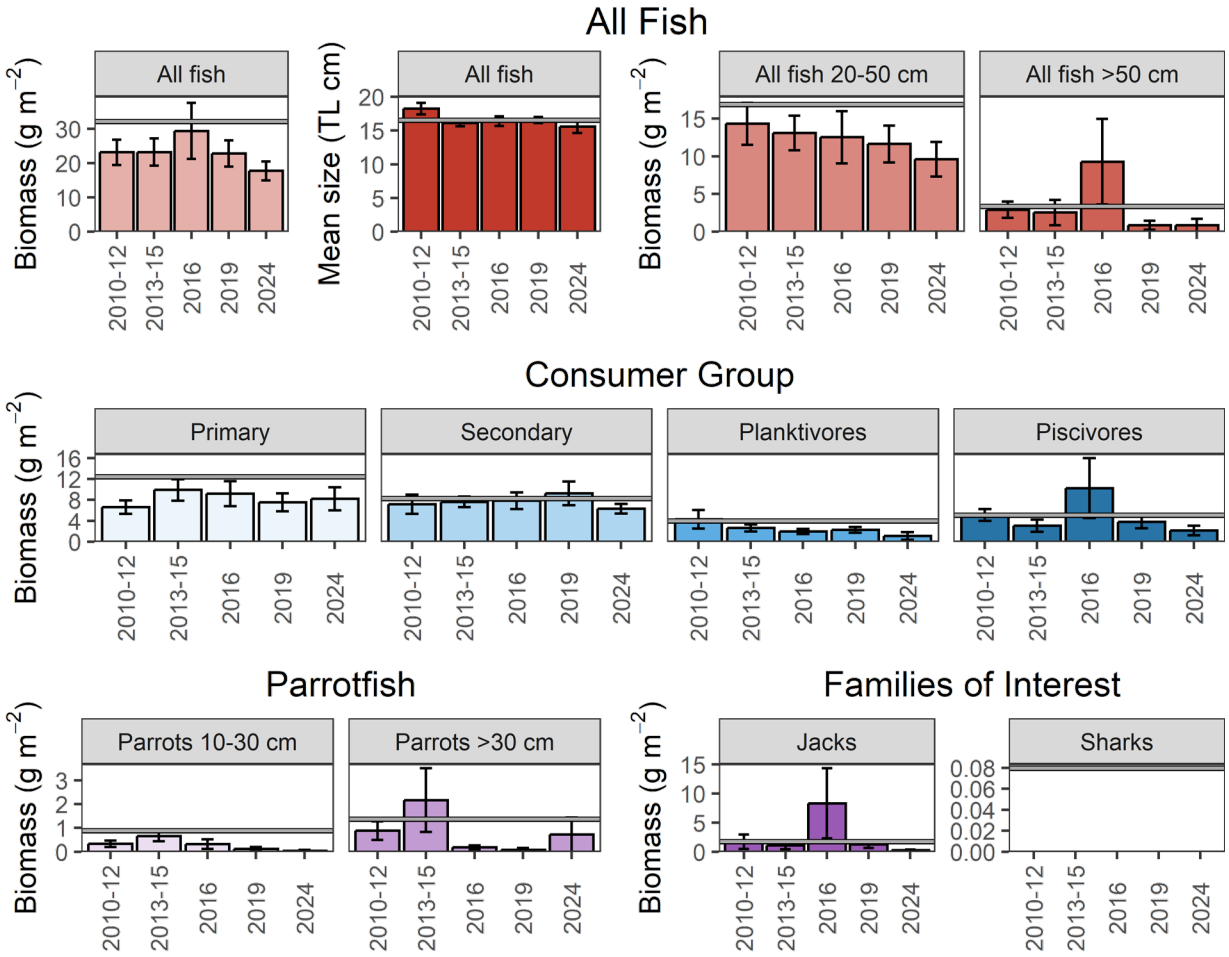

Figure 12. Kauai Island fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Kauai's east sector, indicated by pink (Figure 11).

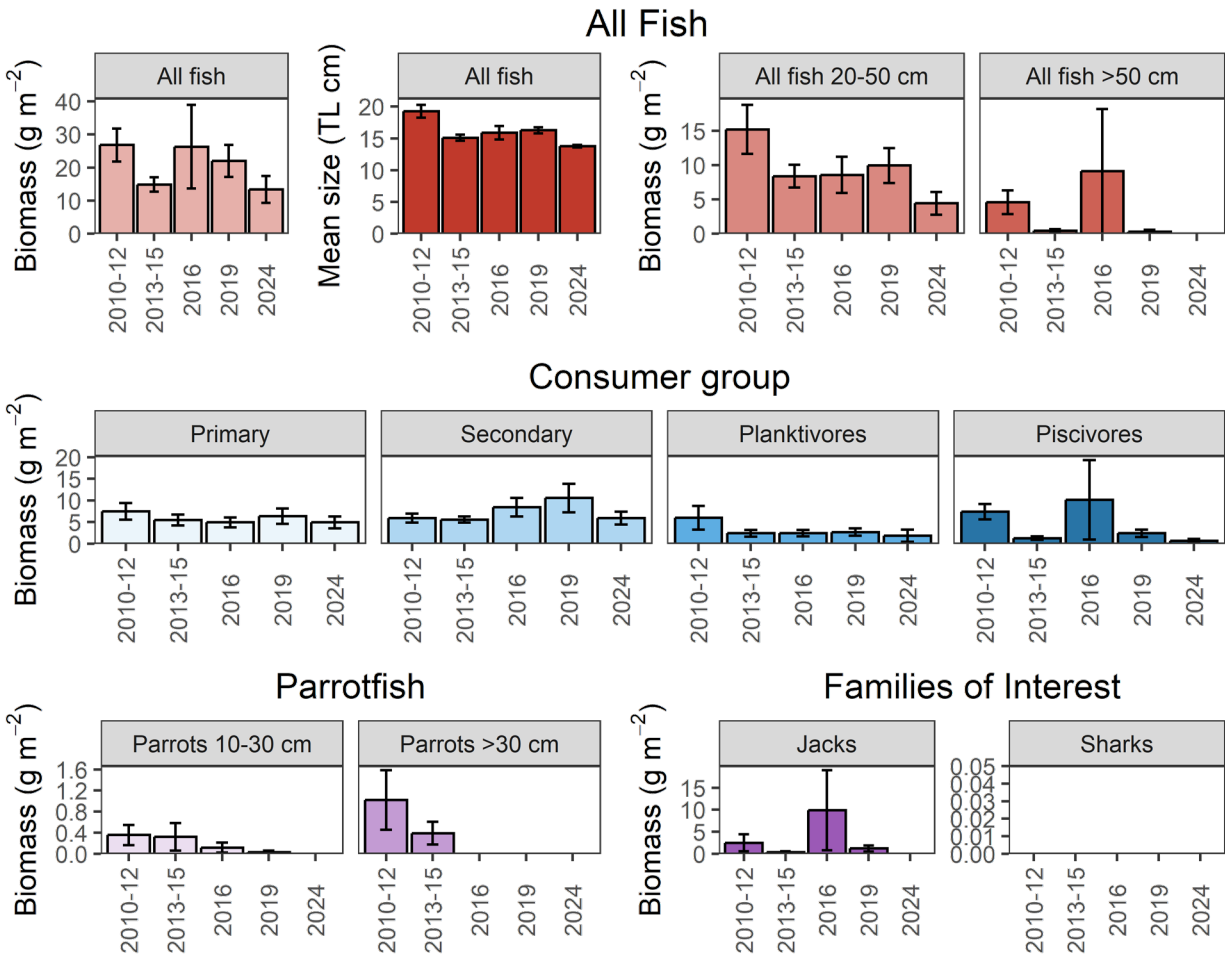

Figure 13. Kauai Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Kauai's napali sector, indicated by blue (Figure 11).

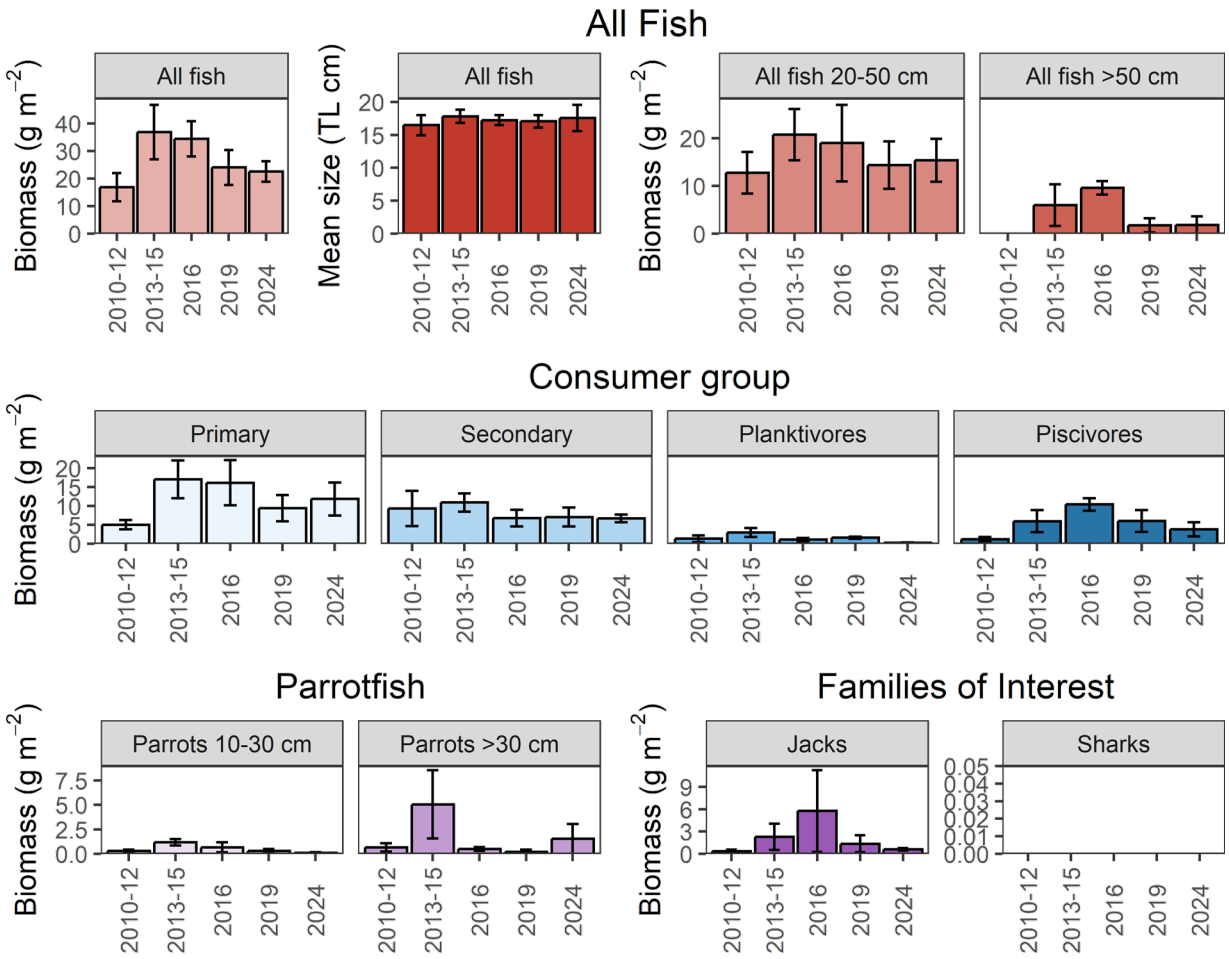

Figure 14. Kauai Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Kahoʻolawe

Table 4. Year surveyed and the number of sites.

Year	2016	2019	2024
Sites	24	20	23

Kahoʻolawe is further broken down into geographic sectors due to its large size. Sectors are indicated by different colors on the map, and summary data are shown at the island level and the sector level. Not all sectors were surveyed each year.

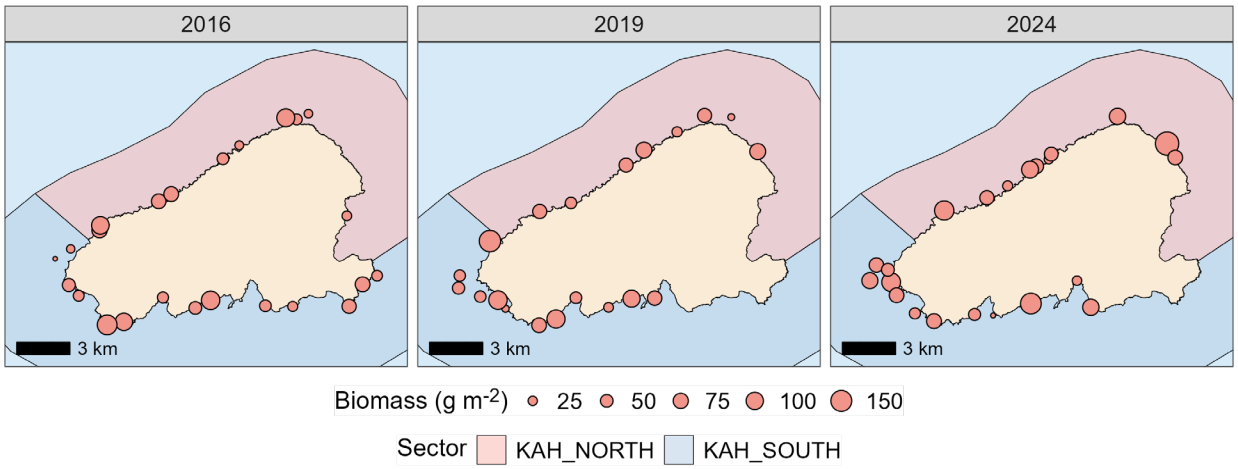

Figure 15. Kahoʻolawe Island site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

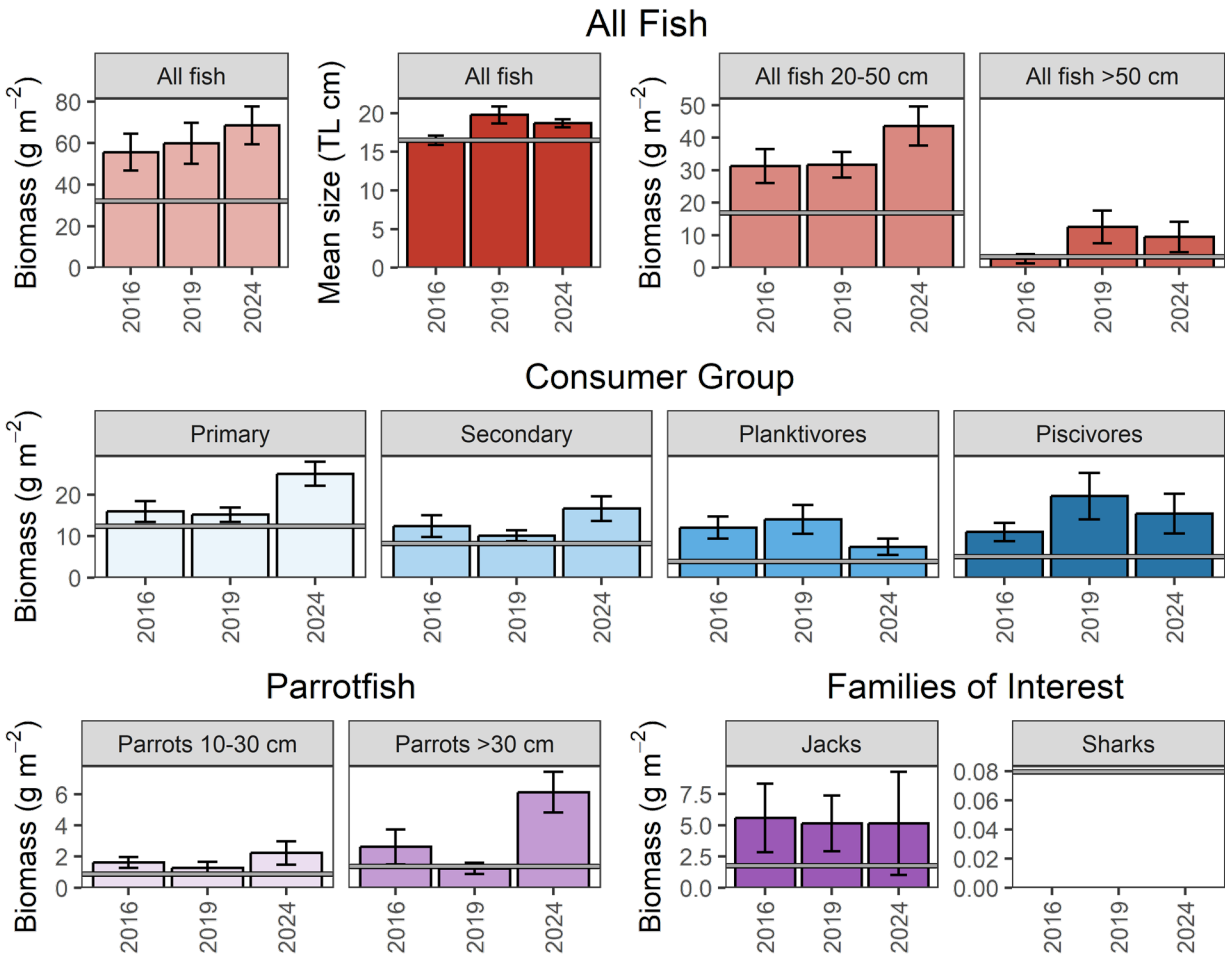

Figure 16. Kahoʻolawe Island fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Kaho‘olawe’s north sector, indicated by pink (Figure 15).

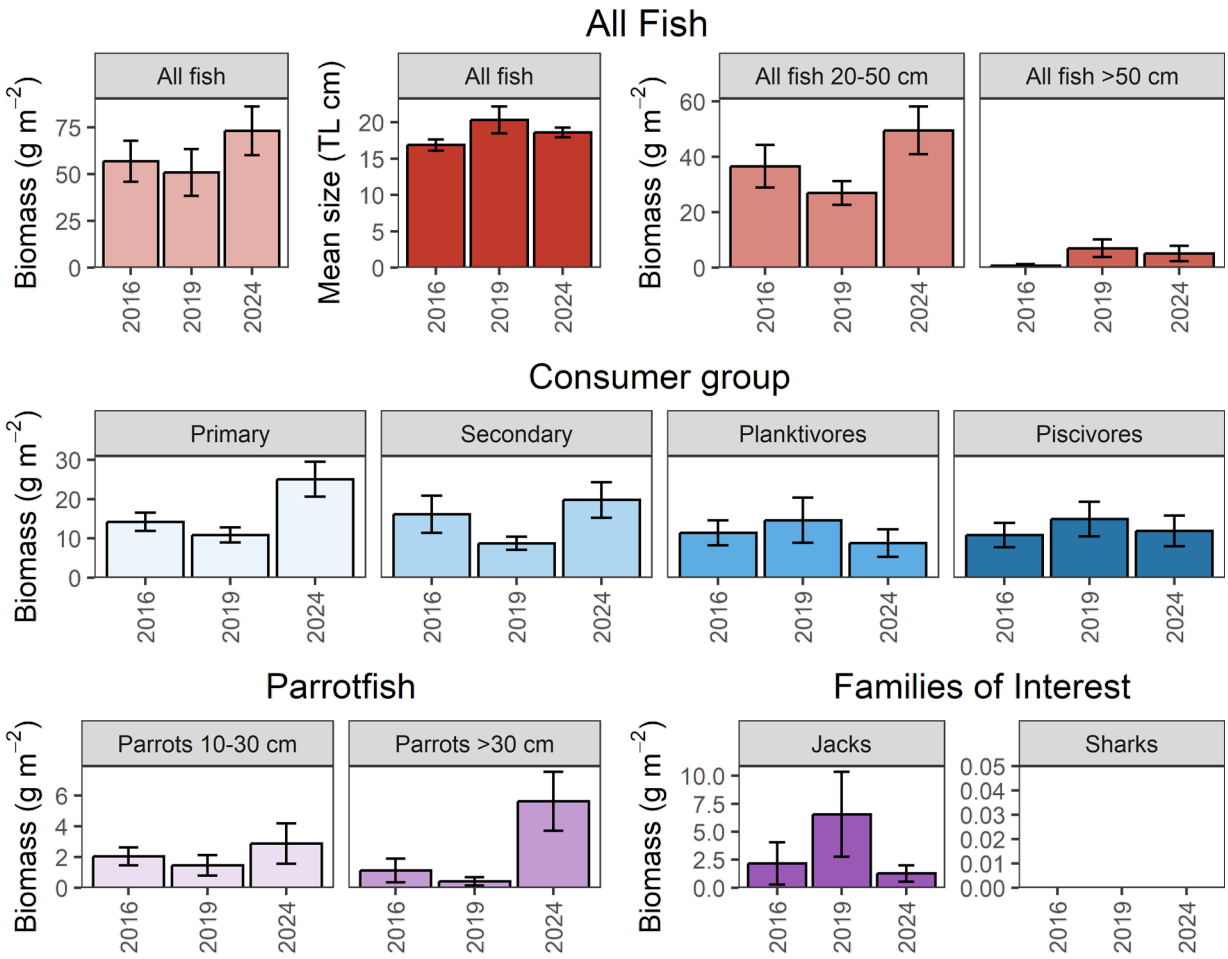

Figure 17. Kaho‘olawe Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Kahoʻolawe's south sector, indicated by blue (Figure 19).

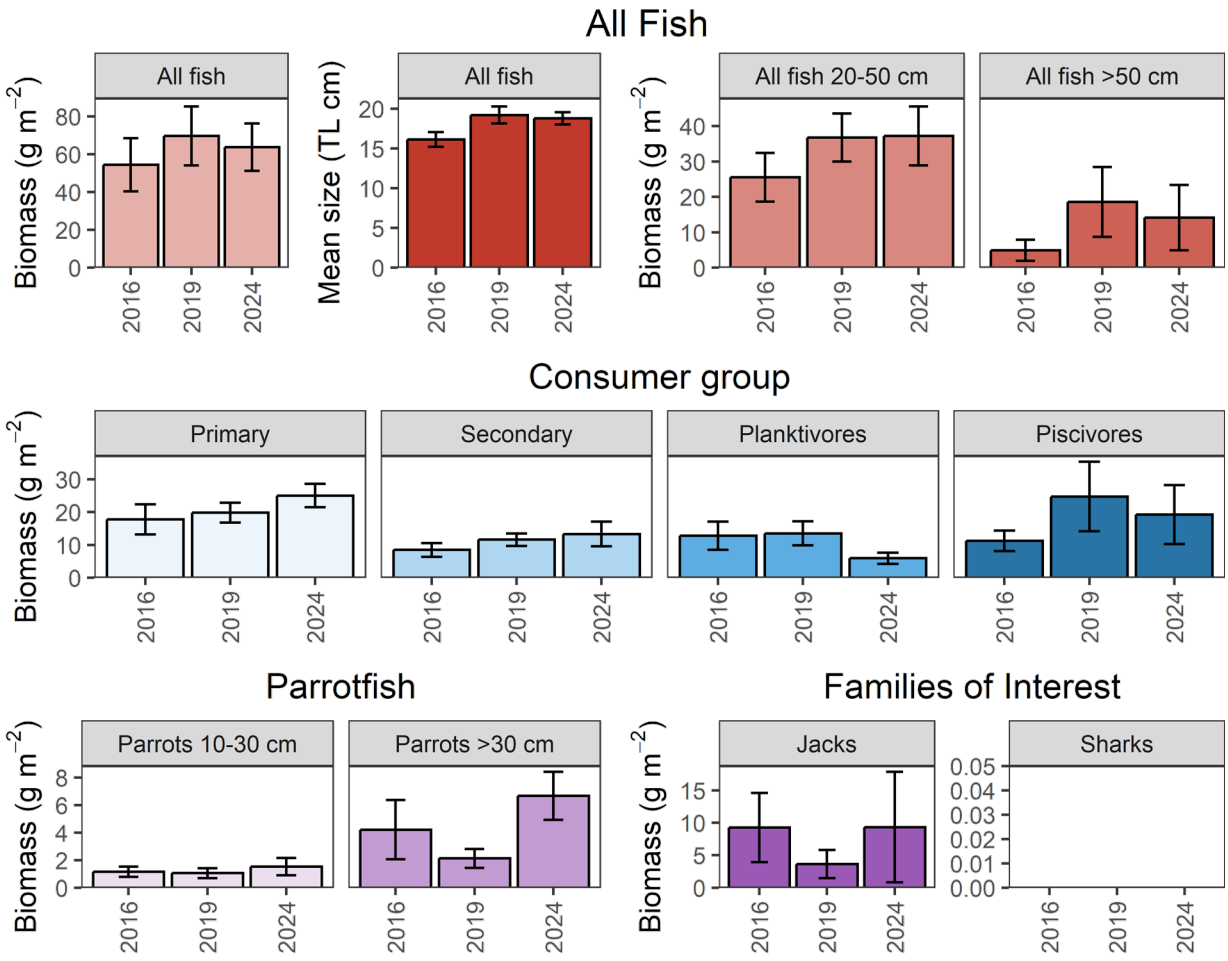

Figure 18. Kahoʻolawe Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Lanaʻi

Table 5. Year surveyed and the number of sites.

Year	2010	2012	2013	2015	2016	2019	2024
Sites	16	29	29	15	26	27	18

Lanaʻi is further broken down into geographic sectors due to its large size. Sectors are indicated by different colors on the map, and summary data are shown at the island level and the sector level. Not all sectors were surveyed each year.

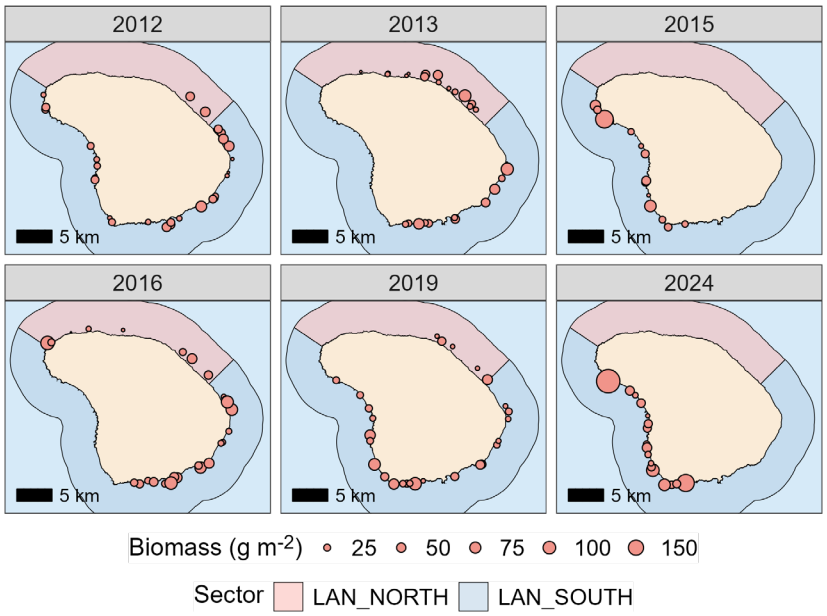

Figure 19. Lanaʻi Island site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

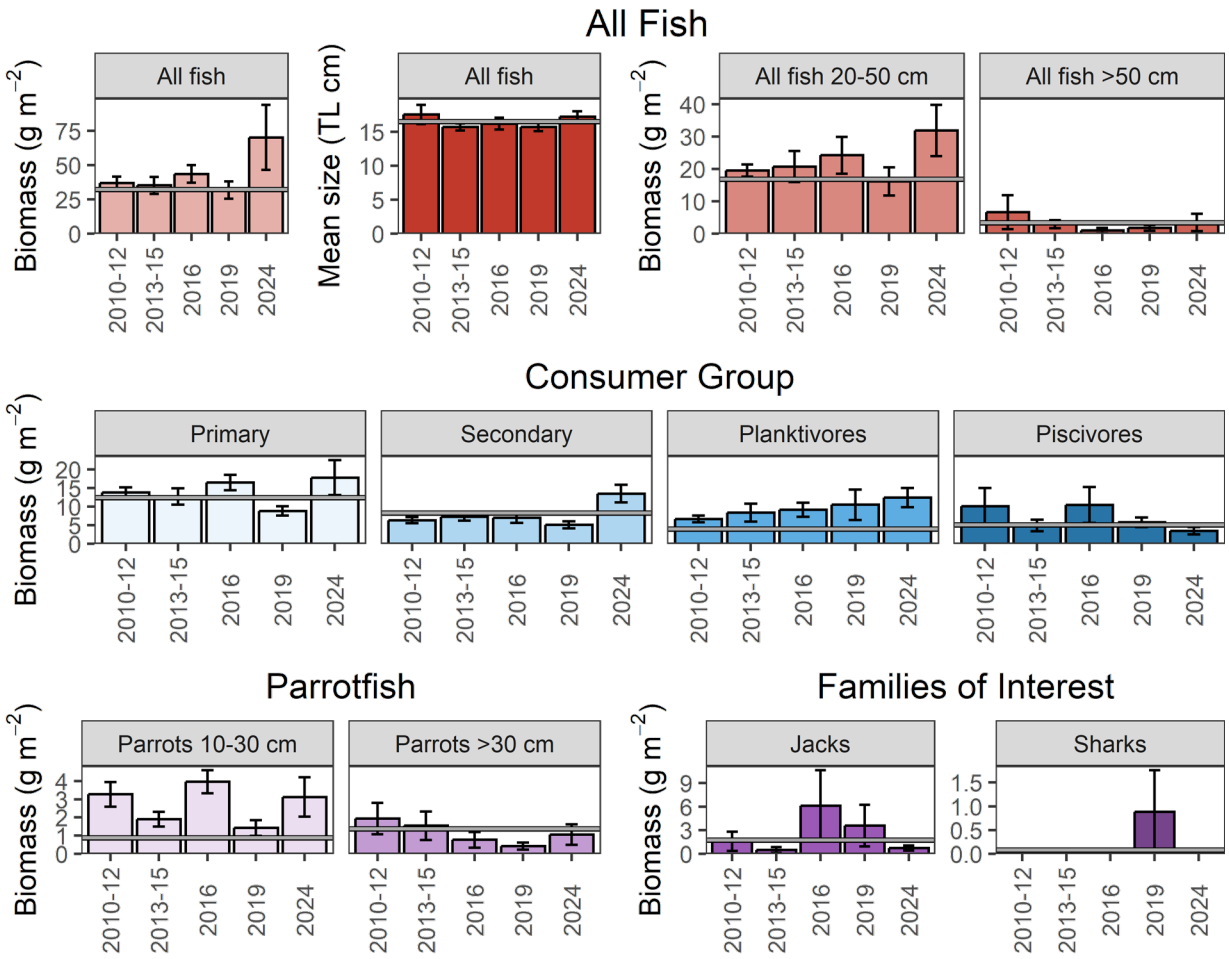

Figure 20. Lana‘i Island fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Lana'i's north sector, indicated by pink (Figure 19).

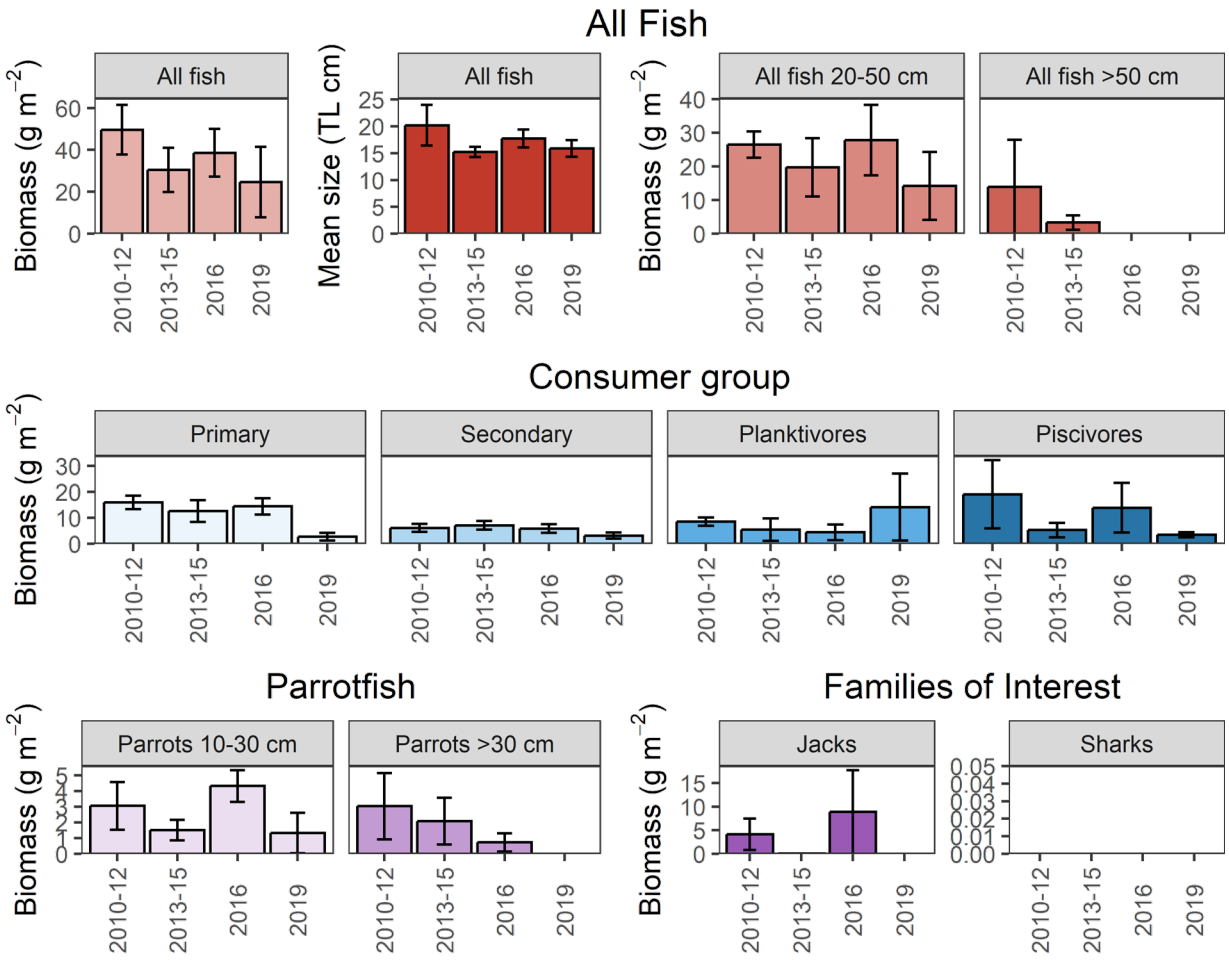

Figure 21. Lana'i Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Lana'i's south sector, indicated by blue (Figure 19).

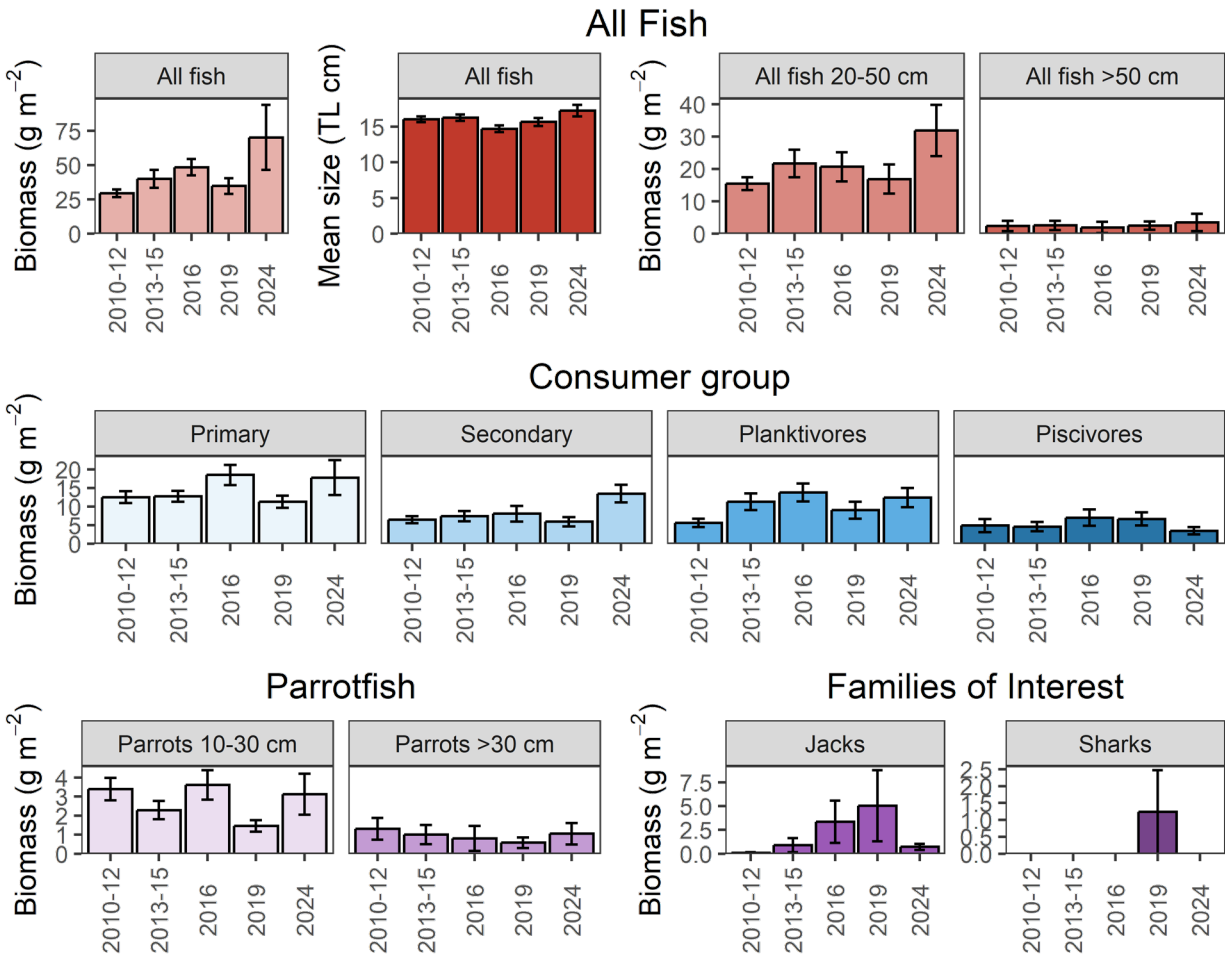

Figure 22. Lana'i Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Maui

Table 6. Year surveyed and the number of sites.

Year	2010	2012	2013	2015	2016	2019	2024
Sites	33	49	34	30	28	42	26

Maui is further broken down into geographic sectors due to its large size. Sectors are indicated by different colors on the map, and summary data are shown at the island level and the sector level. Not all sectors were surveyed each year.

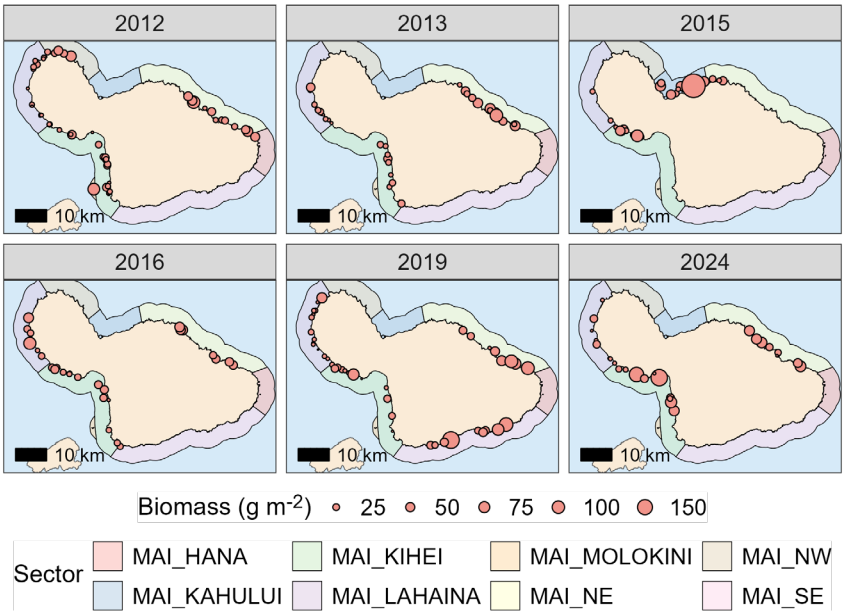

Figure 23. Maui Island site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

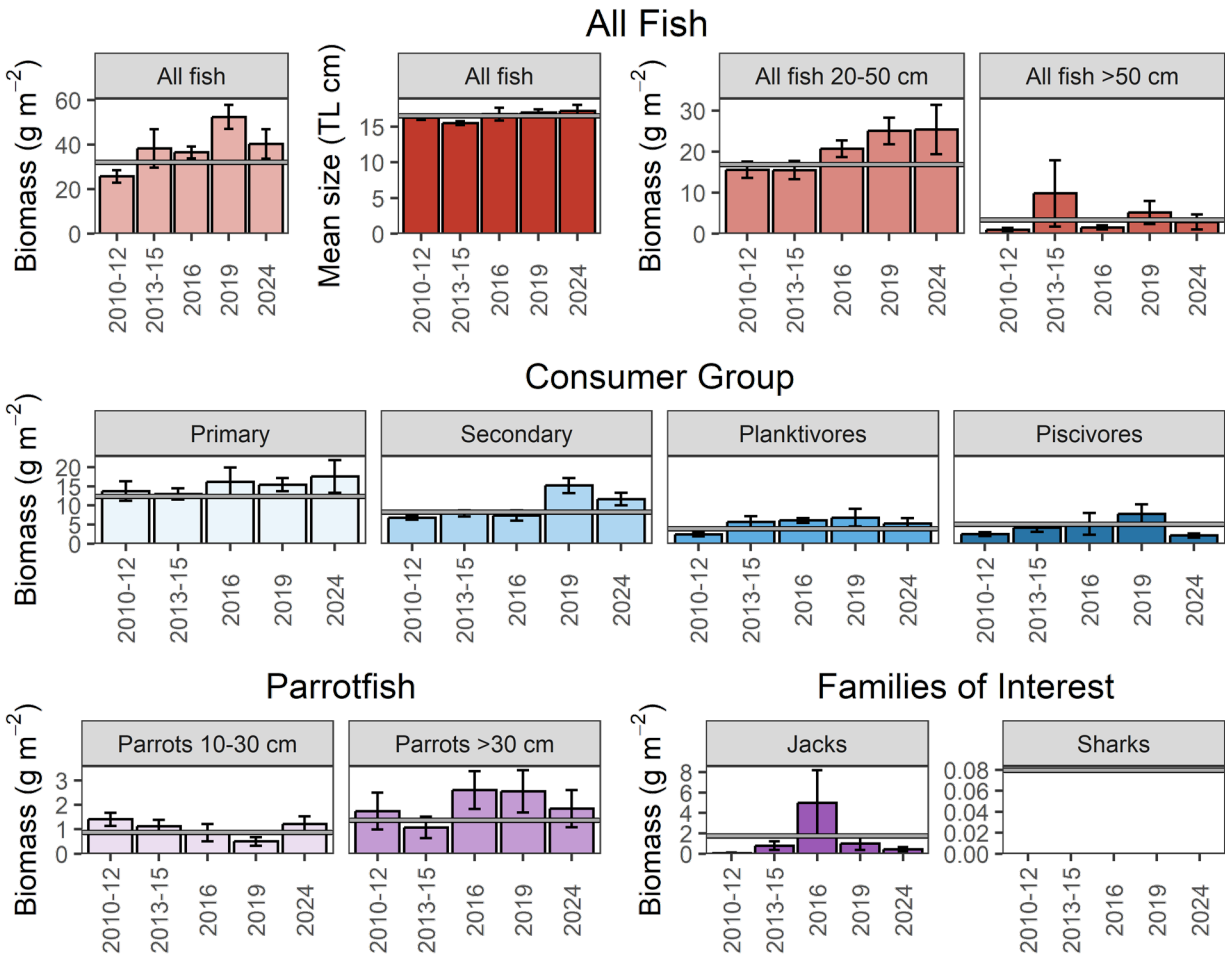

Figure 24. Maui Island fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Maui's Kihei sector, indicated by green (Figure 23).

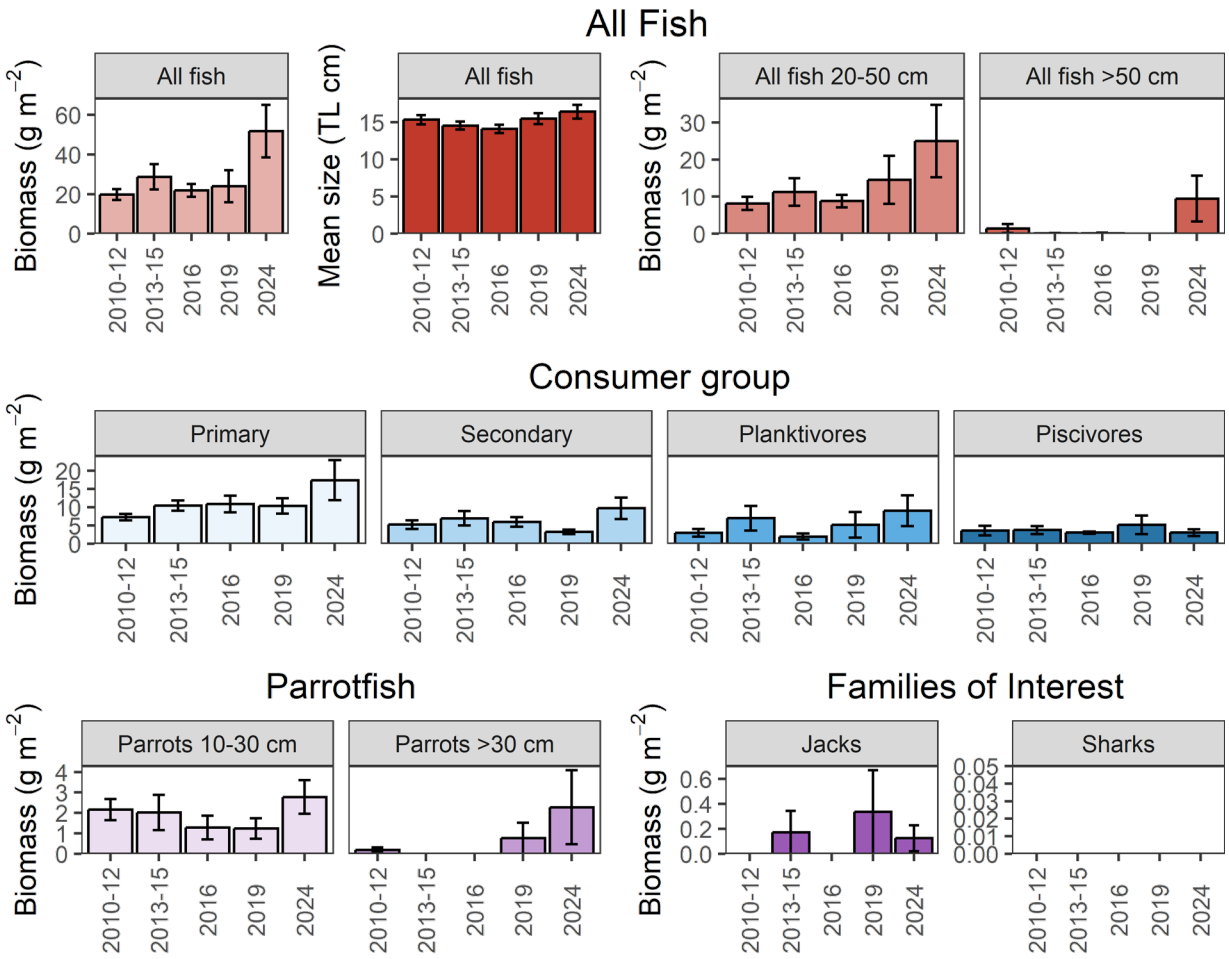

Figure 25. Maui Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Maui's Lahaina sector, indicated by purple (Figure 23).

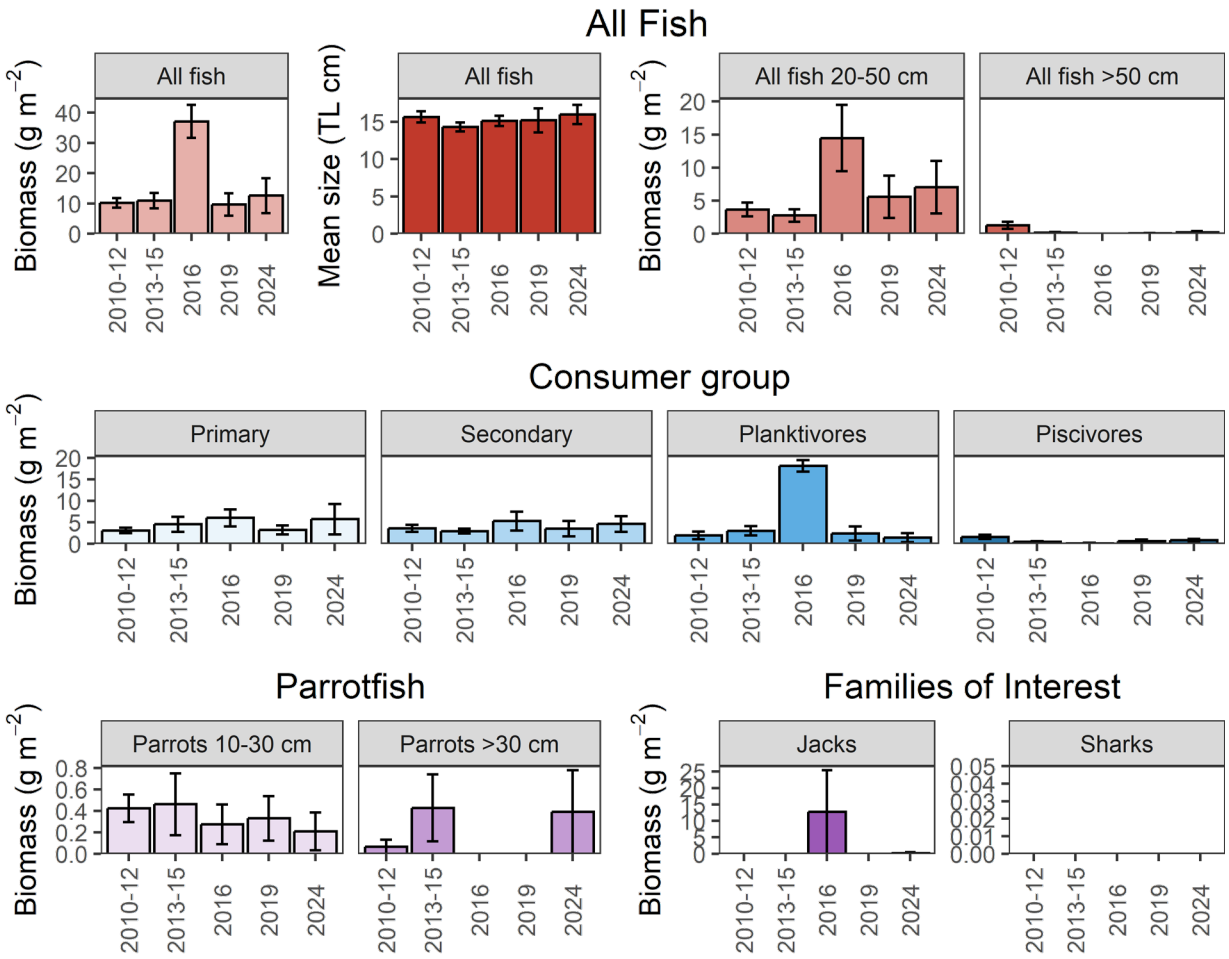

Figure 26. Maui Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Maui's northeast sector, indicated by olive (Figure 23).

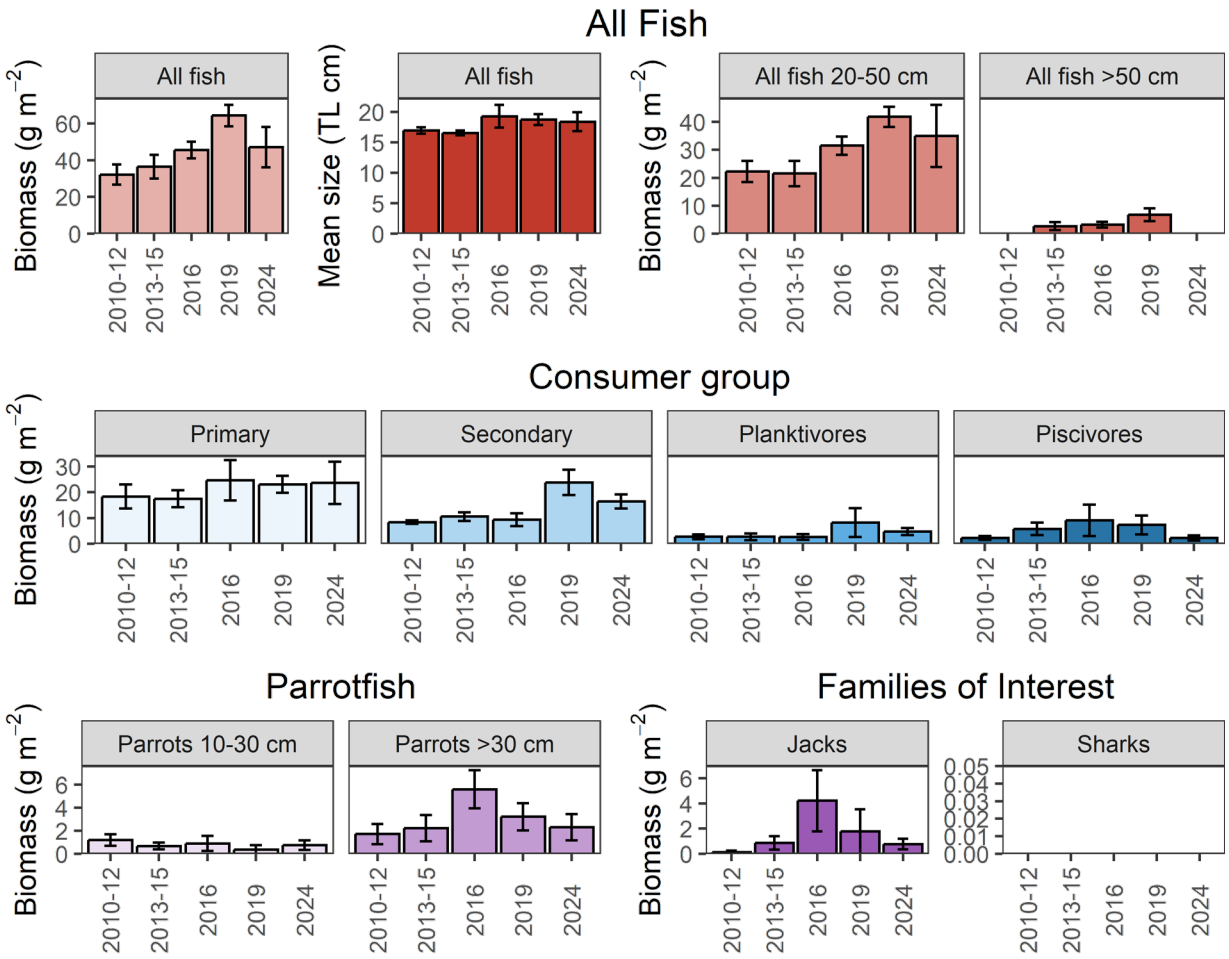

Figure 27. Maui Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Molokaʻi

Table 7. Year surveyed and the number of sites.

Year	2010	2012	2013	2015	2016	2019	2024
Sites	10	50	39	48	23	41	27

Molokaʻi is further broken down into geographic sectors due to its large size. Sectors are indicated by different colors on the map, and summary data are shown at the island level and the sector level. Not all sectors were surveyed each year.

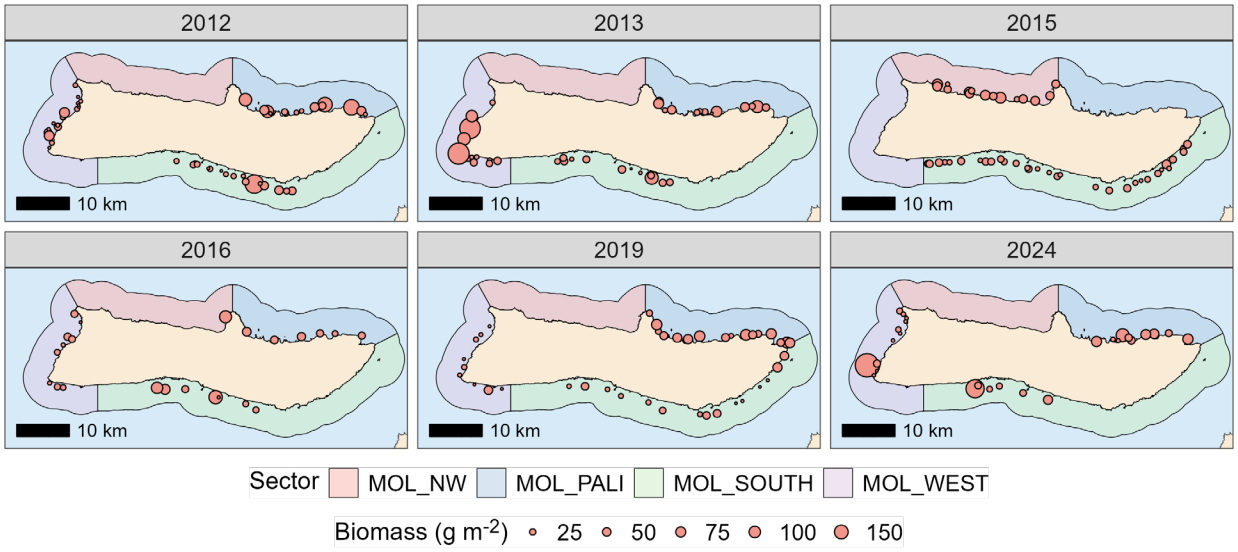

Figure 28. Molokaʻi Island site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

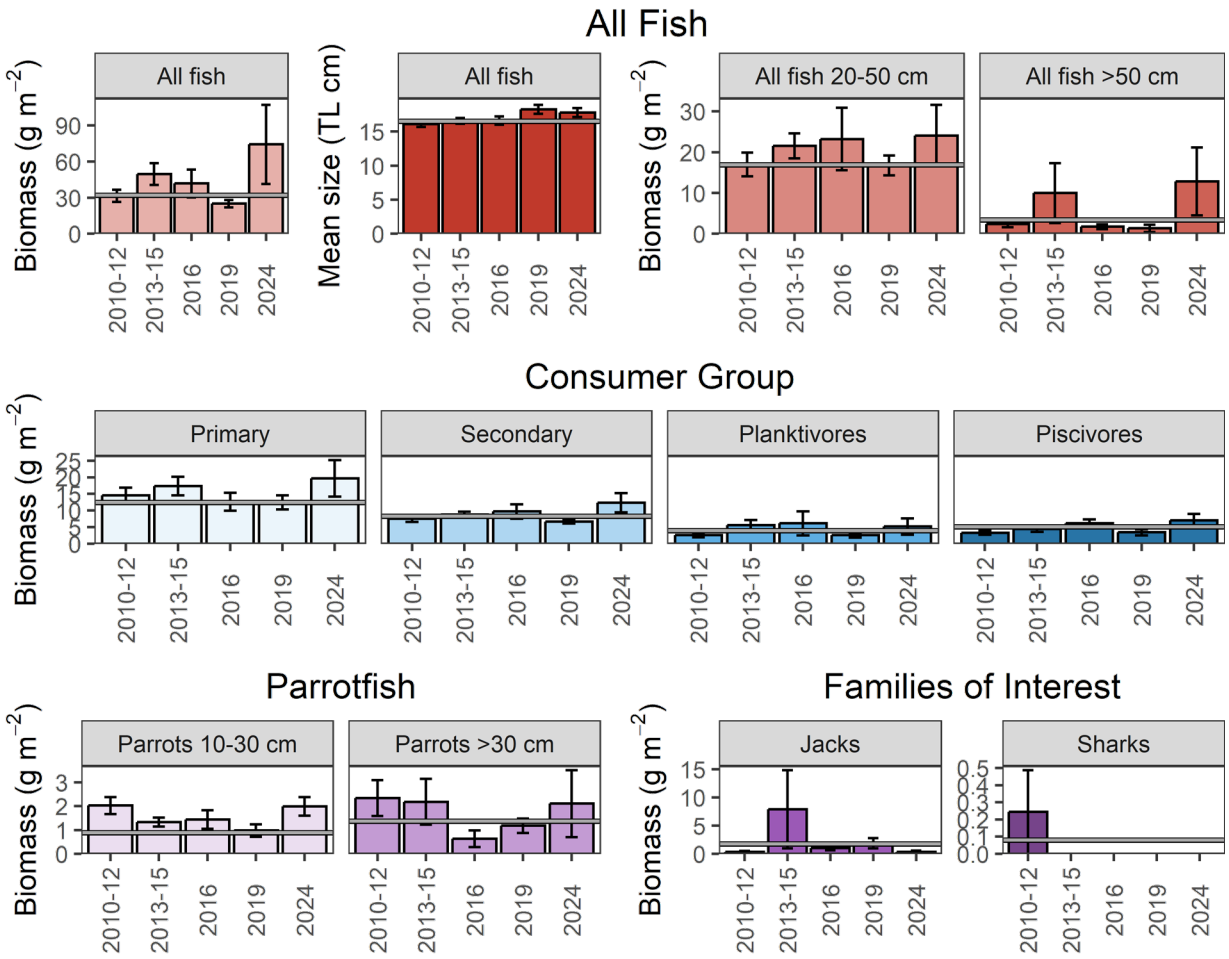

Figure 29. Molokaʻi Island fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Moloka‘i’s pali sector, indicated by blue (Figure 28).

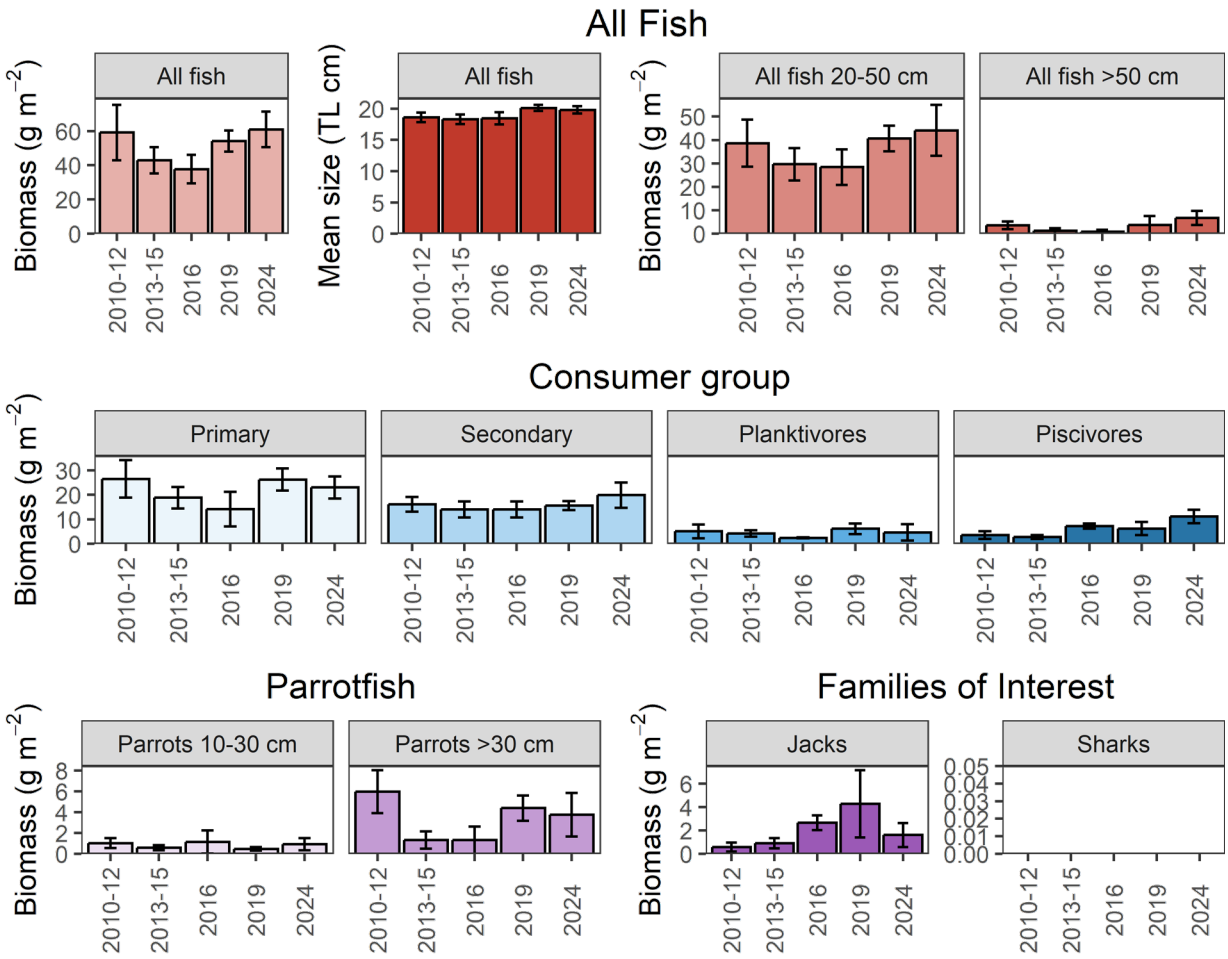

Figure 30. Moloka‘i Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Moloka'i's south sector, indicated by green (Figure 28).

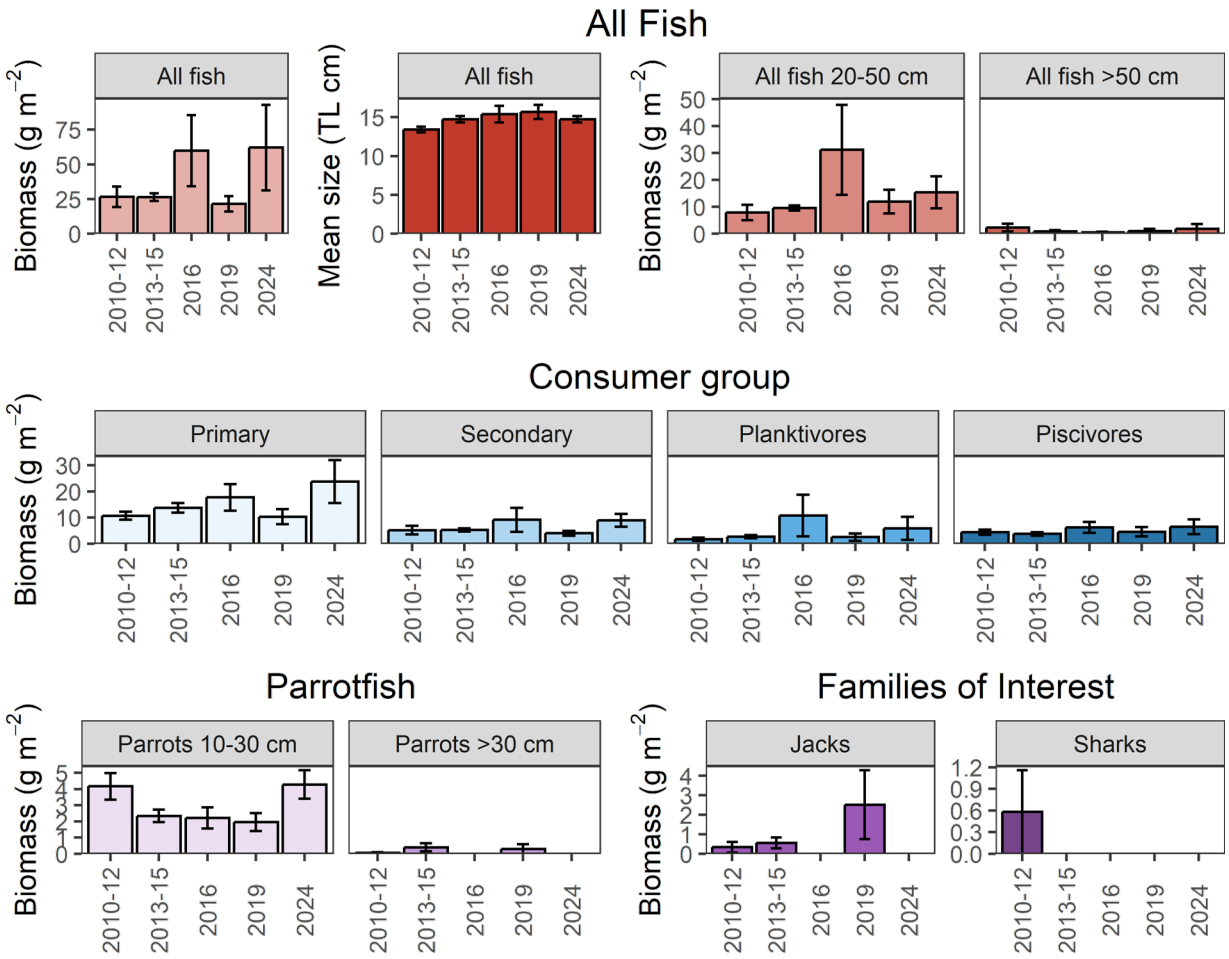

Figure 31. Moloka'i Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Moloka‘i’s west sector, indicated by purple (Figure 28).

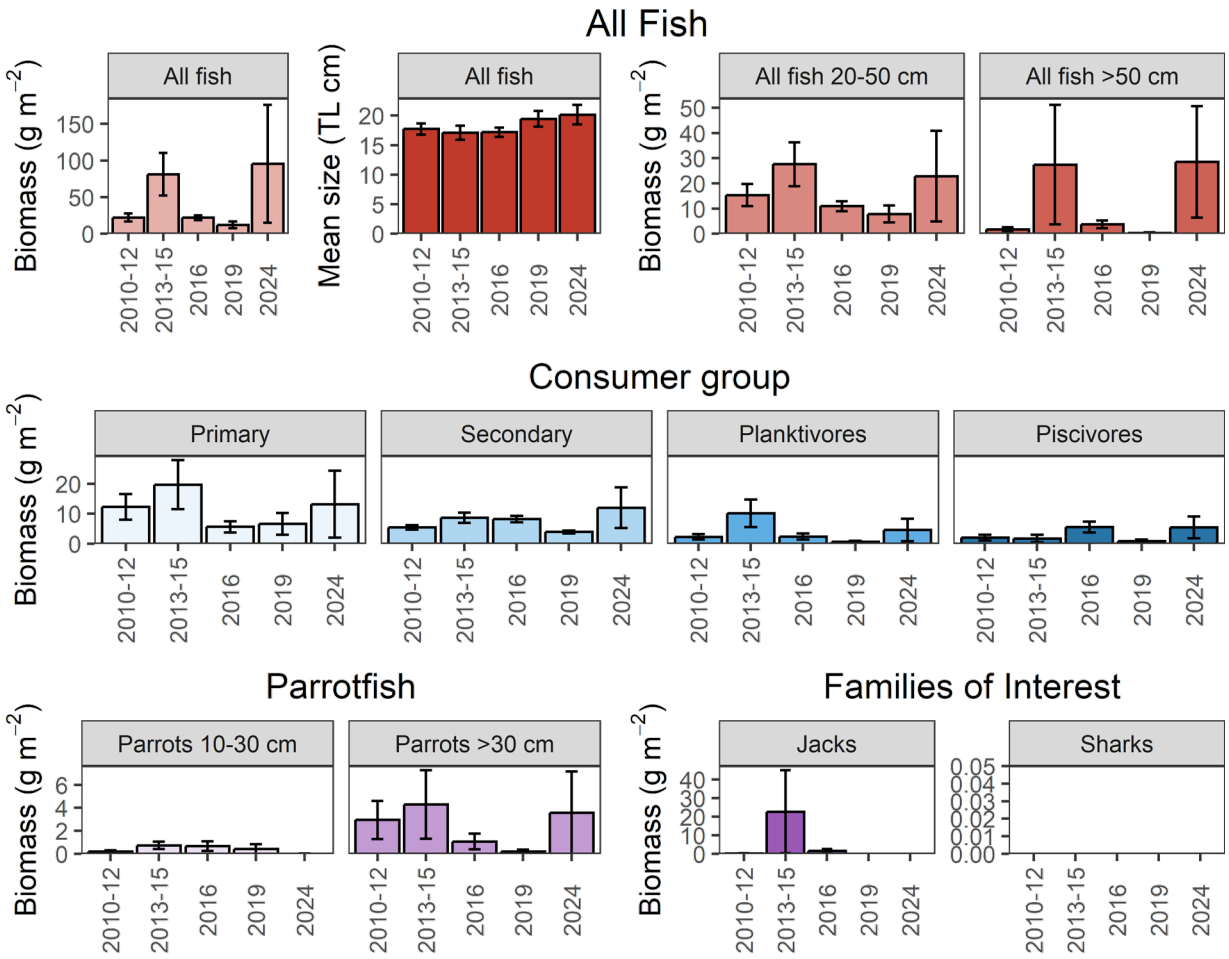

Figure 32. Moloka‘i Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Niʻihau

Table 8. Year surveyed and the number of sites.

Year	2010	2013	2015	2016	2019	2024
Sites	16	26	49	12	17	31

Niʻihau is further broken down into geographic sectors due to its large size. Sectors are indicated by different colors on the map, and summary data are shown at the island level and the sector level. Not all sectors were surveyed each year.

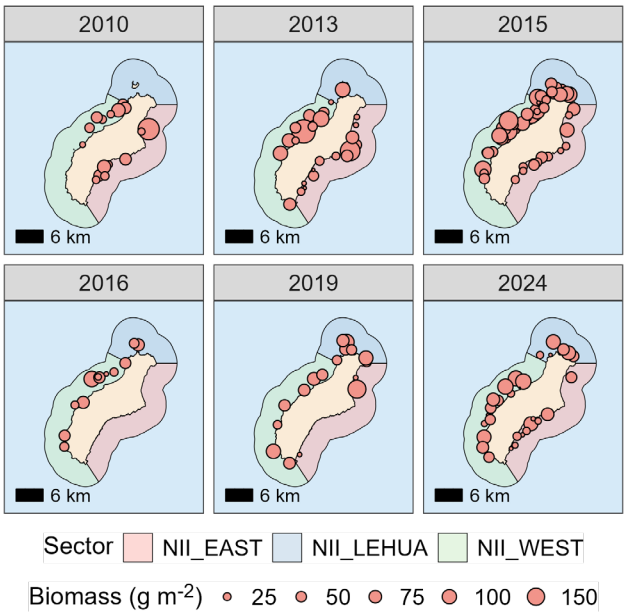

Figure 33. Niʻihau Island site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

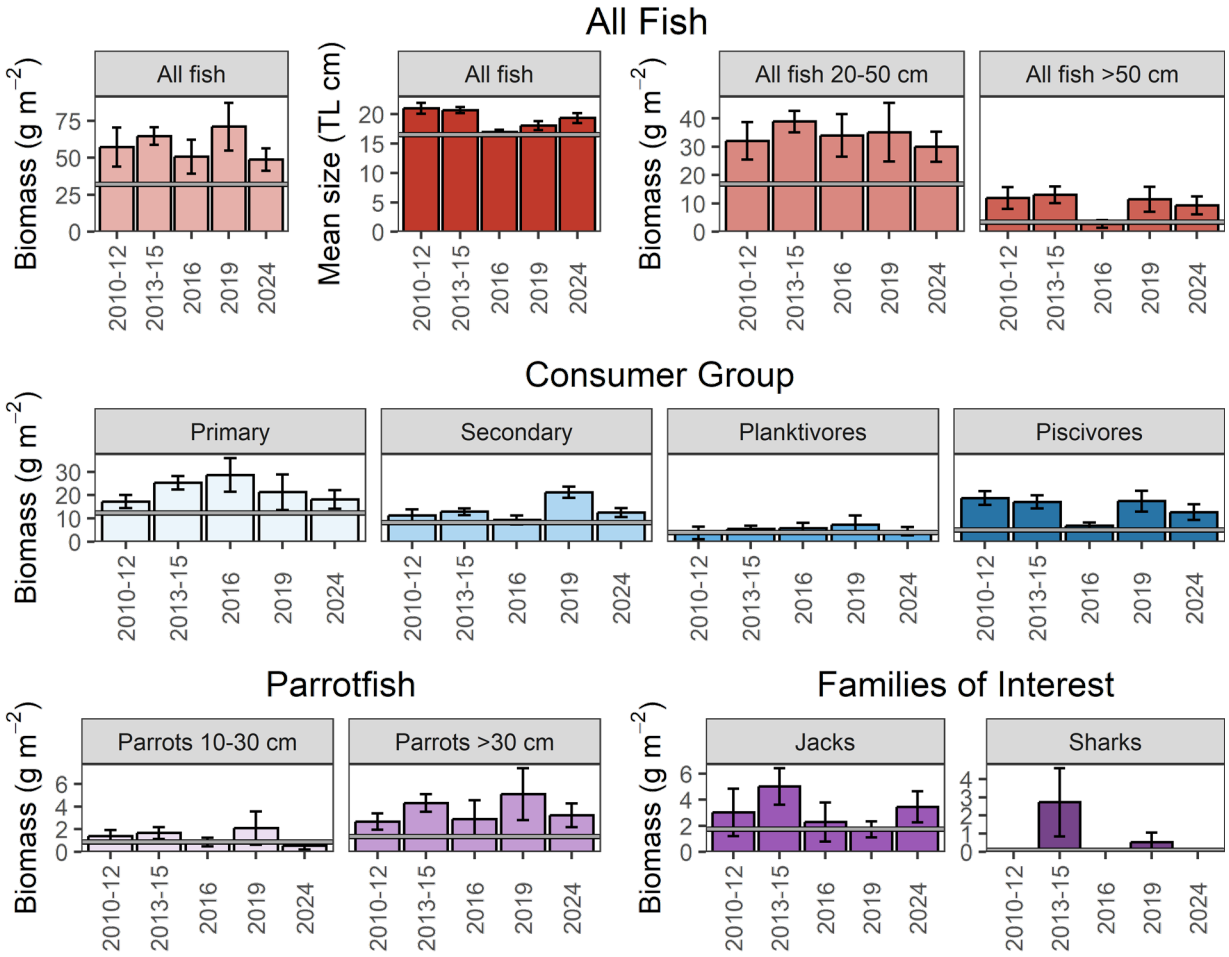

Figure 34. Ni‘ihau Island fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Ni‘ihau’s east sector, indicated by pink (Figure 33).

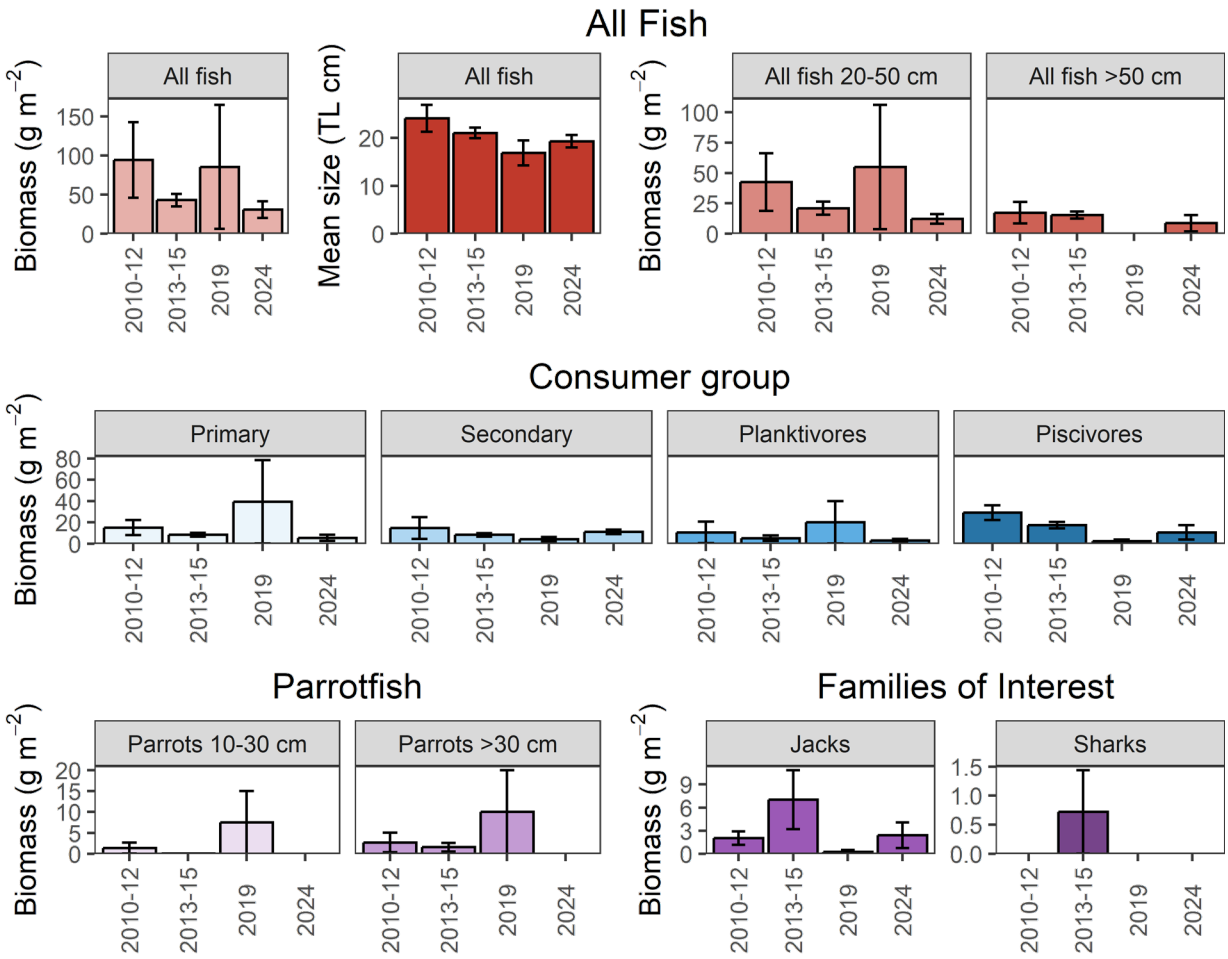

Figure 35. Ni‘ihau Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Ni‘ihau’s Lehua sector, indicated by blue (Figure 33).

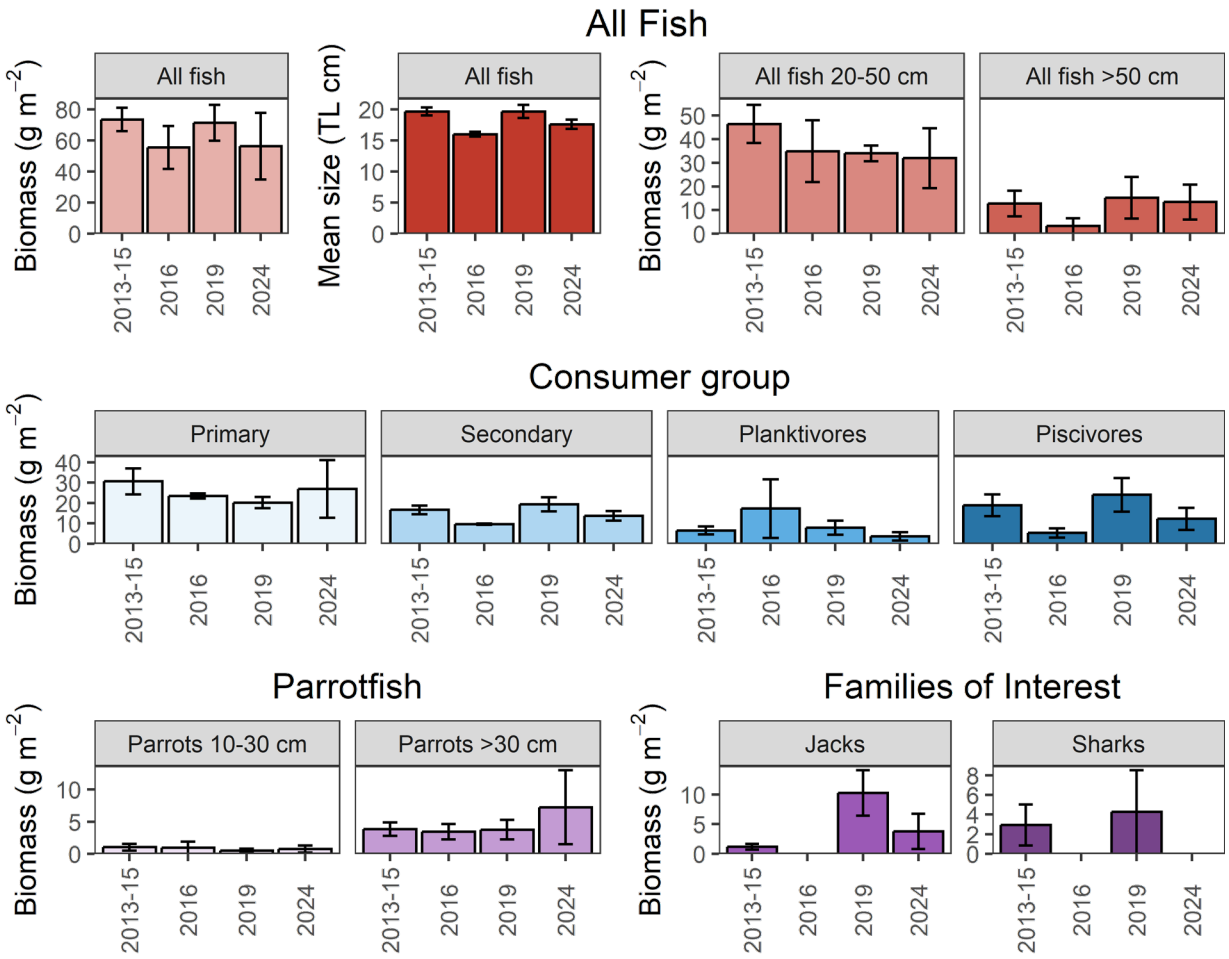

Figure 36. Ni‘ihau Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Ni‘ihau’s west sector, indicated by green (Figure 33).

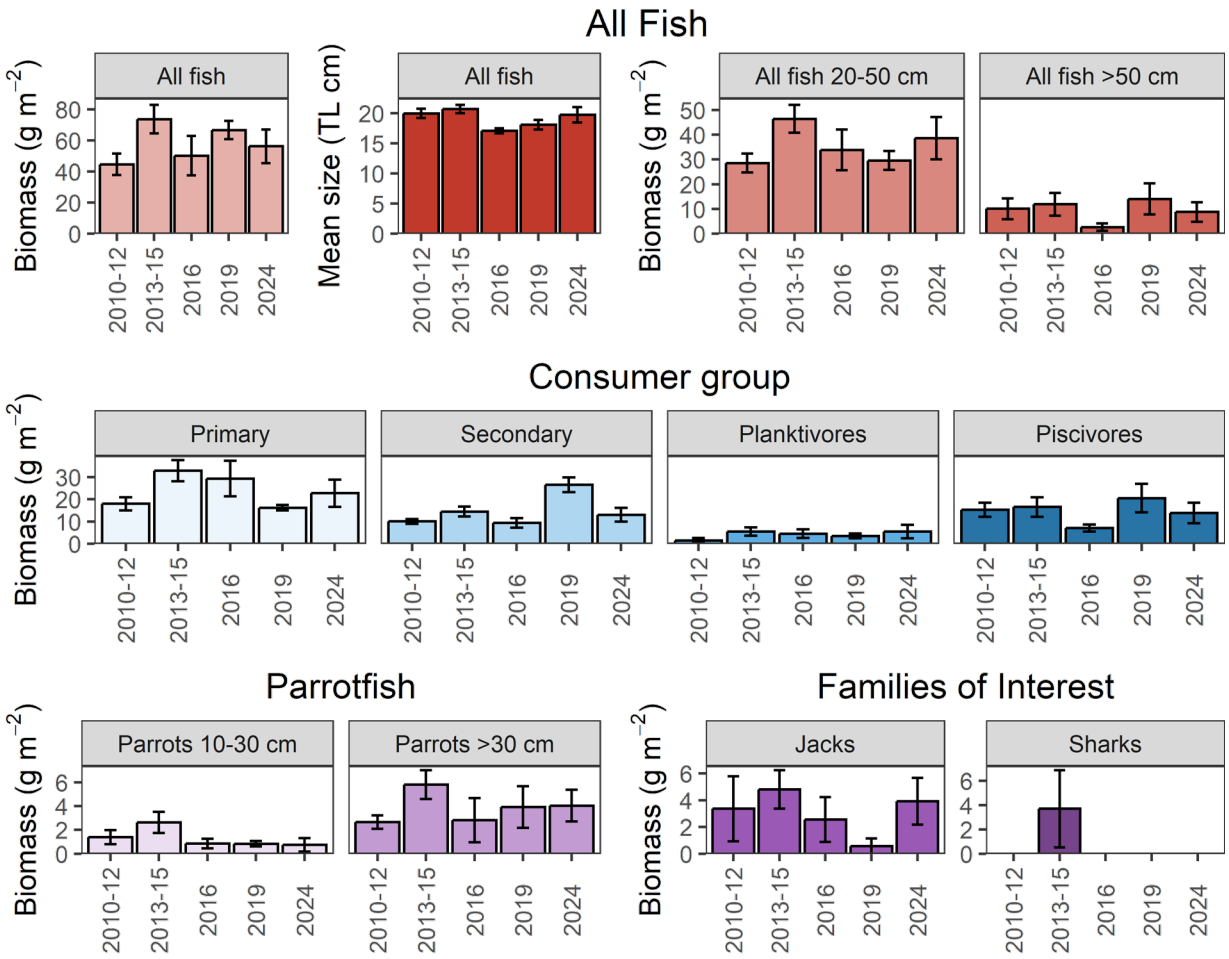

Figure 37. Ni‘ihau Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

O‘ahu

Table 9. Year surveyed and the number of sites.

Year	2010	2012	2013	2015	2016	2019	2024
Sites	40	35	64	35	54	58	64

O‘ahu is further broken down into geographic sectors due to its large size. Sectors are indicated by different colors on the map, and summary data are shown at the island level and the sector level. Not all sectors were surveyed each year.

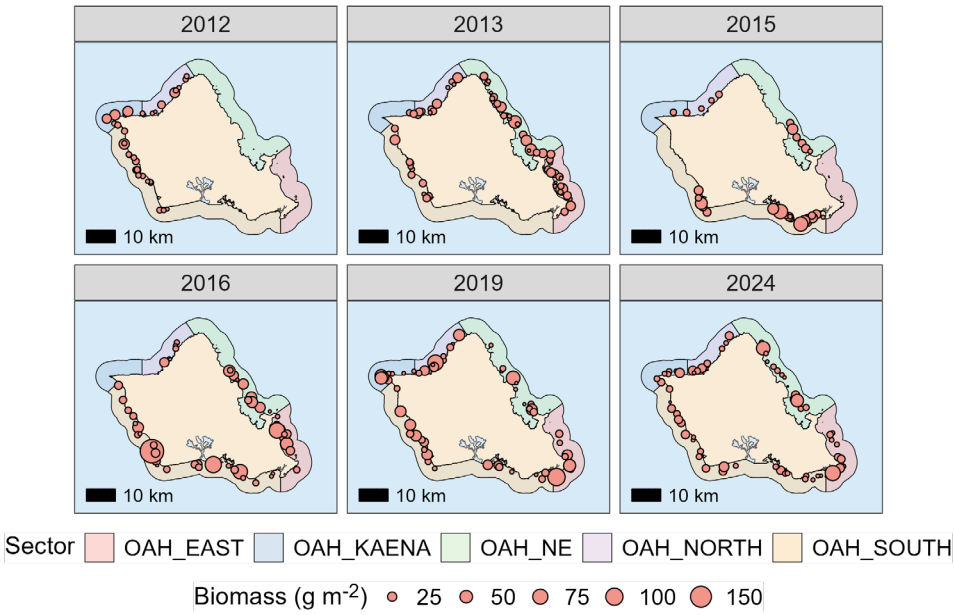

Figure 38. O‘ahu Island site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

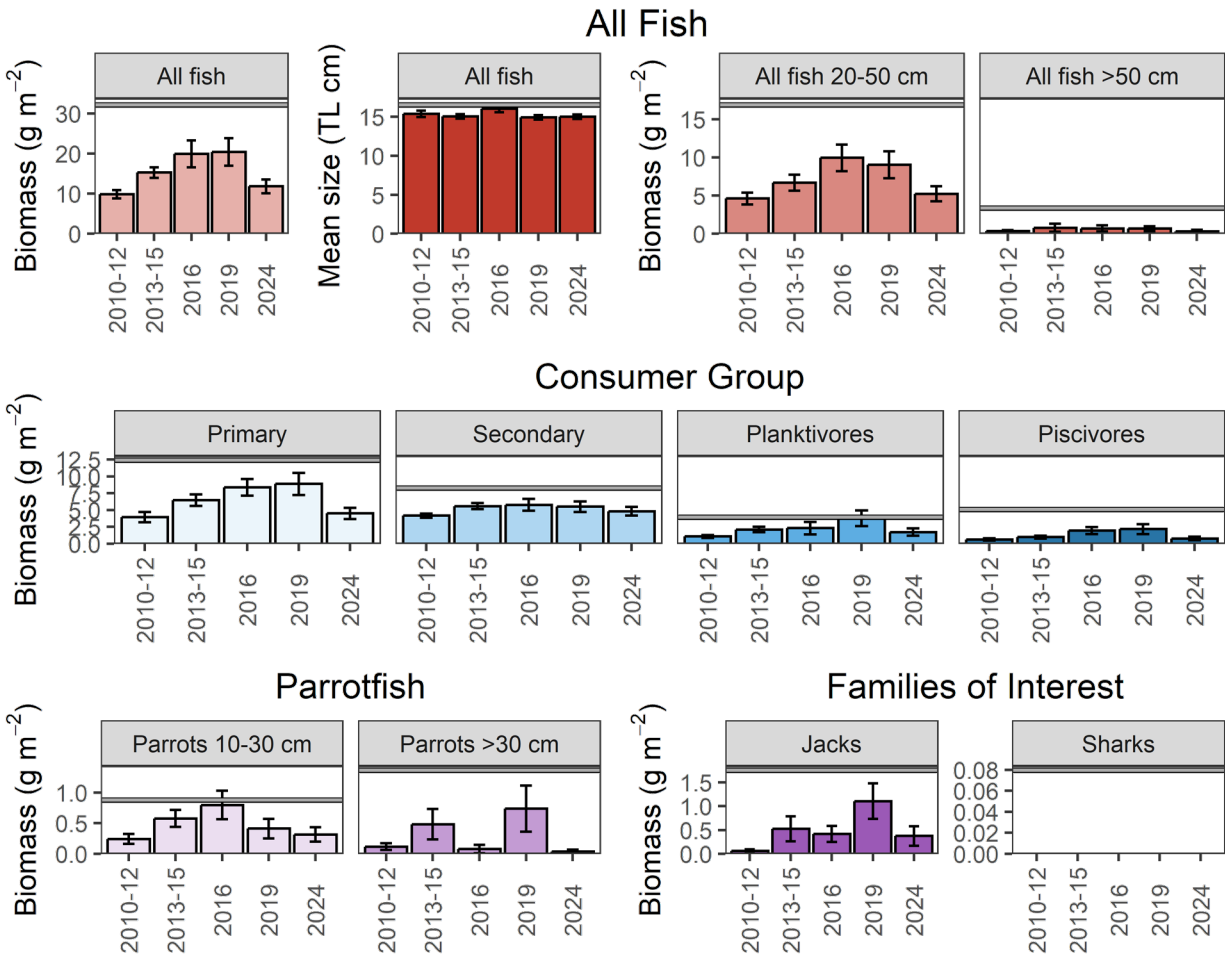

Figure 39. O‘ahu Island fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

O‘ahu’s east sector, indicated by pink (Figure 41).

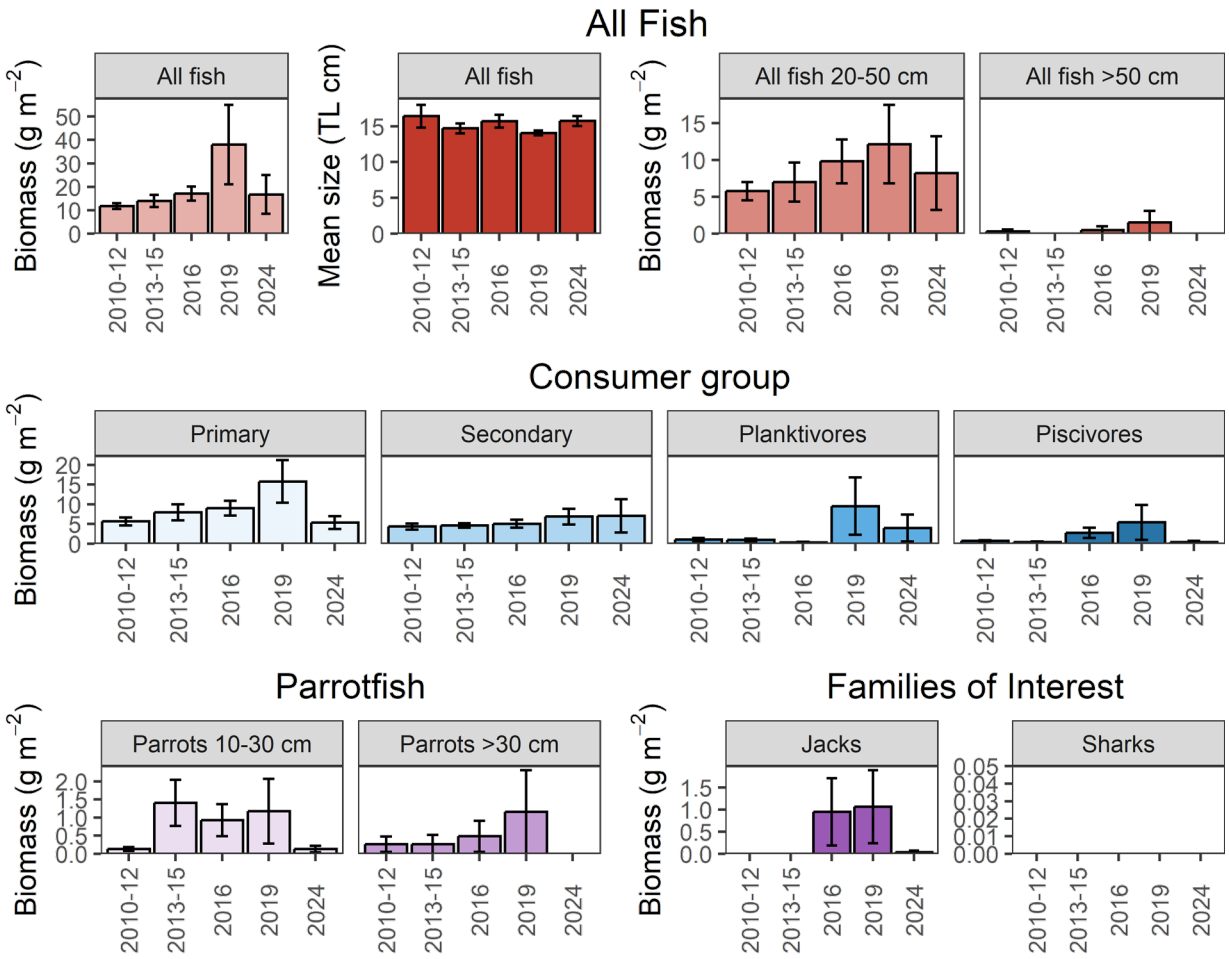

Figure 40. O‘ahu Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

O‘ahu’s Kaena sector, indicated by blue (Figure 38).

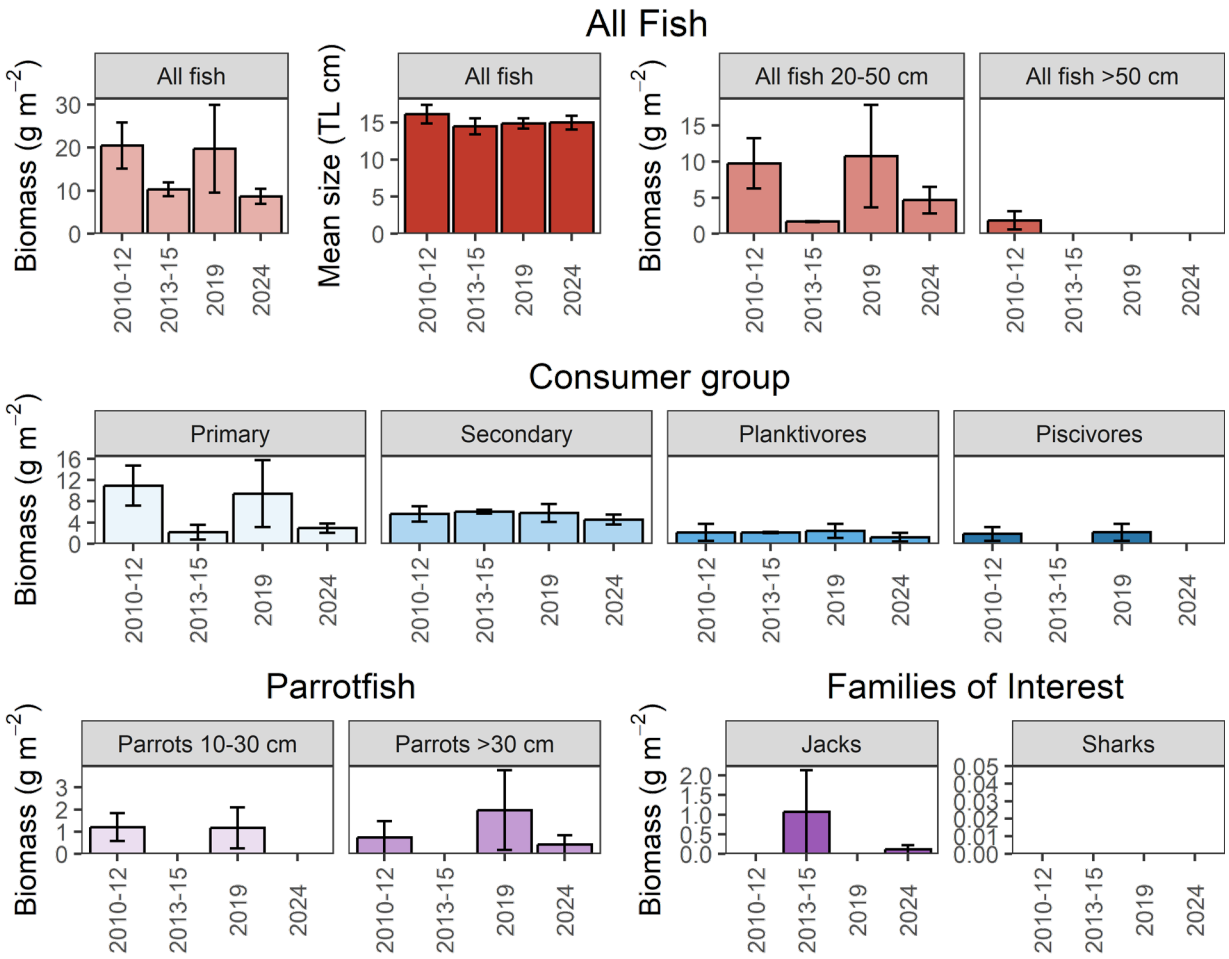

Figure 41. O‘ahu Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

O‘ahu’s northeast sector, indicated by green (Figure 38).

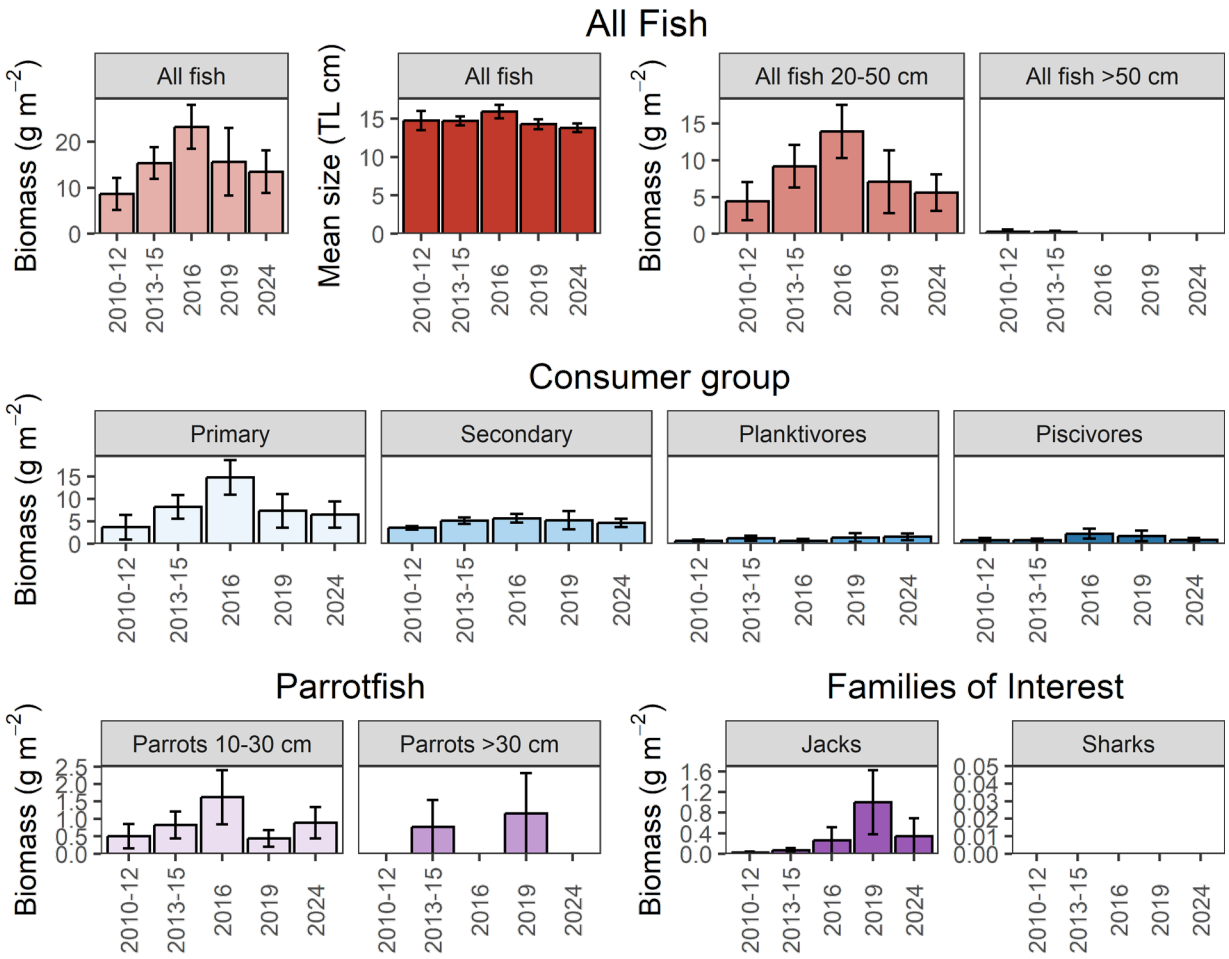

Figure 42. O‘ahu Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

O‘ahu’s north sector, indicated by purple (Figure 38).

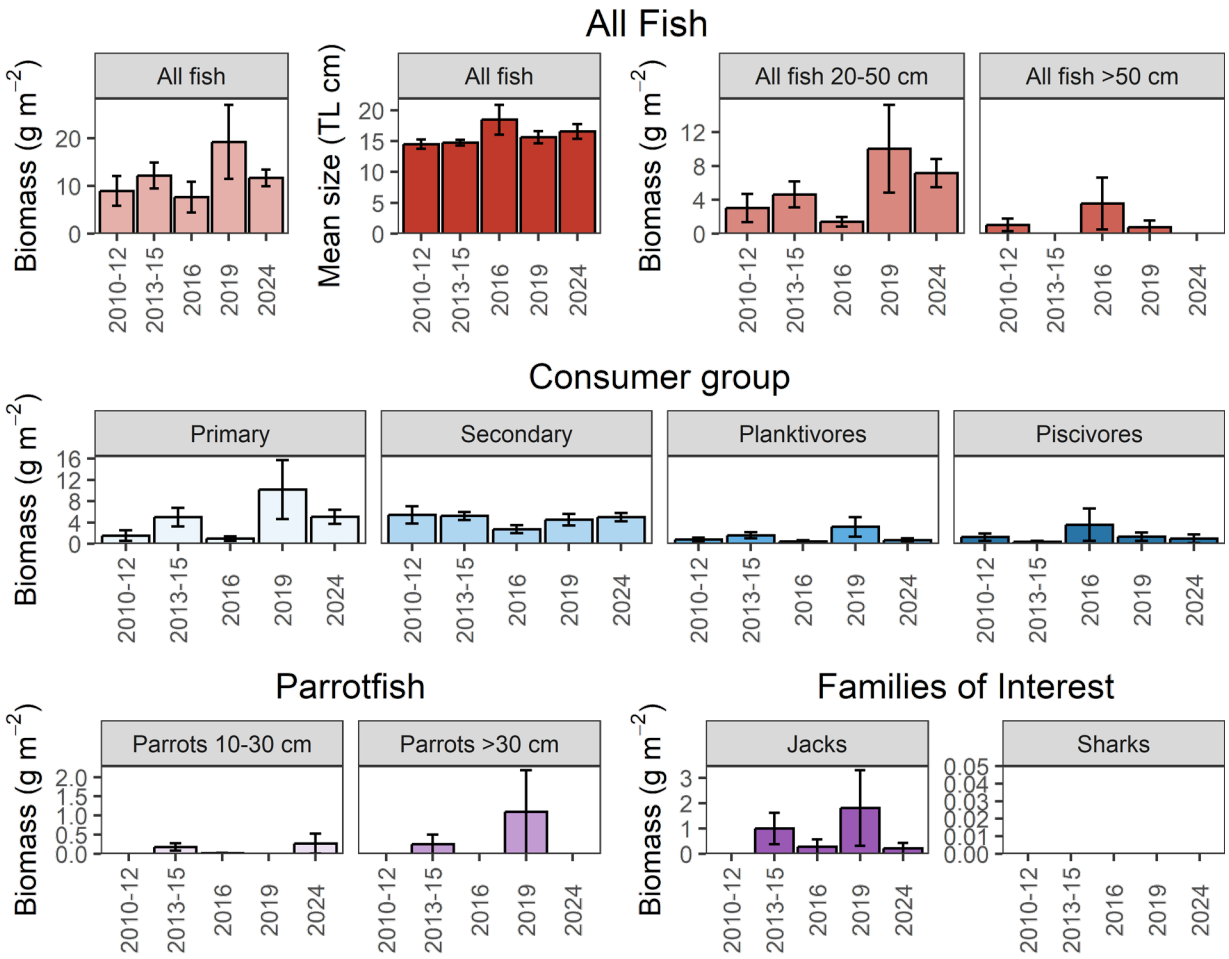

Figure 43. O‘ahu Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

O‘ahu’s south sector, indicated by olive (Figure 38).

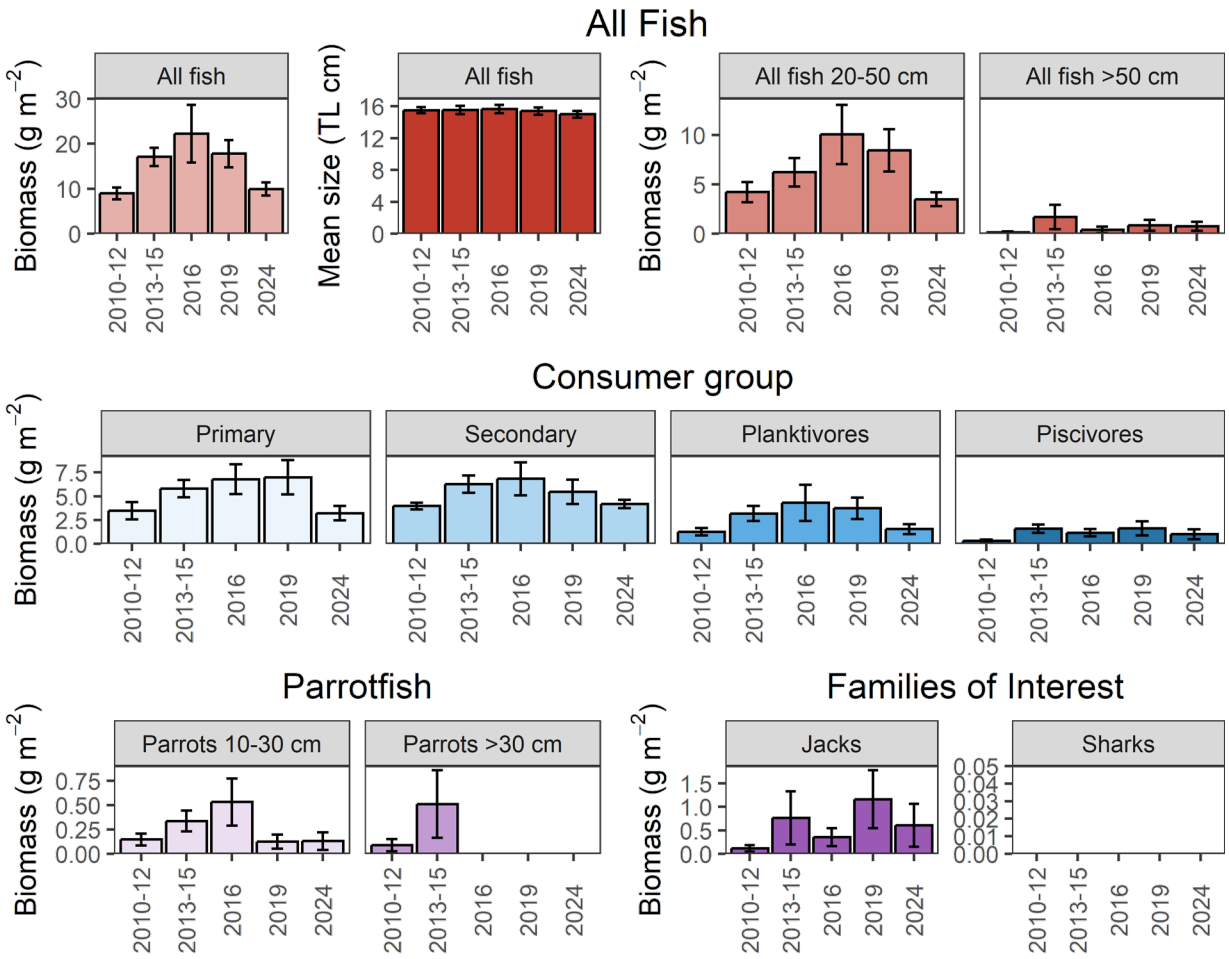

Figure 44. O‘ahu Island sector fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Papahānaumokuākea Marine National Monument

Hōlanikū (Kure)

Table 10. Year surveyed and the number of sites.

Year	2010	2012	2015	2016	2017	2024
Sites	25	20	8	39	6	59

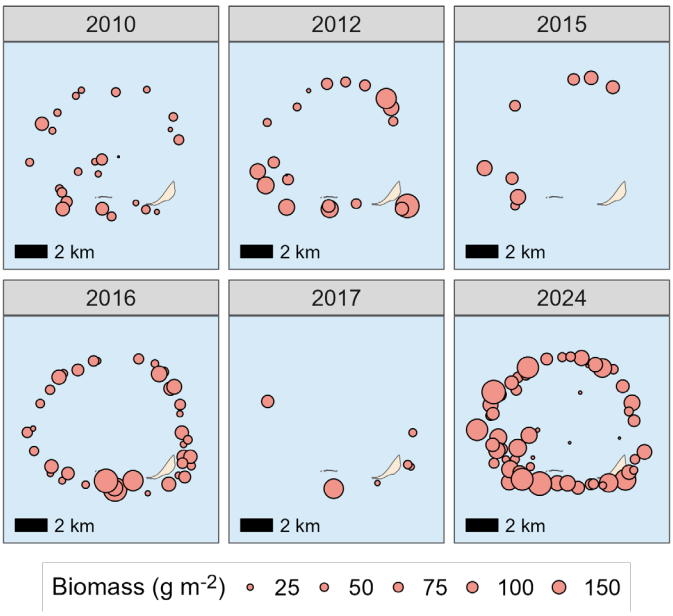

Figure 45. Hōlanikū site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

Hōlanikū, also known as Kure Atoll, is further broken down into different habitat types or reef zones.

Forereef habitat

Table 11. Year surveyed and the number of sites.

Year	2010	2012	2015	2016	2017	2024
Sites	16	14	8	39	6	50

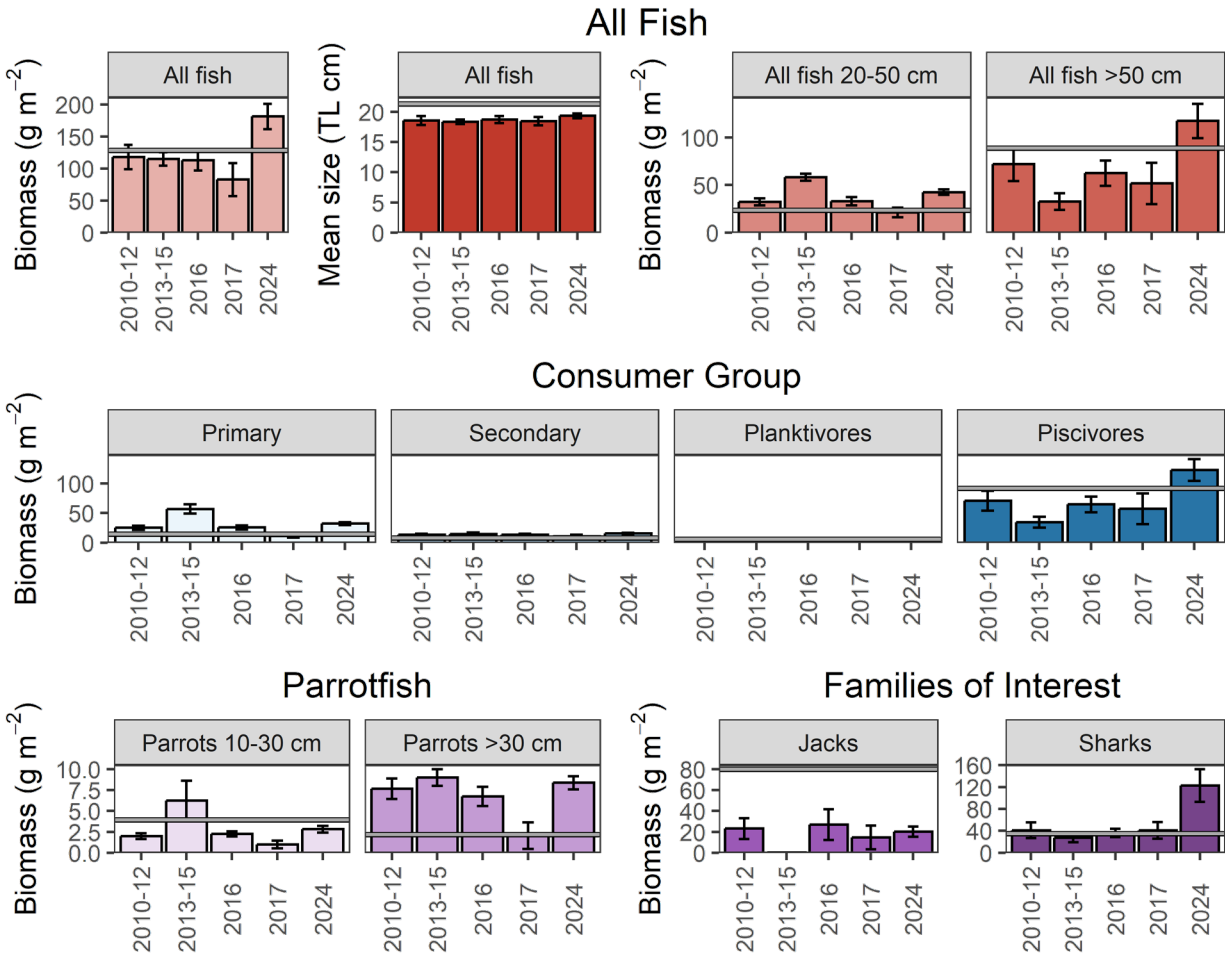

Figure 46. Hōlanikū forereef fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Lagoon habitat

Table 12. Year surveyed and the number of sites

Year	2010	2012	2024
Sites	6	3	7

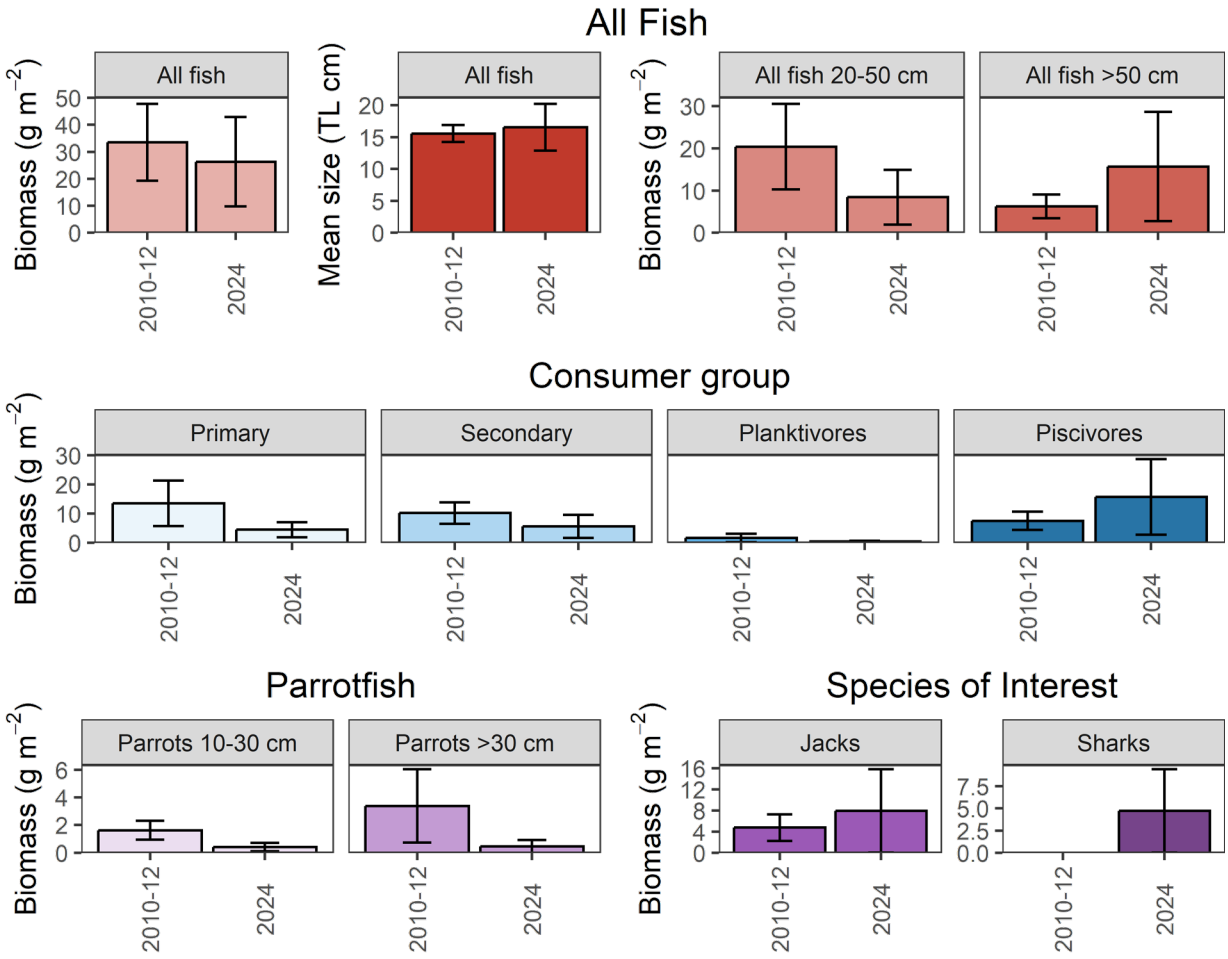

Figure 47. Hōlanikū lagoon fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Backreef habitat

Table 13. Year surveyed and the number of sites

Year	2010	2012	2024
Sites	3	3	2

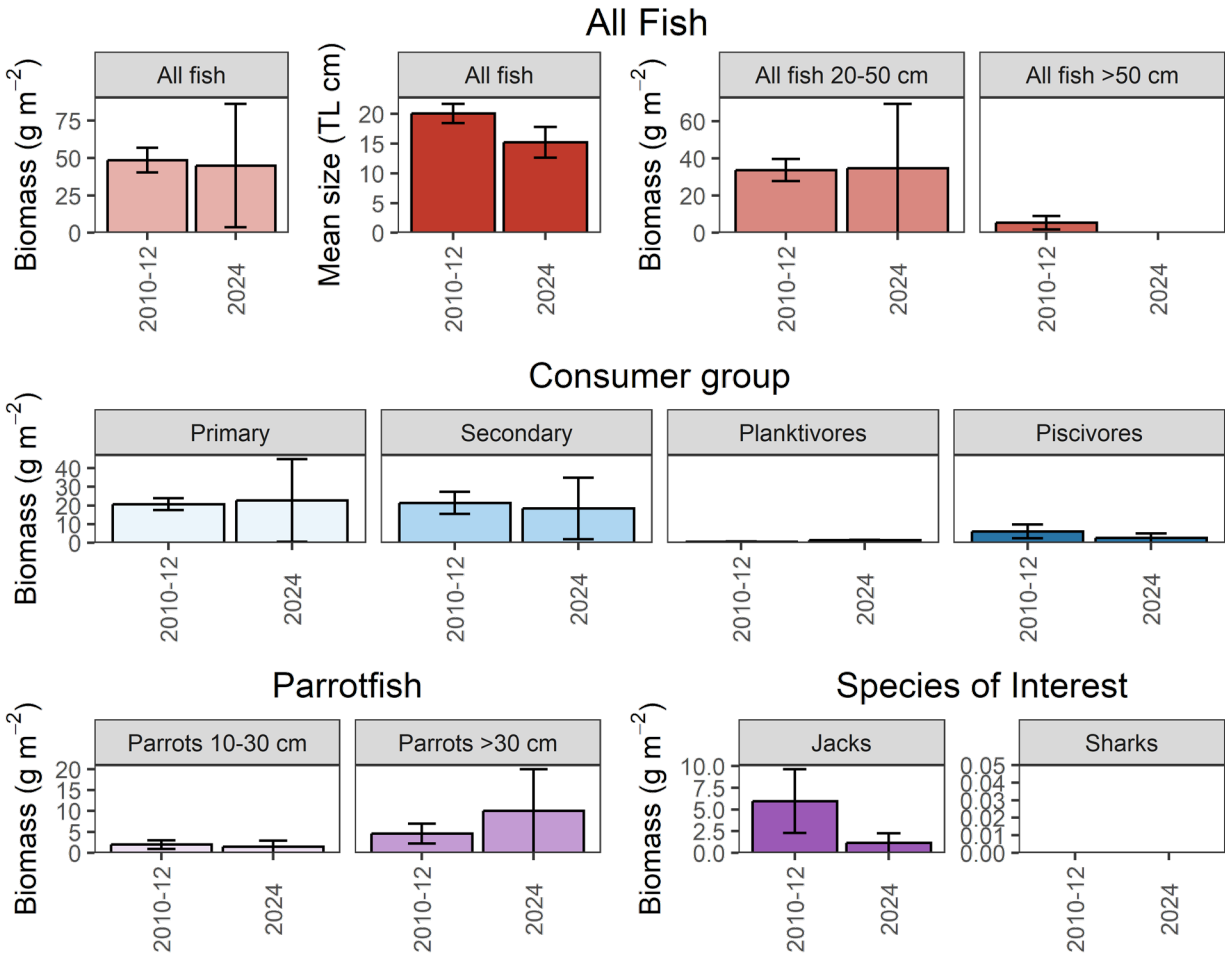

Figure 48. Hōlanikū backreef fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Kamole (Laysan)

Table 14. Year surveyed and the number of sites.

Year	2011	2015	2017	2024
Sites	23	8	11	10

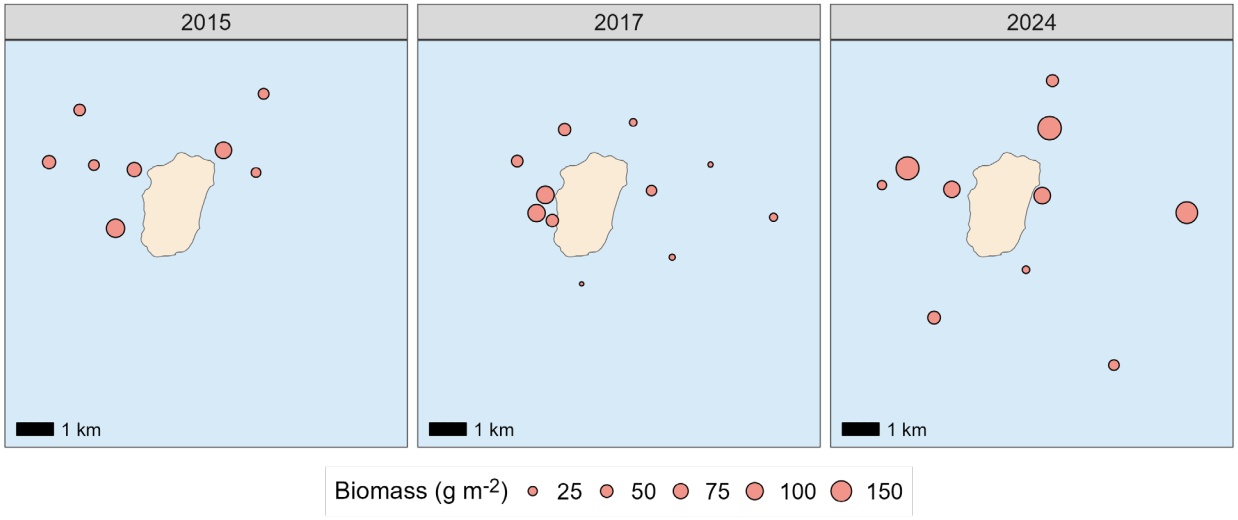

Figure 49. Kamole site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

Kapou (Lisianski)

Table 15. Year surveyed and the number of sites.

Year	2010	2011	2012	2014	2015	2016	2017	2024
Sites	25	9	25	28	18	40	17	60

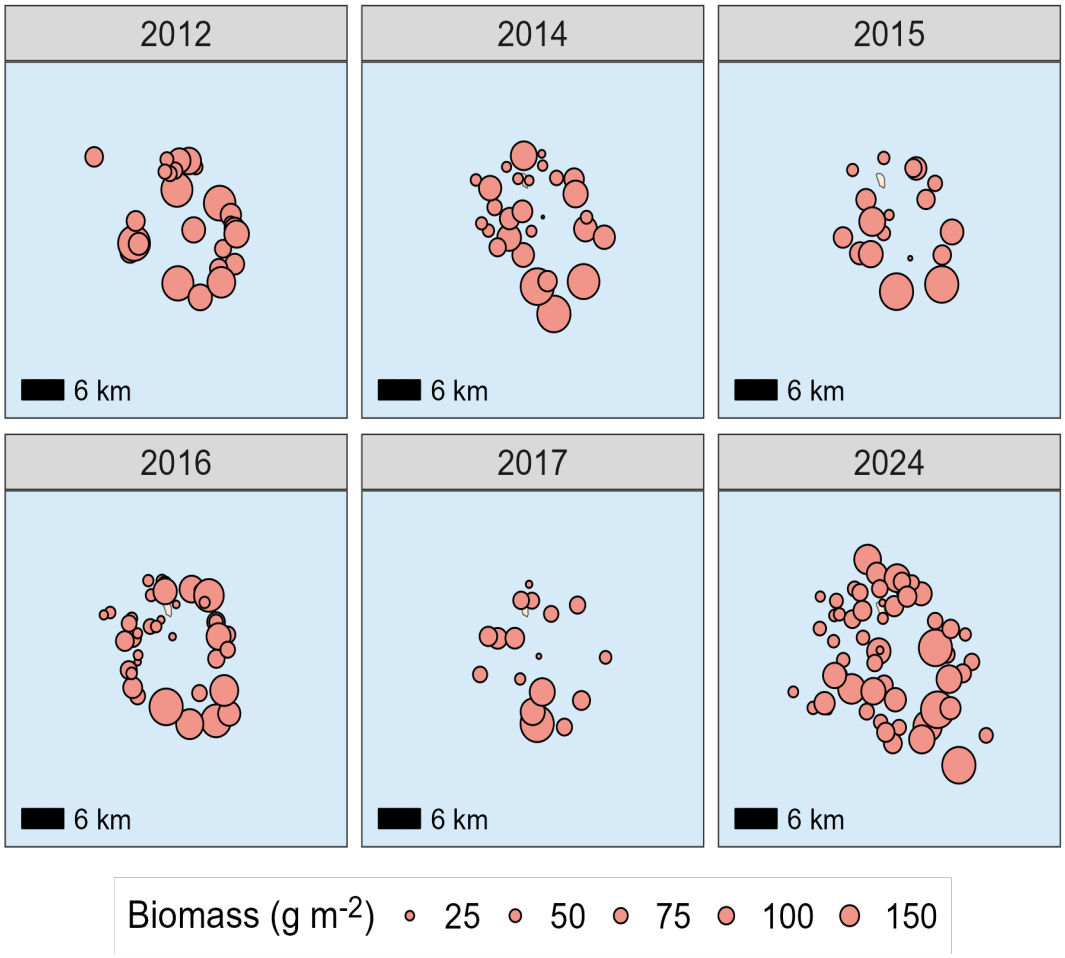

Figure 50. Kapou site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

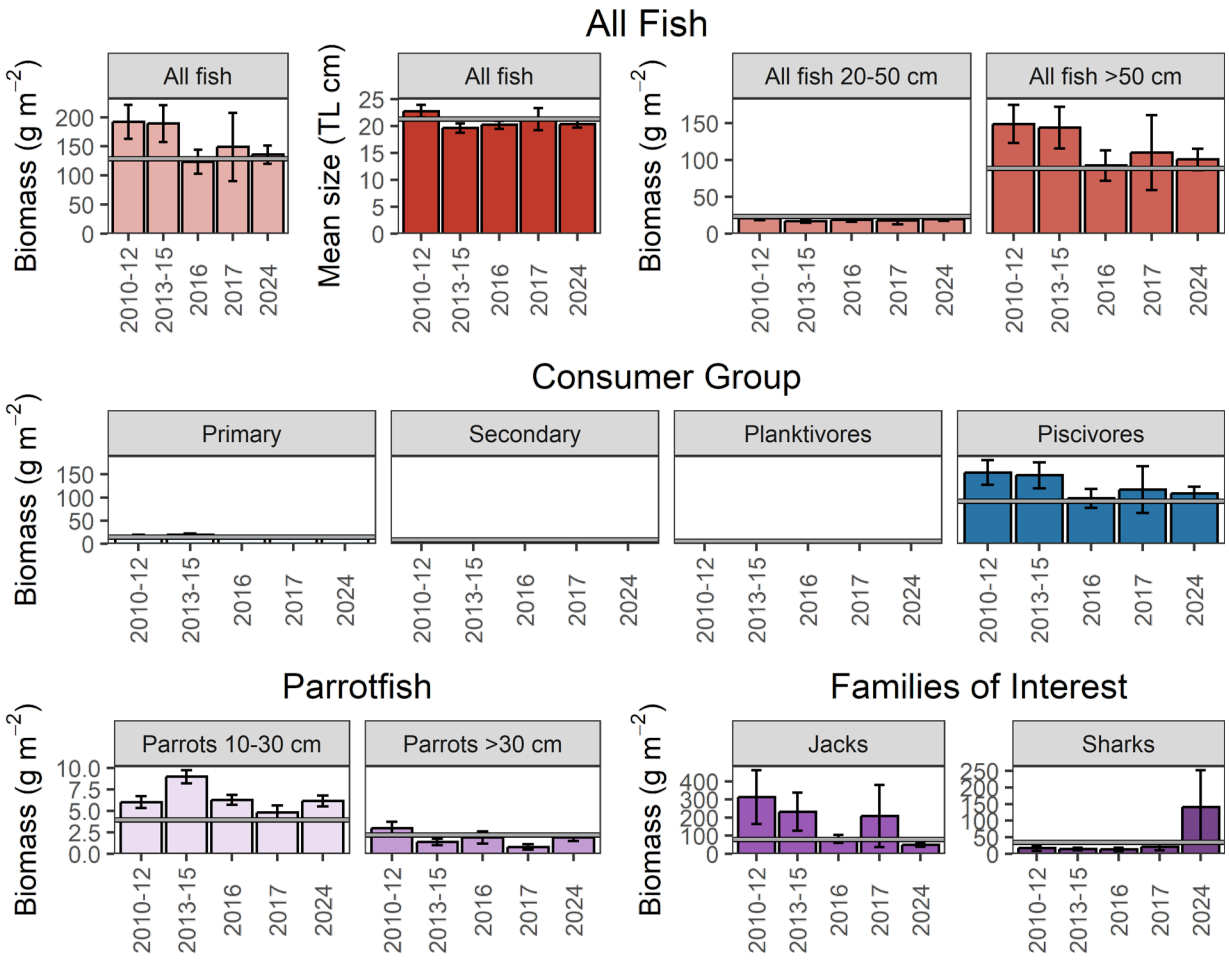

Figure 51. Kapou fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Lalo (French Frigate Shoals)

Table 16. Year surveyed and the number of sites.

Year	2010	2011	2012	2014	2015	2016	2017	2024
Sites	27	8	15	27	8	47	28	65

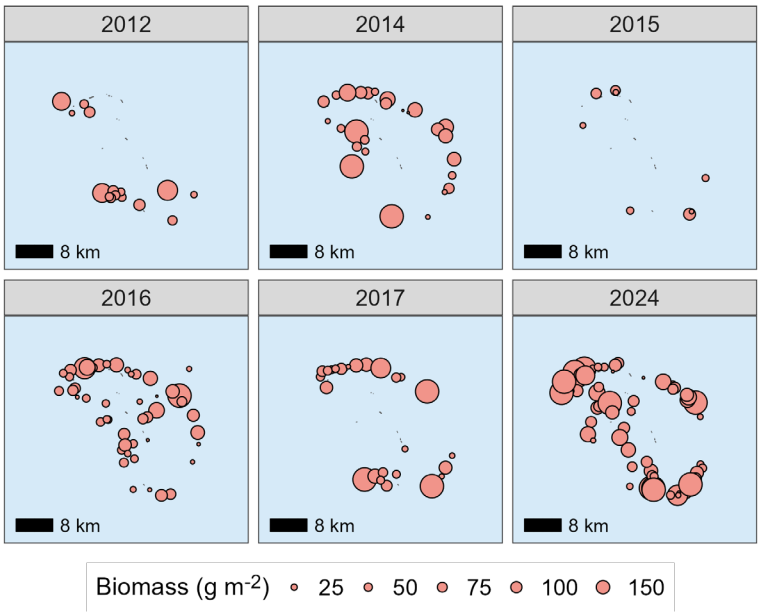

Figure 52. Lalo site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

Lalo, also known as French Frigate Shoals, is further broken down into different habitat types or reef zones.

Forereef habitat

Table 17. Year surveyed and the number of sites.

Year	2010	2012	2014	2015	2016	2017	2024
Sites	9	2	16	6	22	19	36

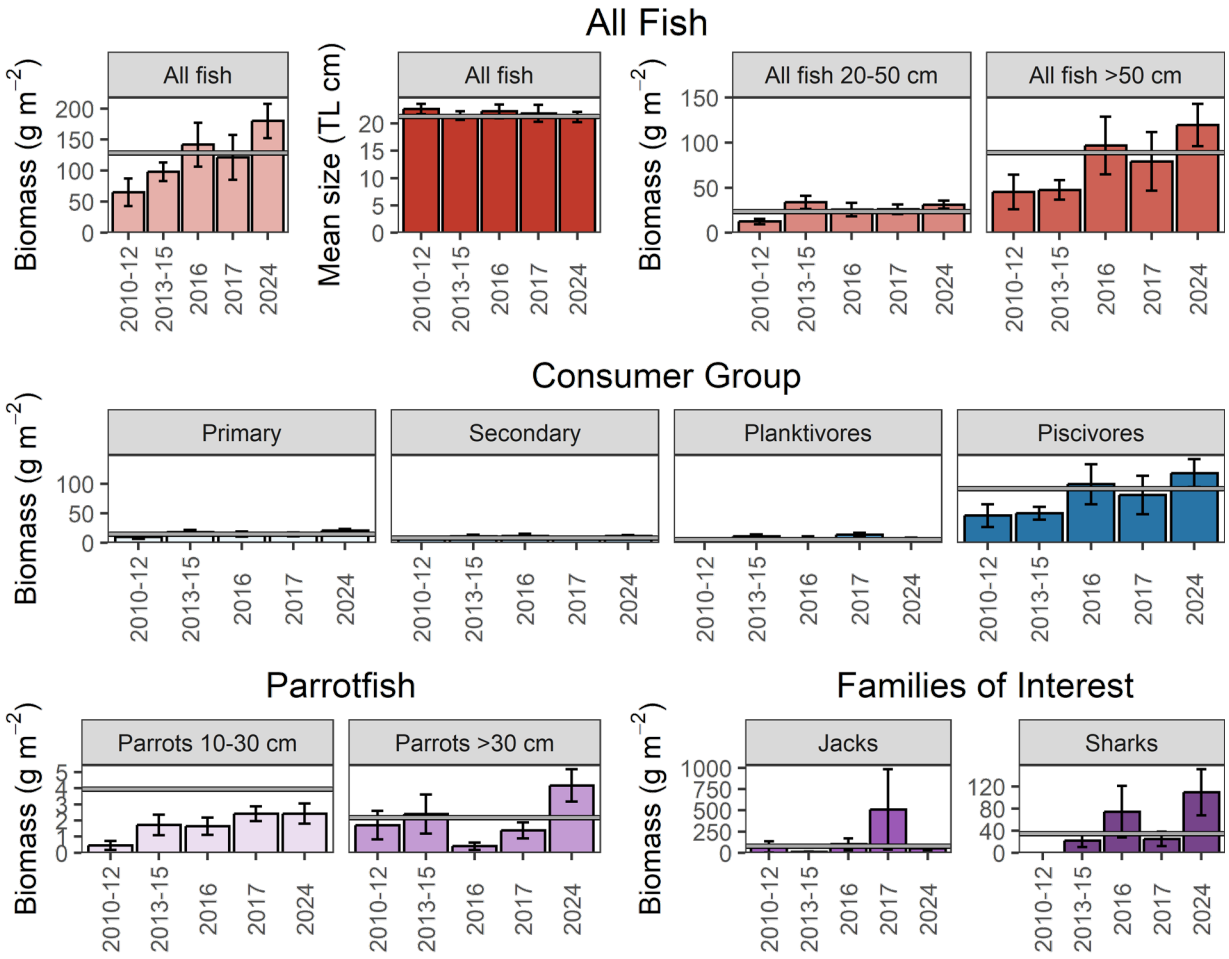

Figure 53. Lalo forereef fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Lagoon habitat

Table 18. Year surveyed and the number of sites

Year	2010	2011	2012	2014	2016	2024
Sites	9	3	3	2	6	5

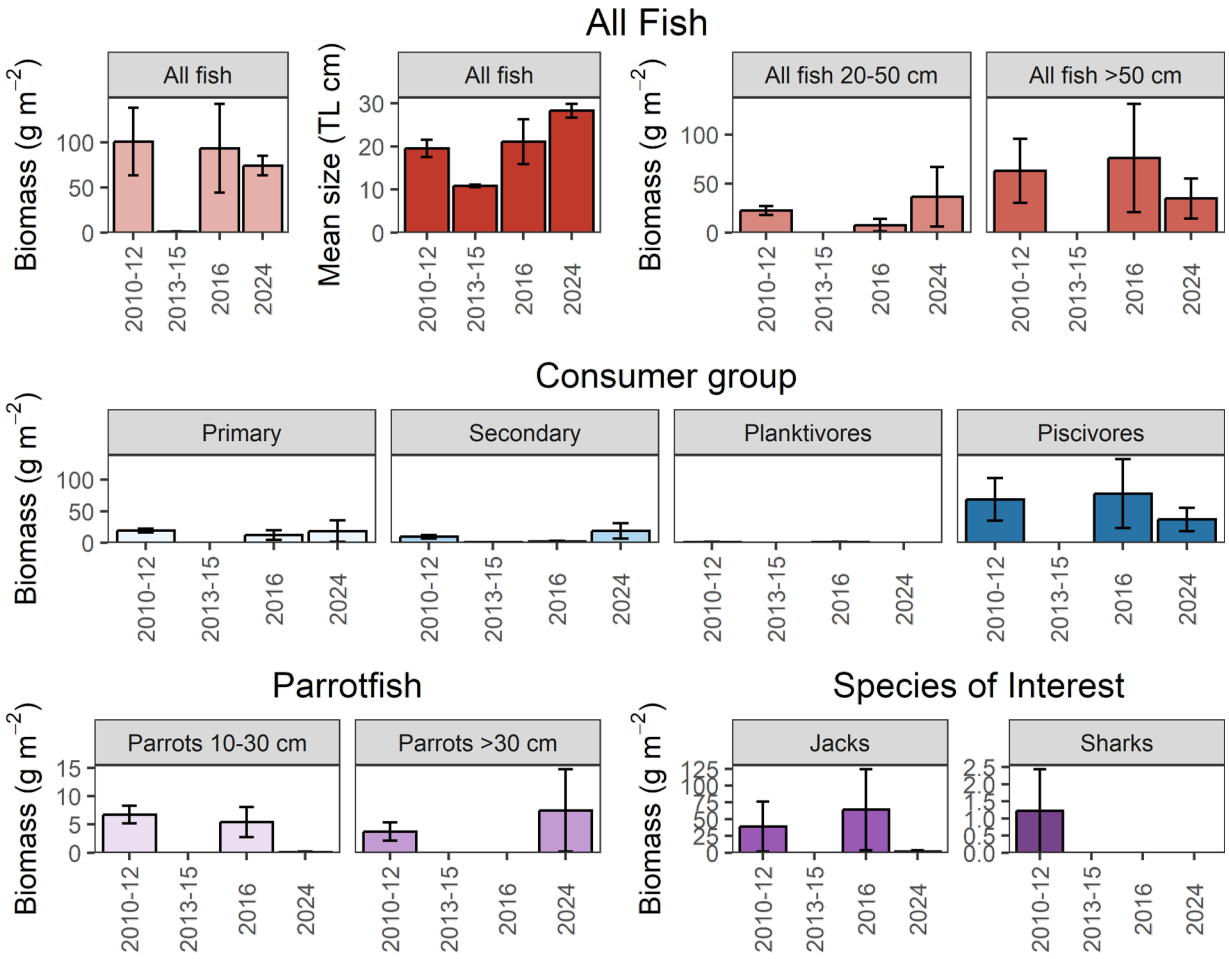

Figure 54. Lalo lagoon fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Protected slope habitat

Table 19. Year surveyed and the number of sites.

Year	2010	2011	2012	2014	2015	2016	2017	2024
Sites	9	4	10	8	2	19	8	24

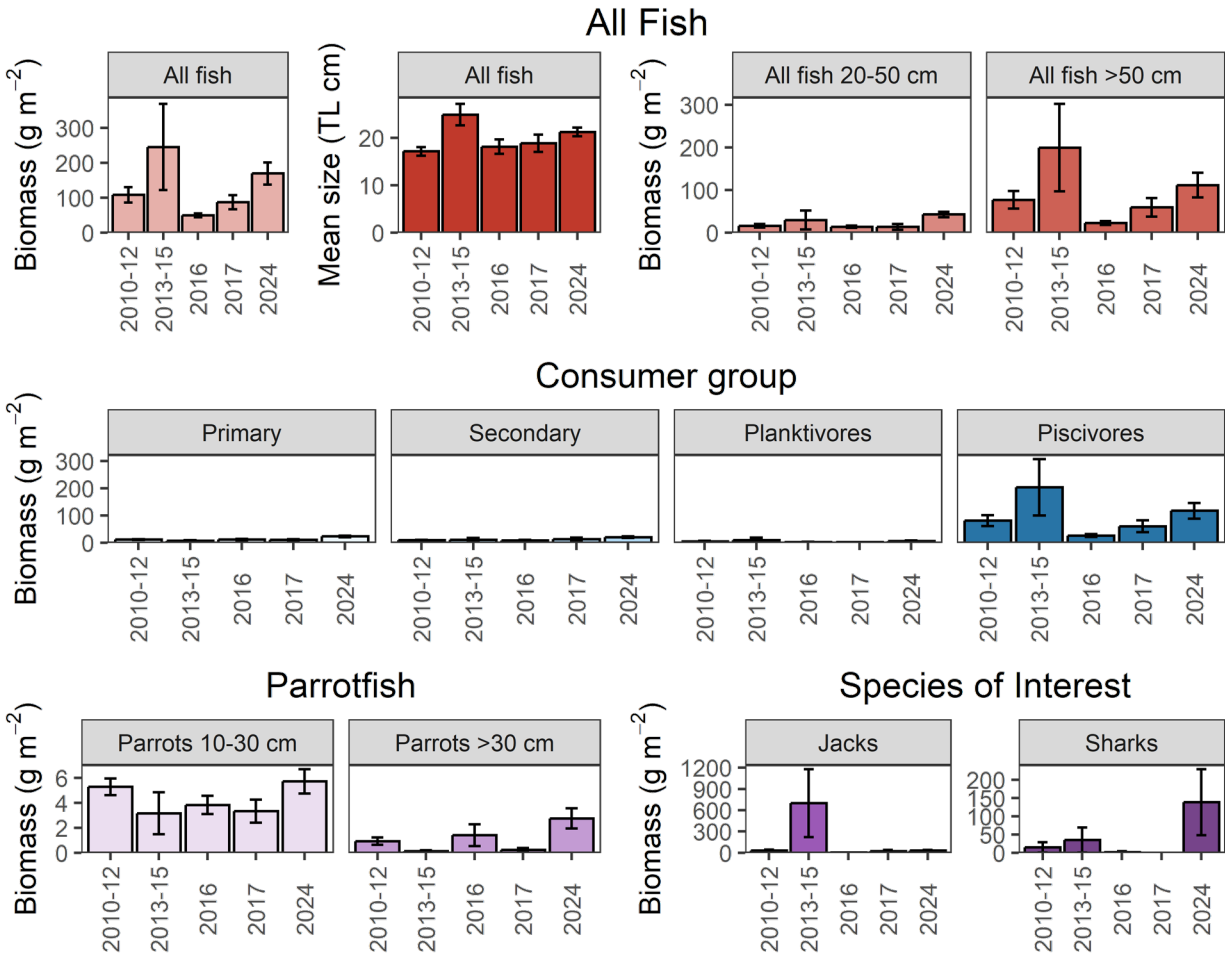

Figure 55. Lalo protected slope fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Manawai (Pearl & Hermes)

Table 20. Year surveyed and the number of sites.

Year	2010	2011	2012	2015	2016	2017	2024
Sites	41	18	31	23	56	20	81

Manawai, also known as Pearl & Hermes, is further broken down into different habitat types or reef zones.

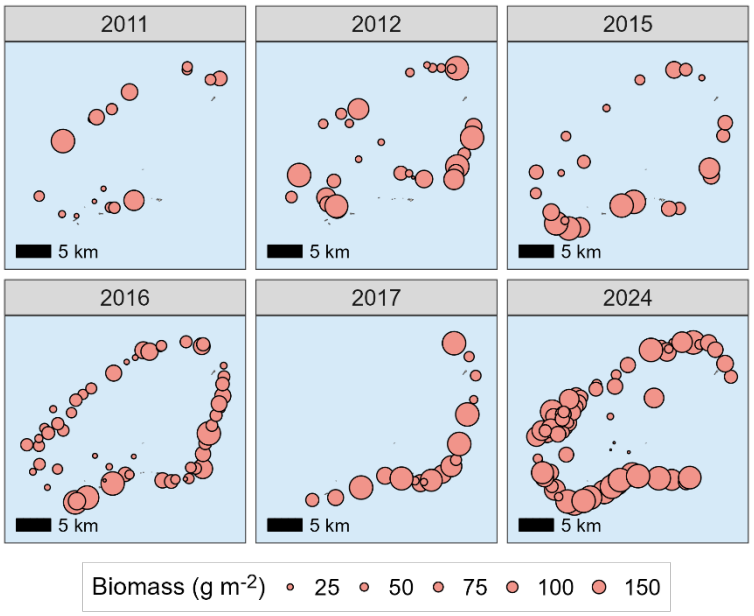

Figure 56. Manawai site survey data by year. Each bubble represents a survey site, and the size of the bubble corresponds to the total fish biomass at each site.

Forereef habitat

Table 21. Year surveyed and the number of sites.

Year	2010	2011	2012	2015	2016	2017	2024
Sites	24	9	15	21	51	20	70

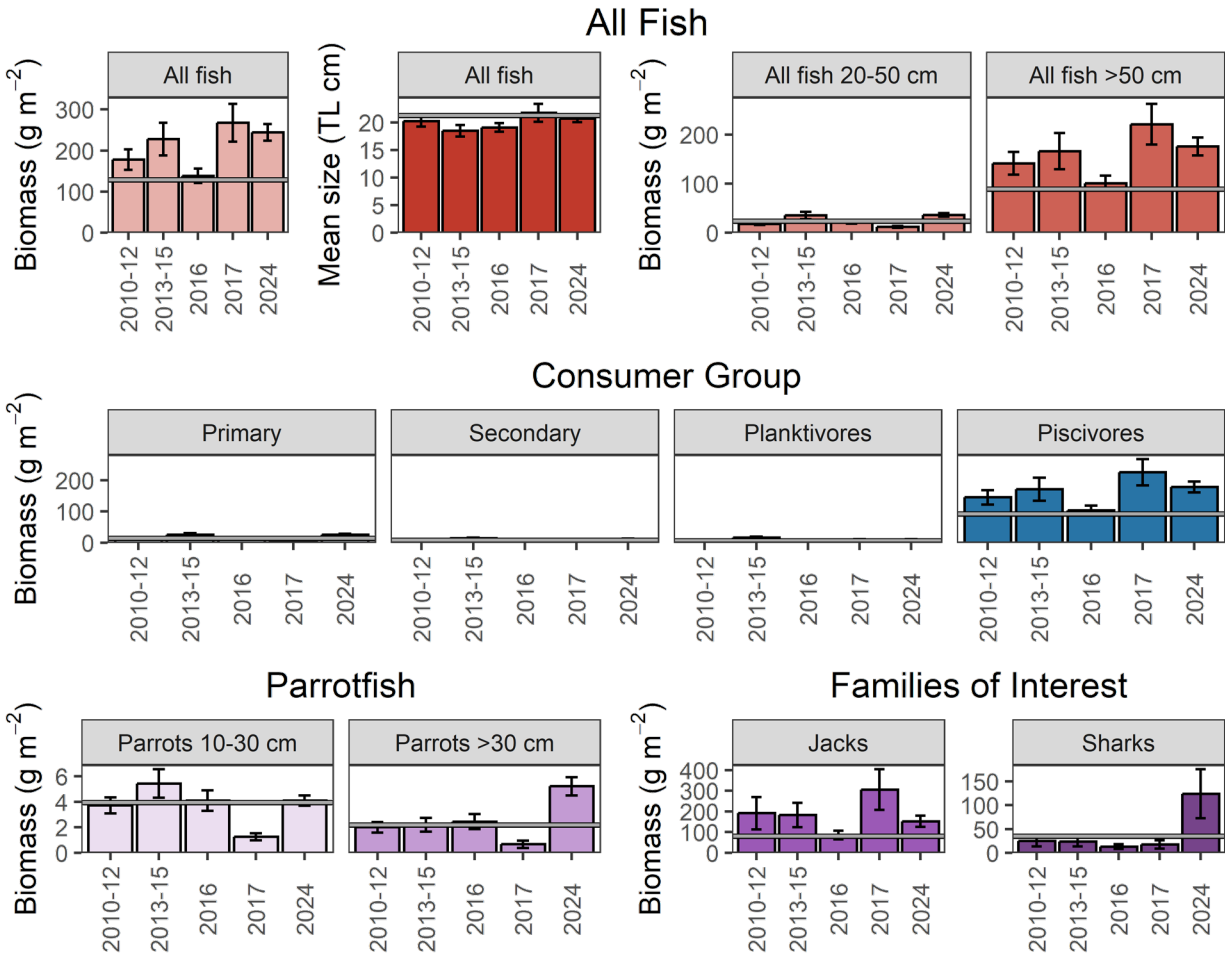

Figure 57. Manawai forereef fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right). The Hawai`i regional mean estimates of each metric are plotted for reference (horizontal gray line).

Lagoon habitat

Table 22. Year surveyed and the number of sites.

Year	2010	2011	2012	2016	2024
Sites	10	9	15	5	10

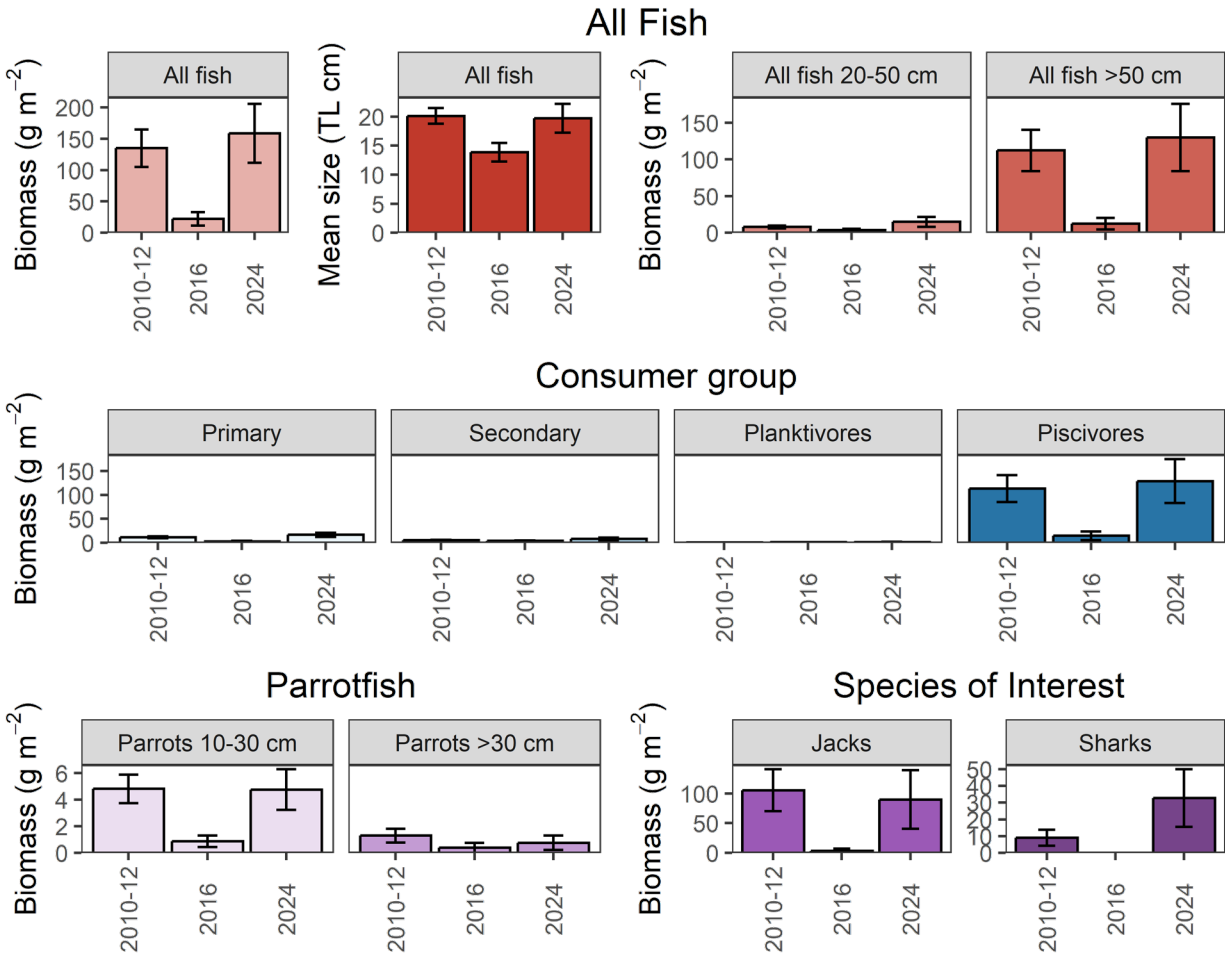

Figure 58. Manawai lagoon fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

Backreef habitat

Table 23. Year surveyed and the number of sites.

Year	2010	2015
Sites	7	2

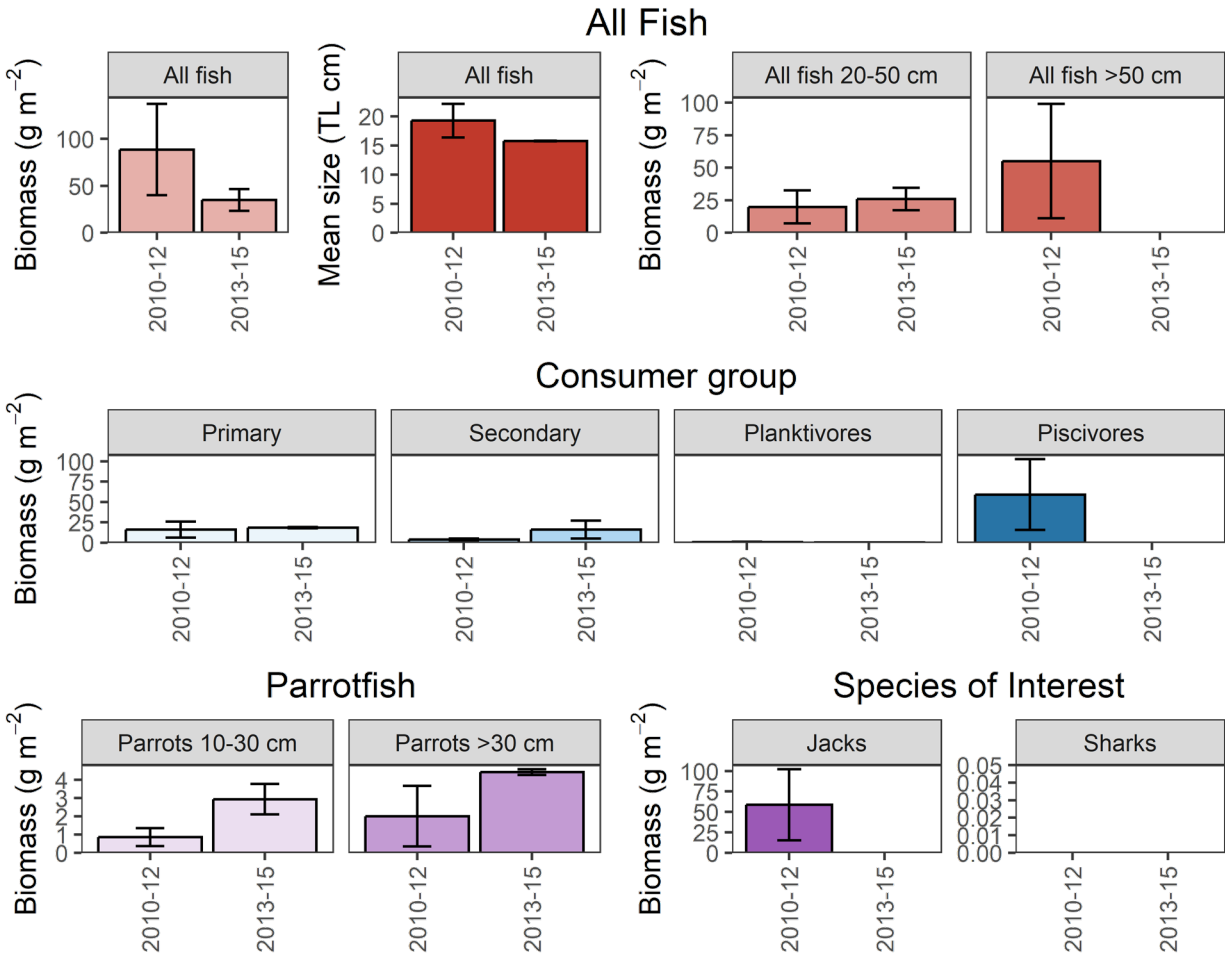

Figure 59. Manawai backreef fish plots. Mean values ± standard error are plotted for biomass, mean size, and biomass per size class of all fishes observed (top); and biomass per consumer group (middle), parrotfish size classes (bottom left), and families of interest (bottom right).

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Appendix A: Surveys per region per year

Table A.1. The number of SPC sites surveyed in Hawai‘i per year. The SPC data collected prior to 2009 are not used in this report because the sites were not selected based on the randomized depth stratified design (see Methods). Furthermore, during the methods transition period, the sites surveyed at the mid-depth strata in 2009 were the haphazardly selected fixed sites from the previous years. Shallow and deep sites were randomly selected. Here, we report all data from 2009 onward, including the non-randomized mid-depth 2009 sites. In the future, these mid-depth sites should be excluded from any time series analyses.

Region	2009	2010	2011	2012	2013	2014	2015	2016	2017	2019	2024
Main Hawaiian Islands	-	184	-	163	287	-	294	256	-	300	251
Papahānaumokuākea	181	118	141	91	-	89	96	182	92	-	275

Appendix B: Samples per sector and strata in 2024

Table B.1. The number of sites surveyed per depth strata and the sector used to pool the data in island-level parameter estimates for the main Hawaiian Islands. During the site selection process, site locations are randomly selected from the strata area for each island. In the main Hawaiian Islands, the islands are broken down into smaller sectors. Deep (>18–30 m), mid (>6–18 m), and shallow (>0–6 m).

Island	Sector	Deep	Mid	Shallow
Hawai‘i	HAW_HAMAKUA	7	6	2
Hawai‘i	HAW_KONA	5	14	5
Hawai‘i	HAW_PUNA	3	3	2
Kaho‘olawe	KAH_NORTH	5	4	2
Kaho‘olawe	KAH_SOUTH	4	5	3
Kauai	KAU_EAST	-	5	3
Kauai	KAU_NAPALI	3	2	2
Lana‘i	LAN_SOUTH	5	9	4
Maui	MAI_KIHEI	4	5	2
Maui	MAI_LAHAINA	2	3	2
Maui	MAI_NE	4	2	2
Moloka‘i	MOL_PALI	3	5	2
Moloka‘i	MOL_SOUTH	2	2	2
Moloka‘i	MOL_WEST	3	6	2
Ni‘ihau	NII_EAST	5	3	2
Ni‘ihau	NII_LEHUA	2	2	2
Ni‘ihau	NII_WEST	5	8	2
O‘ahu	OAH_EAST	3	4	2
O‘ahu	OAH_KAENA	3	2	2
O‘ahu	OAH_NE	2	9	3
O‘ahu	OAH_NORTH	2	5	2
O‘ahu	OAH_SOUTH	6	10	9

Table B.2. The number of sites surveyed per depth strata and reef zone used to pool the data in island-level parameter estimates for Papahānaumokuākea. During the site selection process, site locations are randomly selected from the strata area for each island. Deep (>18–30 m), mid (>6–18 m), and shallow (>0–6 m).

Island	Depth bin	Forereef	Lagoon	Protected Slope	Backreef
French Frigate	Deep	10	-	19	-
French Frigate	Mid	22	2	5	-
French Frigate	Shallow	4	3	-	-
Kure	Shallow	8	4	-	2
Kure	Deep	10	-	-	-
Kure	Mid	32	3	-	-
Laysan	Deep	6	-	-	-
Laysan	Mid	4	-	-	-
Lisianski	Deep	40	-	-	-
Lisianski	Mid	15	-	-	-
Lisianski	Shallow	5	-	-	-
Pearl & Hermes	Shallow	4	6	-	1
Pearl & Hermes	Deep	24	-	-	-
Pearl & Hermes	Mid	42	4	-	-

Appendix C: SPC Quality control: Observer cross-comparison

Estimates are compared between dive partner pairs to check for consistency between observers. This can be done for any parameter estimated, but here total fish biomass, species richness (number of unique species counted), and hard coral cover estimates are highlighted. These are three of the most frequently reported summary metrics from the stationary point count survey data. The differences between the estimates of each diver and those of their dive partner at each site are calculated and referred to here as diver performance. Real differences between dive partners are expected as divers are survey adjacent, not in the same cylinder area. However, if there is no consistent bias in the estimates made by a diver, one would expect the median value of their performance to be close to zero, that is, with estimates in half of the counts being higher than their partner's estimates and half of the counts lower than their partner's estimates. Boxplots of diver performance, therefore, give the following: (1) a strong but general indication of relative bias; if there is no consistent bias, then the median differences between a single diver and their dive partners will be close to zero; and (2) an indication of how variable each diver's counts are compared to their dive partners; if a particular diver's performance varies widely compared to their partner's (i.e., several very high and/or several very low counts), that may indicate variability in their performances. As dive teams are regularly rotated throughout the course of a survey mission, measures of individual diver's counts reflect their performance relative to the entire pool of other divers participating in those surveys. These boxplots are routinely generated during and after field operations to give divers feedback on their performance relative to their colleagues and are summarized here by region

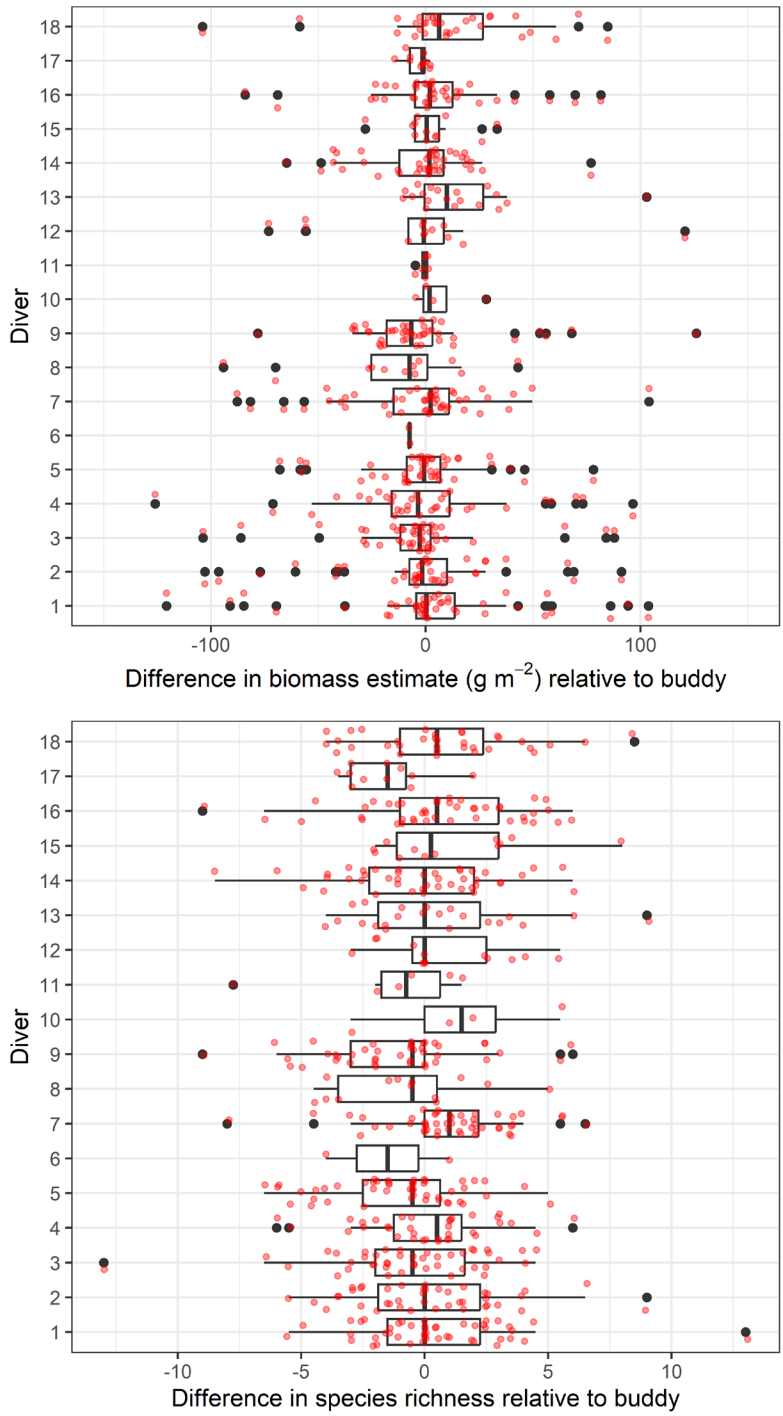

Figure C.1. Comparison of observer diver vs. diver partner estimates in the main Hawaiian Islands for total fish biomass (top plot) and species richness (bottom plot) during the 2024 surveys. The boxplot shows the median difference (thick vertical line) in estimates for each diver. The box represents the location of 50% of the data. Lines extending from each box are 1.5 times the interquartile range, which represents approximately 2 standard deviations; points greater than this (outliers) are plotted individually (black dots).

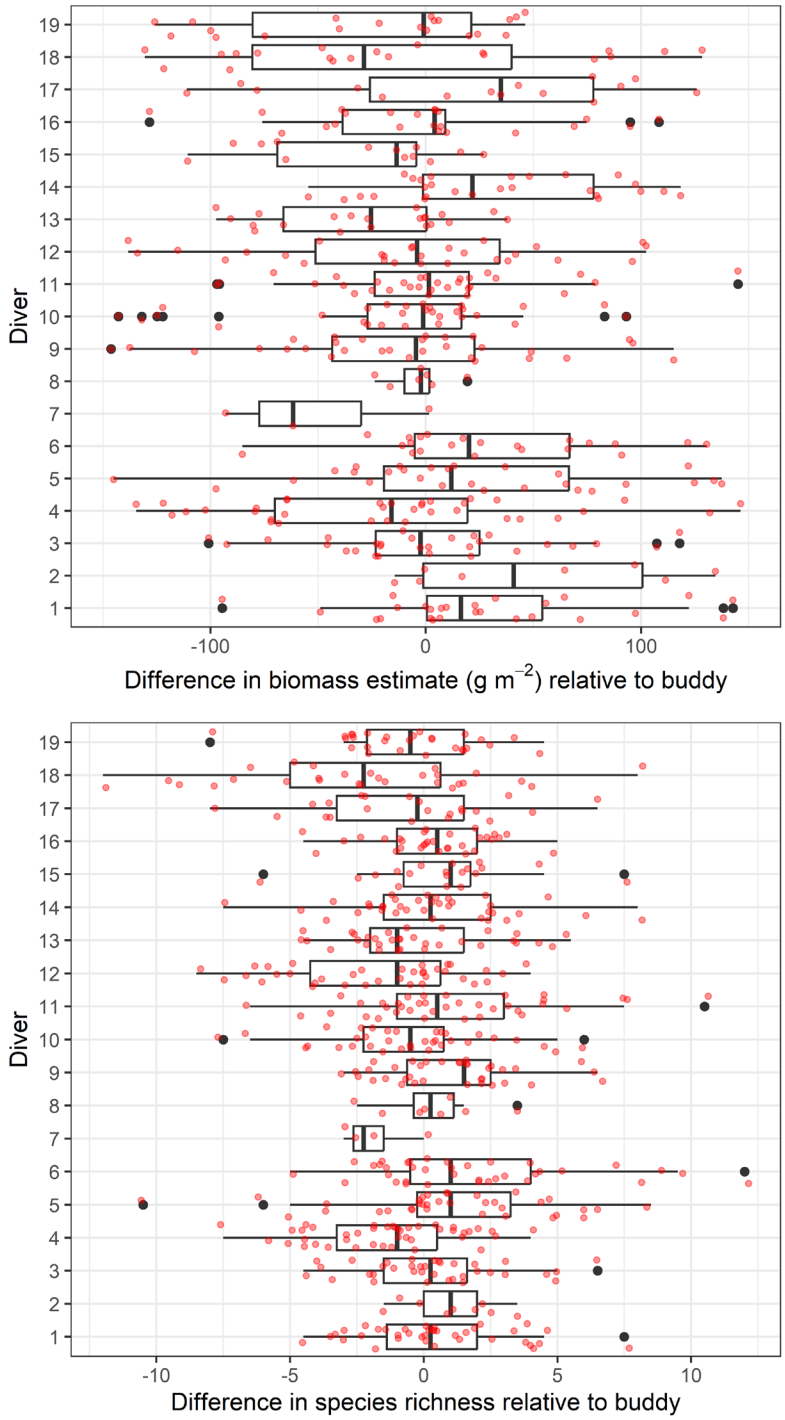

Figure C.2. Comparison of observer diver vs. diver partner estimates in Papahānaumokuākea for total fish biomass (top plot) and species richness (bottom plot) during the 2024 surveys. The boxplot shows the median difference (thick vertical line) in estimates for each diver. The box represents the location of 50% of the data. Lines extending from each box are 1.5 times the interquartile range, which represents approximately 2 standard deviations; points greater than this (outliers) are plotted individually (black dots).

Appendix D: Random stratified sites surveyed at each island per year

Table D.1. The total number of sites surveyed per island per year under the stratified-random sampling design, using the stationary point count method to survey the fish assemblage. MHI = main Hawaiian Islands, PMNM = Papahānaumokuākea Marine National Monument.

Region	Island	2009	2010	2011	2012	2013	2014	2015	2016
MHI	Hawai‘i	-	43	-	-	58	-	97	59
MHI	Kauai	-	26	-	-	37	-	20	30
MHI	Lana‘i	-	16	-	29	29	-	15	26
MHI	Maui	-	33	-	49	34	-	30	28
MHI	Moloka‘i	-	10	-	50	39	-	48	23
MHI	Ni‘ihau	-	16	-	-	26	-	49	12
MHI	O‘ahu	-	40	-	35	64	-	35	54
MHI	Kaho‘olawe	-	-	-	-	-	-	-	24
PMNM	Hōlanikū	43	25	-	20	-	-	8	39
PMNM	Kamole	14	-	23	-	-	-	8	-
PMNM	Kapou	19	25	9	25	-	28	18	40
PMNM	Lalo	-	27	8	15	-	27	8	47
PMNM	Manawai	-	41	18	31	-	-	23	56

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We are committed to providing ecological monitoring information that is transparent, readily accessible, and relevant to the sound management of coral reef resources. For data requests contact: Andrew.Shantz@noaa.gov.

We would welcome comments from any users of this data report on how to improve the utility of this document for future versions. Comments or suggestions on the content of this annual data report may be submitted to: Kaylyn.McCoy@noaa.gov with the subject line, “Feedback on Monitoring Report.”