Pacific Reef Assessment and Monitoring Program

Data Report

Ecological monitoring 2022—reef fishes of the Mariana Archipelago

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This report outlines a portion of the coral reef monitoring surveys conducted by the National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Fisheries Science Center's (PIFSC) Archipelagic Research Program (ARP) of the Ecosystem Sciences Division (ESD) in 2022 in the Mariana Archipelago.

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Report, figures, and maps compiled by K. McCoy. Cover photos credit: NOAA Fisheries/Jeff Milisen

Acronyms

ARP	Archipelagic Research Program
BSR	Benthic substrate ratio
CRCP	Coral Reef Conservation Program
ESD	Ecosystem Sciences Division
FL	fork length
GIS	geographic information system
GLTMP	Guam Long-term Coral Reef Monitoring Program
LL	length-length
LW	length-to-weight
NCRMP	National Coral Reef Monitoring Program
NOAA	National Oceanic and Atmospheric Administration
PIFSC	Pacific Islands Fisheries Science Center
RAMP	Reef Assessment and Monitoring Program
SPC	Stationary Point Count
TL	total length

Contents

Introduction

Background

The Archipelagic Research Program of the Ecosystem Sciences Division (ESD) at the Pacific Islands Fisheries Science Center (PIFSC) leads the U.S. Pacific National Coral Reef Monitoring Program (NCRMP), formerly known as the Pacific Reef Assessment and Monitoring Program (RAMP), providing scientific information that supports ecosystem approaches to the management and conservation of coral reefs. Since its inception in 2000, Pacific RAMP has established baseline ecosystem assessments and conducted long-term monitoring that integrates biological observations with water quality and oceanographic data. In 2011, the effort was expanded into the Atlantic, Caribbean, and Puerto Rico and renamed NCRMP, with the goal of establishing a long-term effort to monitor the status and trends of U.S. coral reef ecosystems by conducting integrated, consistent, and comparable monitoring of coral reefs across all U.S.-affiliated regions (Figure 1).

Figure 1. Coral reef areas surveyed for Pacific NCRMP. White areas represent the exclusive economic zones for each U.S. Pacific region surveyed.

Pacific NCRMP encompasses interdisciplinary monitoring of oceanographic conditions and biological surveys of organisms associated with hard-bottomed habitats in the 0–30 m depth range. From 2000 to 2011, regions were surveyed on a biennial basis, changing to a triennial cycle in 2012, as part of the implementation of NOAA's National Coral Reef Monitoring Program (NCRMP) funded by the NOAA CRCP (NOAA CRCP, 2014).

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. Data gathered by GLTMP is therefore readily merged with NCRMP data resulting in increased survey domain for local research efforts.

The NCRMP has three themes: biological, climate, and socioeconomic monitoring. Under the biological monitoring theme, the Pacific NCRMP collects the following reef fish data:

- species abundance
- species size structure
- diversity
- key fish taxa

This report focuses on the data collected using the stationary point count (SPC) method to survey the fish assemblage (see Section: Methods). The Pacific NCRMP collects additional, related benthic data via benthic transects (for more information see NOAA Coral Program 2021), which are not included in this report.

Monitoring scope and historical programmatic changes

Pacific NCRMP includes the following biological monitoring goals:

- develop and implement consistent and comparable methods and standard operating procedures which 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 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 NCRMP and the CRCP support for baseline observations and monitoring (refer to NOAA Coral Program, 2021, NCRMP 2014, and NOAA CRCP 2009 for more details).

Pacific NCRMP involves monitoring over very large spatial scales: ~ 40 islands and atolls spread over thousands of kilometers. The target of Pacific NCRMP 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. The NCRMP is therefore explicitly a "wide-but-thin" survey program, with the aim of generating large-scale, regional status and trend information of the nation's shallow water (0–30 m) coral reef ecosystems, to provide a broad-scale context and perspective to local jurisdictions and other survey programs.

The sampling design and methods used to monitor coral reef fish species and habitats have evolved. Specifically, from 2000 to 2006, surveys were conducted at haphazardly located permanent sites using various belt transect methods. During 2007 to 2009, comparative reef fish surveys were conducted using both the belt transect and the SPC methods and incorporated a stratified random sampling survey design. Survey replication (i.e., the number of sites sampled) greatly increased over this period, and this higher level of replication has been maintained (Appendix 1: Surveys per region per year and method used). Following this methods calibration period, from 2009 onwards, the SPC method and depth-stratified random sampling were applied routinely in Pacific NCRMP for surveying reef fishes and associated benthic communities.

Report structure

This report summarizes the reef fish survey data collected in the Mariana Archipelago during the Pacific NCRMP survey mission in 2022. The status of reef fish assemblages is described at the island scale. By collecting data using the same methods over time, we are able to present time series. Even though surveys began in 2000, given the substantial changes in methods and design used for the reef fish assemblage surveys, this section shows observations collected since 2009.

All data used in this report are available upon request to Tye.Kindinger@noaa.gov.

Methods

Sampling domain and design

The target sampling domain is hard-bottom habitat in water shallower than 30 m. All islands/atolls within 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). The areas surveyed in the Mariana Archipelago are all considered 'forereef,' and the island of Guam is further stratified into sectors per island. Sector boundaries are designed to reflect broad differences in oceanographic exposure, reef structure, and local human population density (Appendix 2: Sector maps). Some of the smaller, more closely spaced islands are always pooled into single reporting and sampling units (i.e., Alamagan, Guguan, and Sarigan). Due to their small size, these island groups are only allocated a limited number of sea days per cruise; therefore, total sampling effort per island is inadequate to report out data at the island level. Details of sectors and sampling effort on survey cruises covered by this report are given in Appendix 3: Samples per sector and strata in 2022.

Table 1. Sampling terms and definitions.

Term	**Definition**
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.
Reporting unit	A collection of sample sites, typically an island or atoll and in some cases, small island groups or sectors of larger islands.
Sampling domain	Hard-bottom habitat in water less than 30 m depth.
Strata	Reef zone (backreef, forereef, lagoon, protected slope) Depth zone (shallow > 0–6 m, mid > 6–18 m, deep > 18–30 m) Sectors (e.g., management units and stretches of coastline with broadly similar habitat attributes and local human population density).

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

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 PIFSC-affiliated Pacific Islands Benthic Habitat Mapping Center at the University of Hawaiʻi at Mānoa, and prior knowledge gained from previous visits to survey locations.

During cruise planning, logistics and weather conditions factor into the allocation of monitoring effort around each island or atoll. Prior to the cruises, these constraints determine the area of target habitat from which sites are randomly selected. For instance, one side of an island may be unable to be surveyed due to seasonal wave conditions. or the NCRMP allocation of sea days aboard the NOAA research vessel may curtail the time spent in a particular area. The density of sites that are sampled per stratum is therefore determined by proportionally allocating effort (e.g., the number of sites to be surveyed) based on a weighting factor calculated from the area per stratum per reporting unit and the variance of the target output metrics (e.g., consumer group biomass and total fish biomass; see Section: Fish groupings), combined with time constraints of ship time allotted per island or atoll.

During field operations on a 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 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 surveyed (Appendix 3: Samples per sector and strata in 2022). For further details on the methods and maps used to select sites, see Williams et al. (2011) or Ayotte et al. (2015).

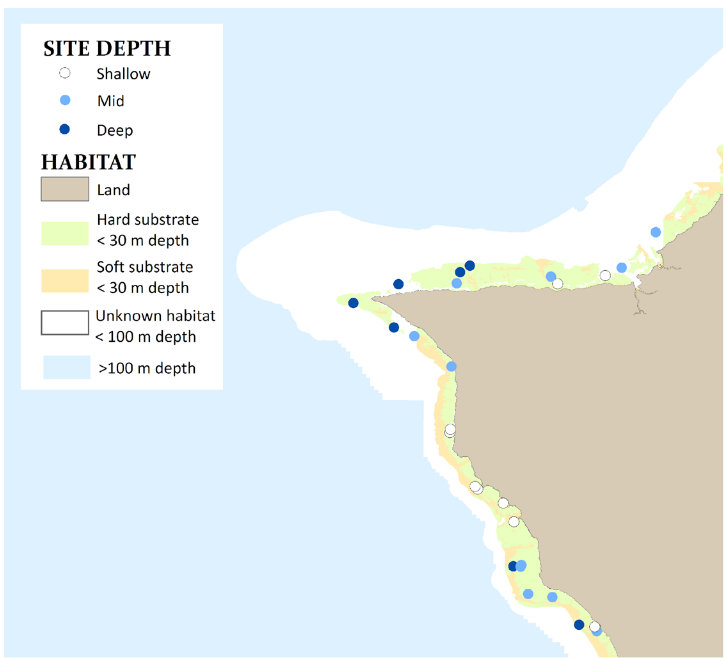

Figure 2. An example of the benthic habitat and depth strata information used in the site selection process. Reef fish survey sites are randomly selected within each depth stratum. Survey effort is allocated to optimize island-scale biomass estimates. Prior to surveying, a series of primary sites is selected. Each circle identifies a site which 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). An alternate set of depth-stratified sites is also generated in the event that primary sites are not suitable or accessible.

Sampling methods

At each reef fish survey site, two types of data are collected: visual counts of the fish assemblage and surveys of the benthic habitat (Figure 3). The benthic data are not presented in this report as the fish survey sites are only a subset of the overall benthic sampling effort for NCRMP; these data are available upon request from Tom Oliver (Thomas.Oliver@noaa.gov).

Counting and sizing reef fishes

The SPC protocol closely follows that used by Ault and colleagues (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 pair, 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, in which they systematically work through their species list and record the number and estimated size (total length, TL, to the nearest cm) 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, i.e., when observers cannot distinguish the edges of their cylinder (Ayotte et al., 2015).

Once the fish survey is complete, divers estimate benthic habitat composition and a benthic photo-transect is collected, spanning the two cylinders. If time permits, more images are captured for creation of a 3-dimensional model of the reef assembled with a method referred to as 'Structure-from-Motion'.

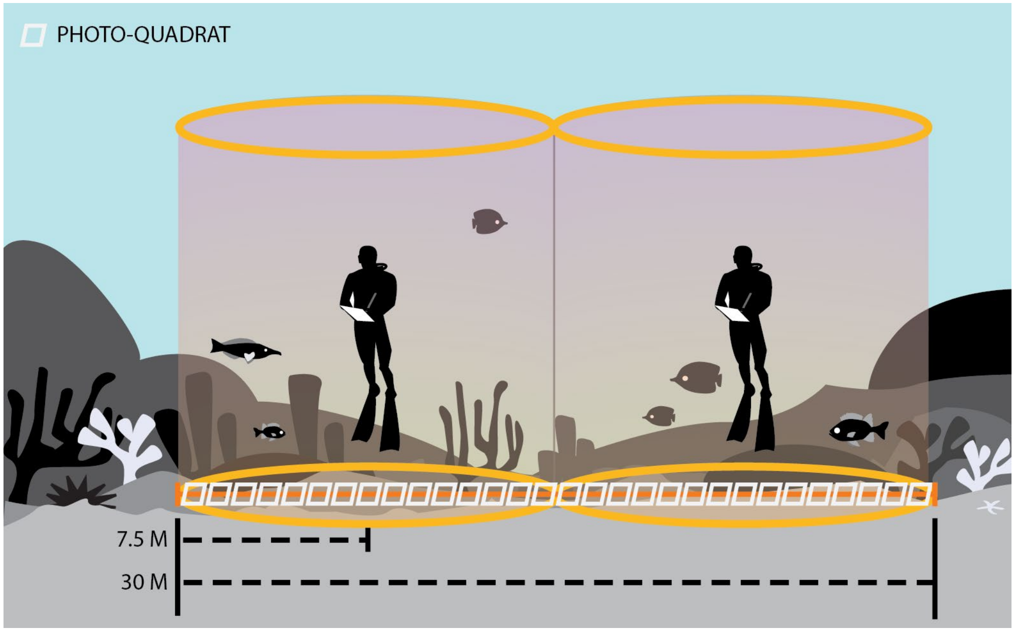

Figure 3. Side view of the stationary point count method. Dive partners count and size fishes within adjacent cylinders measuring 7.5 m in radius.

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 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 2022 are in Appendix 4: SPC Quality. control:

Observer cross-comparison.

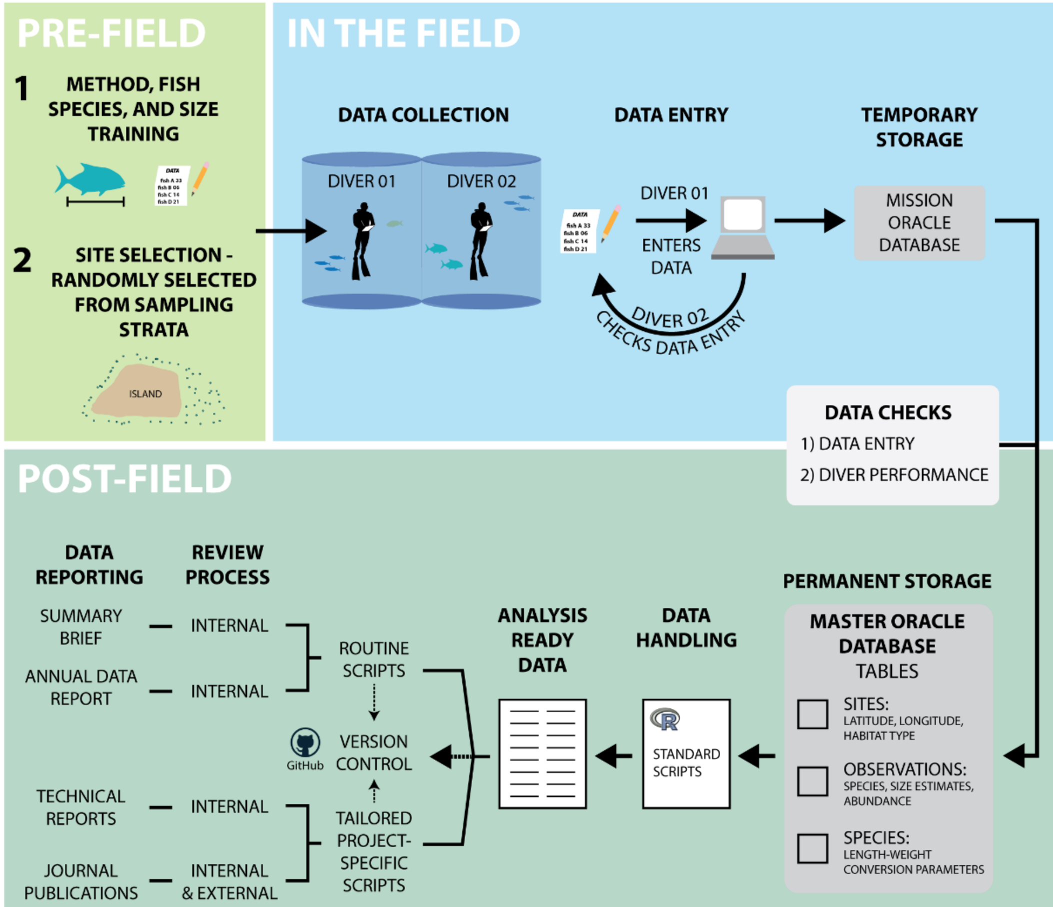

Figure 4. The training, data collection, data processing, and reporting phases for Pacific NCRMP SPC surveys.

Data handling

Calculating fish biomass per site

Using the count and size estimate data collected per observer in each replicate survey, the body weight of 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 and 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 and Pauly 2010). Size classes for parrotfish are 10–30 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 the formulas below. For example, with respect to biomass we have:

(1) pooled mean biomass (X) across S strata: $X = \sum_1^S (X_i * w_i)$; and

(2) pooled variance of mean biomass (VAR) across S strata: $VAR = \sum_1^S (VAR_i * w_i^2)$

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, i.e., if a stratum is 50% of the total habitat area surveyed at an island, its weighting factor will be 0.5, and 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 onwards; Appendix 5: Random stratified sites surveyed at each island per year). 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) and biomass per consumer group and parrotfish size class (mean and variance) are calculated by year (see Section: 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 between 2009 and 2022, when comparable methods were used. For each island within a region, maps illustrate the SPC site-level data from 2014 through 2022 (2007–2012 site locations can be found in earlier reports, but are not shown in this report to prevent overcrowding of the maps), and a standard set of graphs shows summary information on the fish community at the habitat and island scales for each year, starting in 2009. On each fish biomass graph for the forereef habitat, a reference line indicates the region-wide mean estimate across all surveyed years (2009–2022), provided as a relevant regional comparison for island-level estimates. Fish biomass estimates are shown for each year of all fish combined ('total fish'), parrotfish in two size classes, and by consumer group. Total fish, consumer group, and parrotfish biomass are core NCRMP indicators (NOAA NCRMP 2014). Large parrotfishes are believed to be important grazers, so parrotfish biomass is separately reported for two size groups: large (> 30 cm TL) and small (10–30 cm TL) fishes. Mean size per island and year is also reported, as it can be a useful indicator of fishing pressure; fishes smaller than 10 cm are excluded to reduce noise from variable levels of recent recruitment.

Mariana Archipelago – Southern Marianas

Aguijan Island

SPC surveys were conducted in Aguihan Island in 2009 (n = 6), 2011 (n = 13), 2014 (n = 10), 2017 (n =17), and 2022 (n = 15).

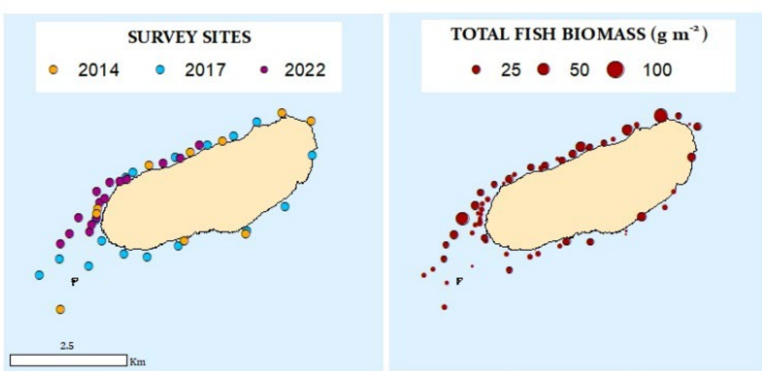

Figure 5. Aguijan Island site survey data for 2014, 2017, and 2022. Site location identified by year and total fish biomass recorded at each site.

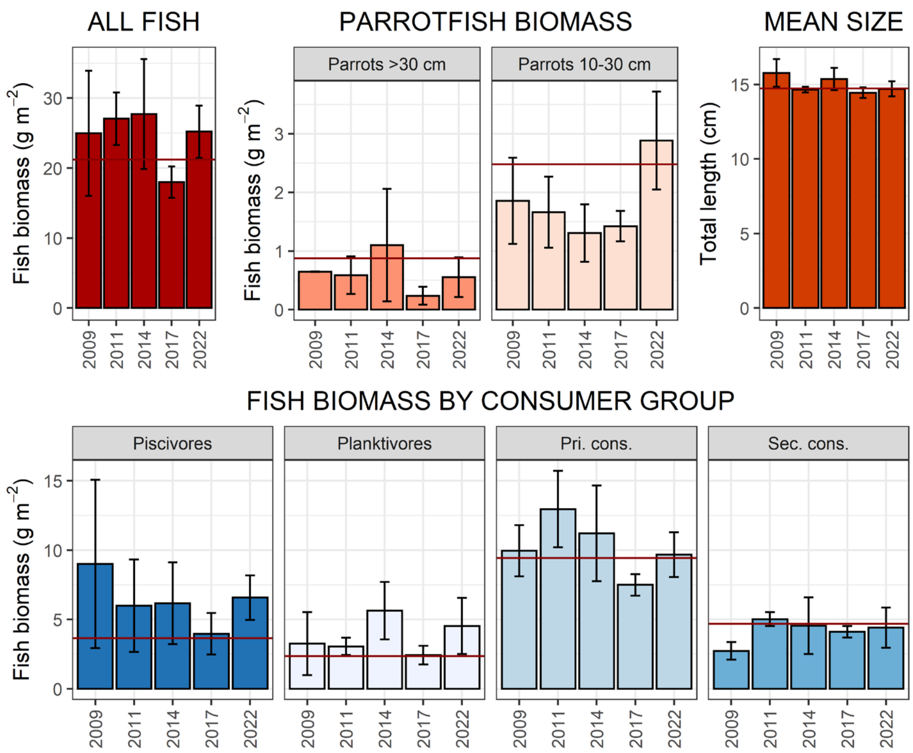

Figure 6. Aguijan Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top), and per consumer group (middle), as well as mean size (TL cm, top). The S. Mariana region mean estimates of fish biomass are plotted for reference (red line).

Guam Island

Guam Island was surveyed in 2009 (n = 25), 2011 (n = 133), 2014 (n = 104), 2017 (n = 66), and 2022 (n = 93).

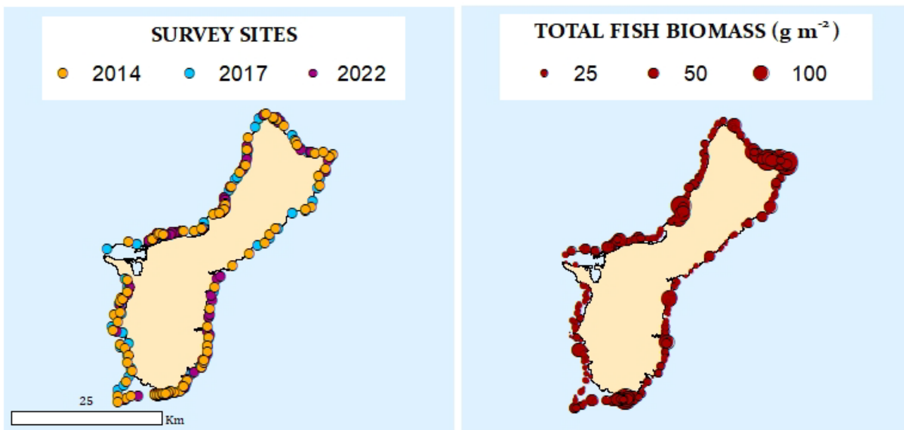

Figure 7. Guam Island site survey data for 2014, 2017, and 2022. Site location identified by year and total fish biomass recorded at each site.

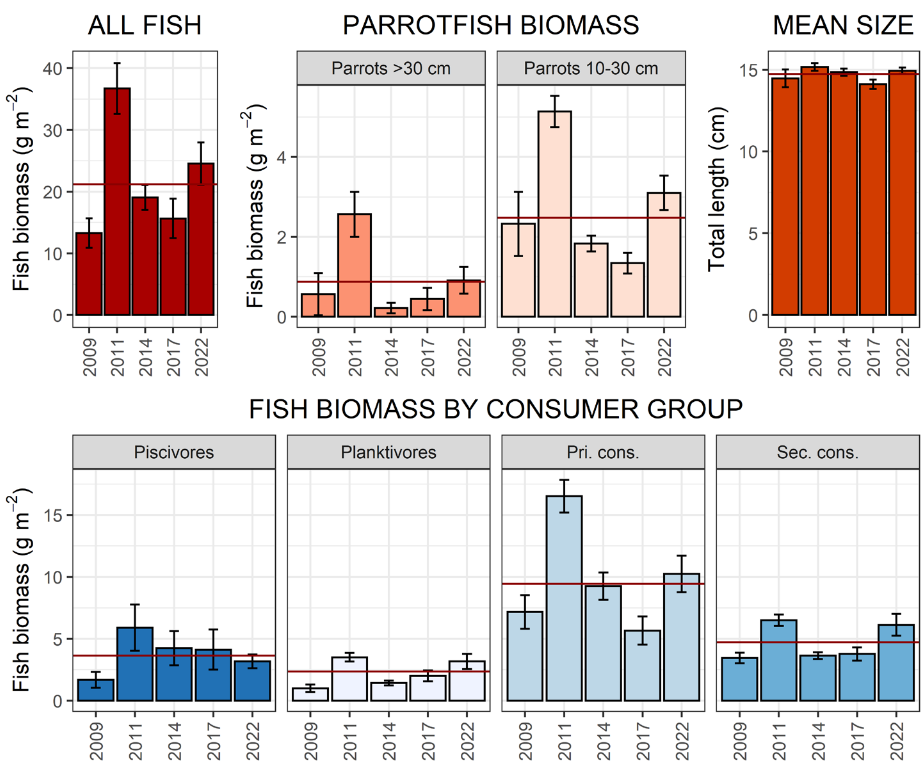

Figure 8. Guam Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top), and per consumer group (middle), as well as mean size (TL cm, top). The S. Mariana region mean estimates of fish biomass are plotted for reference (red line).

Rota Island

Rota Island was surveyed in 2009 (n = 14), 2011 (n = 24), 2014 (n = 28), 2017 (n = 28), and 2022 (n = 16).

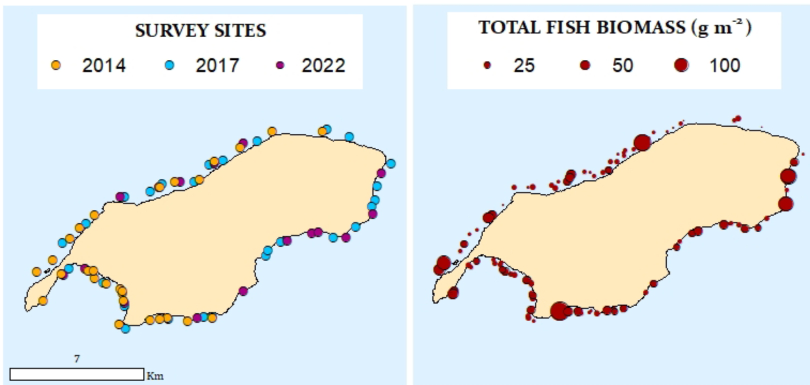

Figure 9. Rota Island site survey data for 2014, 2017, and 2022. Site location identified by year and total fish biomass recorded at each site.

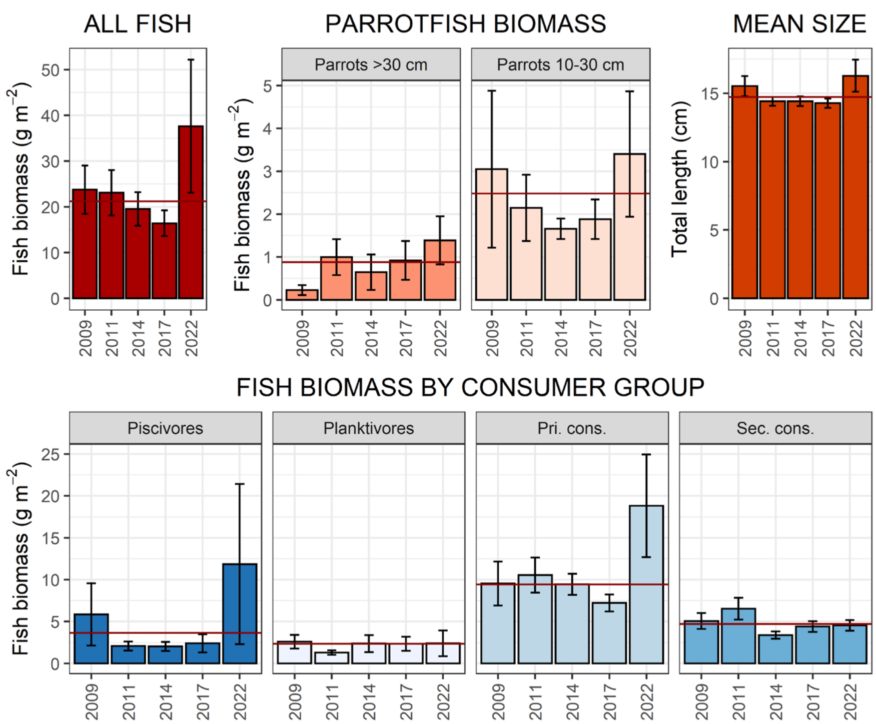

Figure 10. Rota Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top), and per consumer group (middle), as well as mean size (TL cm, top). The S. Mariana region mean estimates of fish biomass are plotted for reference (red line).

Saipan Island

Saipan Island was surveyed in 2009 (n = 23), 2014 (n = 30), 2014 (n = 48), 2017 (n= 37), and 2022 (n = 54).

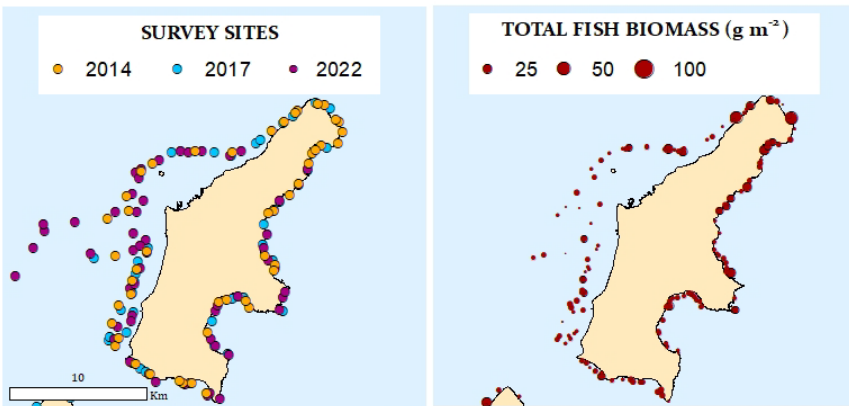

Figure 11. Saipan Island site survey data for 2014, 2017, and 2022 Site location identified by year and total fish biomass recorded at each site.

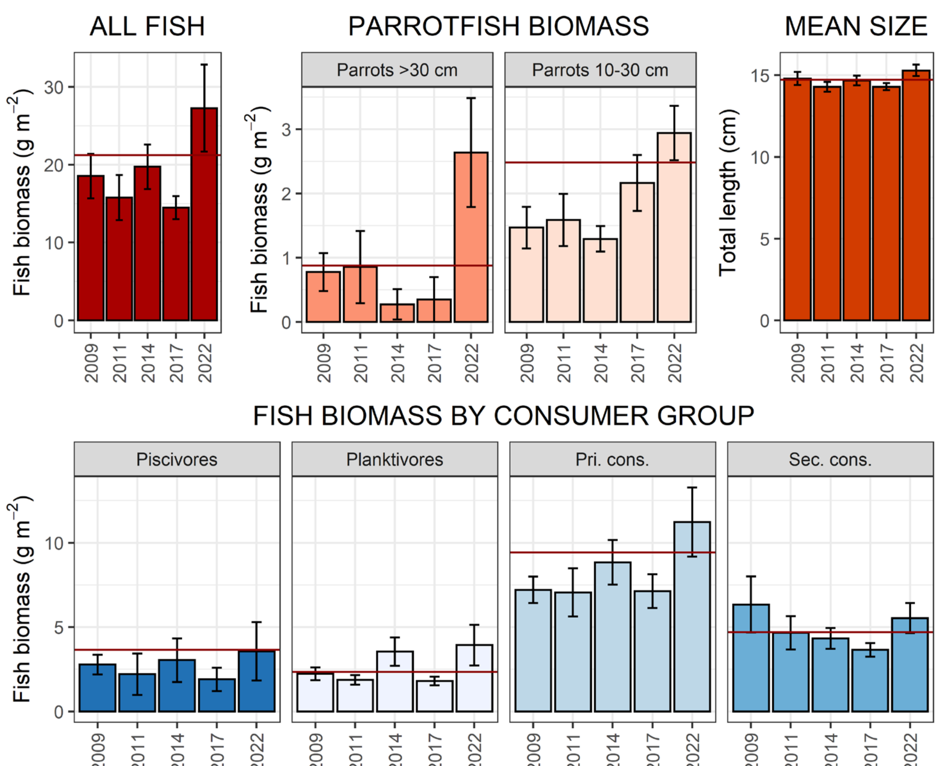

Figure 12. Saipan Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top), and per consumer group (middle), as well as mean size (TL cm, top). The S. Mariana region mean estimates of fish biomass are plotted for reference (red line).

Tinian Island

Tinian Island was surveyed in 2009 (n = 19), 2011 (n = 19), 2014 (n = 19), 2017 (n = 24), and 2022 (n = 19).

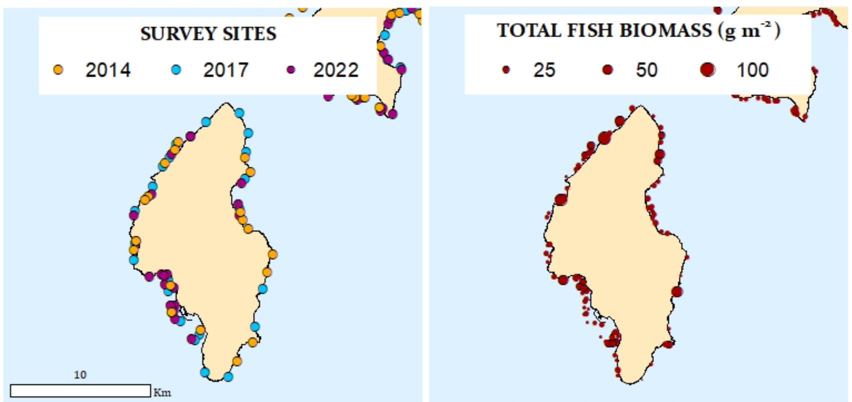

Figure 13. Tinian Island site survey data for 2014, 2017, and 2022 Site location identified by year and total fish biomass recorded at each site.

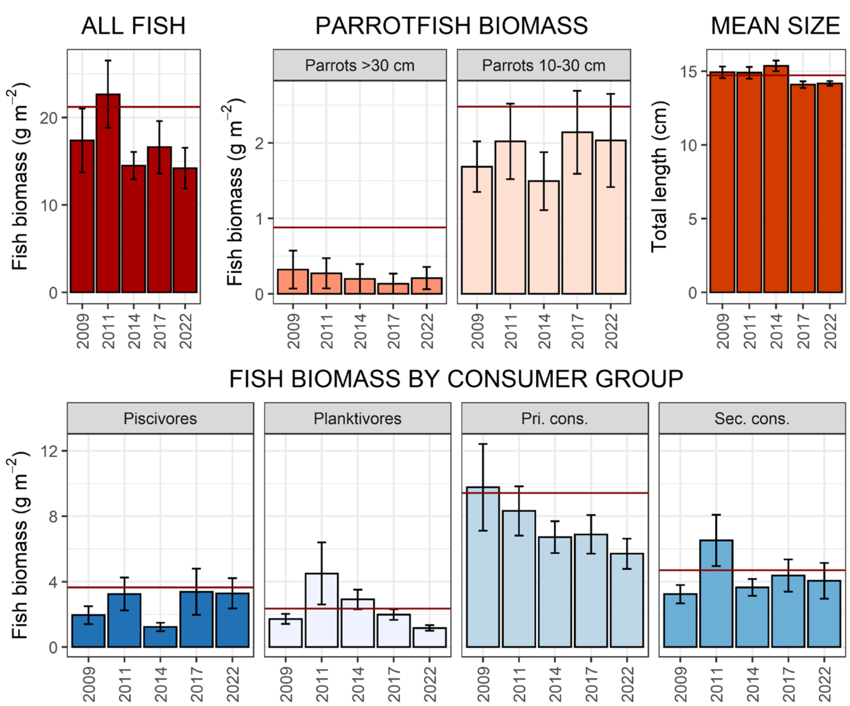

Figure 14. Tinian Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top), and per consumer group (middle), as well as mean size (TL cm, top). The S. Mariana region mean estimates of fish biomass are plotted for reference (red line).

Mariana Archipelago – Northern Marianas

Agrihan Island

Agrihan Island was surveyed in 2009 (n = 14), 2011 (n = 20), and 2017 (n = 19). Agrihan was not surveyed during 2014 or 2022 due to time restrictions.

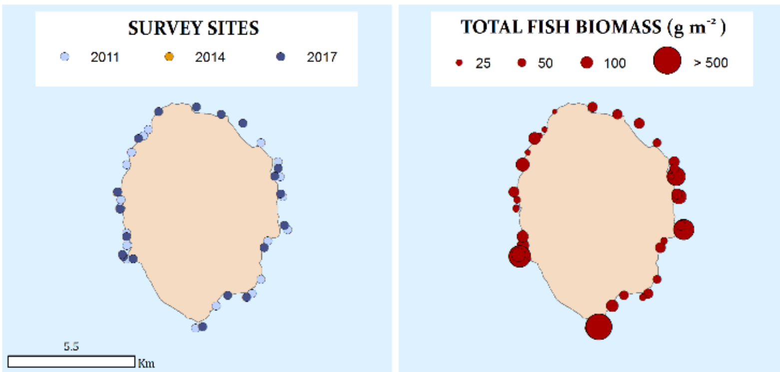

Figure 15. Agrihan Island site survey data for 2011 and 2017. Site location identified by year and total fish biomass recorded at each site.

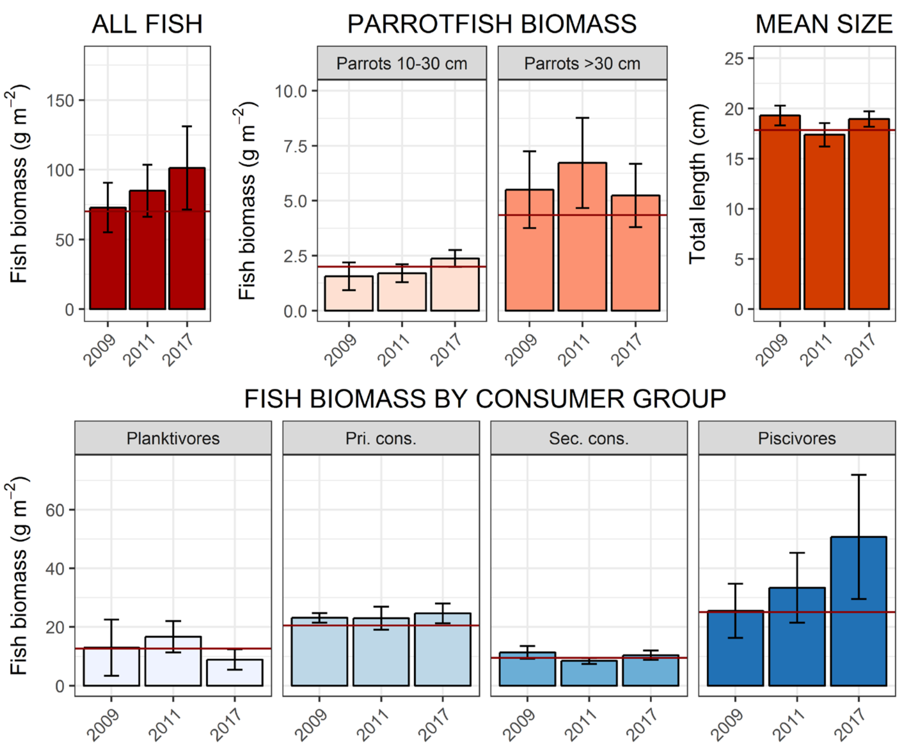

Figure 16. Agrihan Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top), and per consumer group (middle), as well as mean size (TL cm, top). The N. Mariana region mean estimates of fish biomass in 2017 are plotted for reference (red line).

Asuncion Island

Asuncion Island was surveyed in 2009 (n = 13), 2011 (n = 20), 2014 (n = 21), 2017 (n = 19), and 2022 (n = 15).

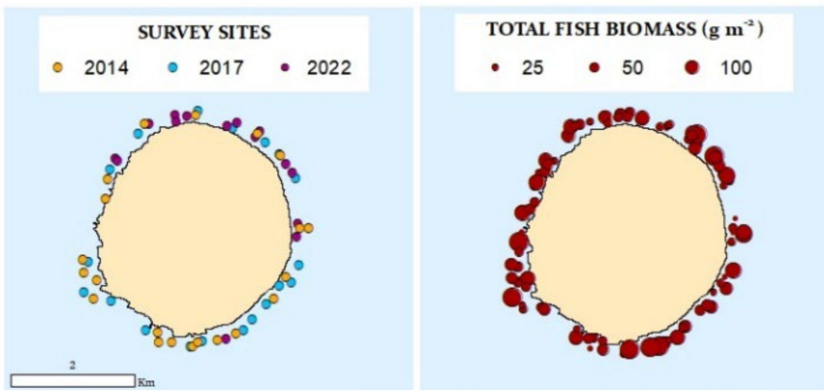

Figure 17. Asuncion Island site survey data for 2014, 2017, and 2022. Site location identified by year and total fish biomass recorded at each site.

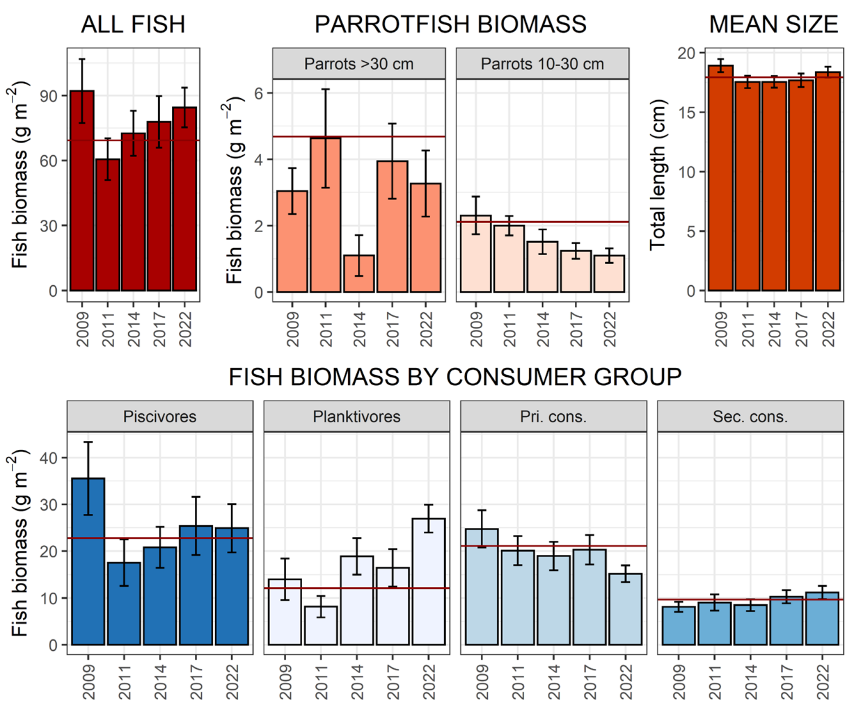

Figure 18. Asuncion Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top), and per consumer group (middle), as well as mean size (TL cm, top). The N. Mariana region mean estimates of fish biomass are plotted for reference (red line).

Farallon de Pajaros Island

Farallon de Pajaros Island was surveyed in 2009 (n = 7), 2011 (n = 12), 2014 (n = 11), 2017 (n = 16), and 2022 (n = 9).

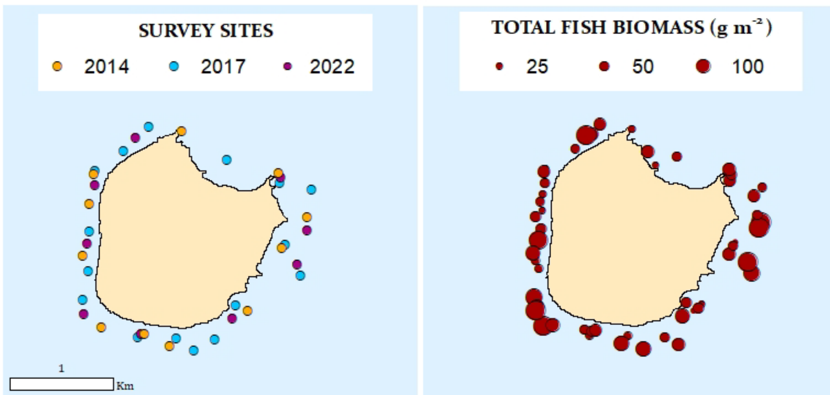

Figure 19. Farallon de Pajaros Island site survey data 2014, 2017, and 2022 Site location identified by year and total fish biomass recorded at each site.

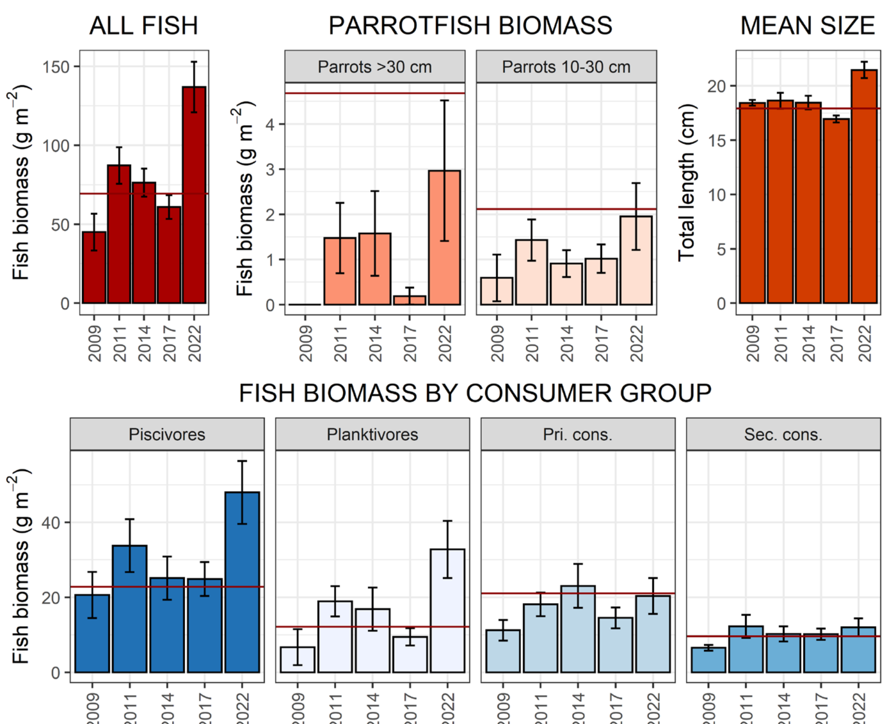

Figure 20. Farallon de Pajaros Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top), and per consumer group (middle), as well as mean size (TL cm, top). The N. Mariana region mean estimates of fish biomass are plotted for reference (red line).

Maug Island

Maug Island was surveyed in 2009 (n = 21), 2011 (n = 30), 2014 (n = 40), 2017 (n = 38), and 2022 (n = 30).

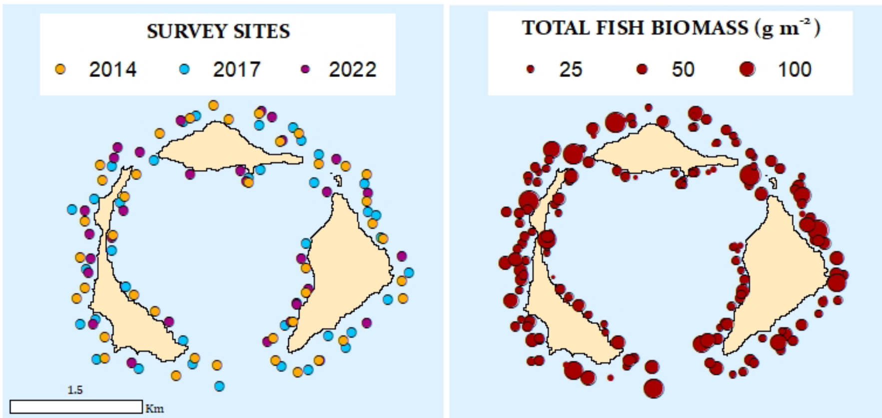

Figure 21. Maug Island site survey data for 2014, 2017, and 2022 Site location identified by year and total fish biomass recorded at each site.

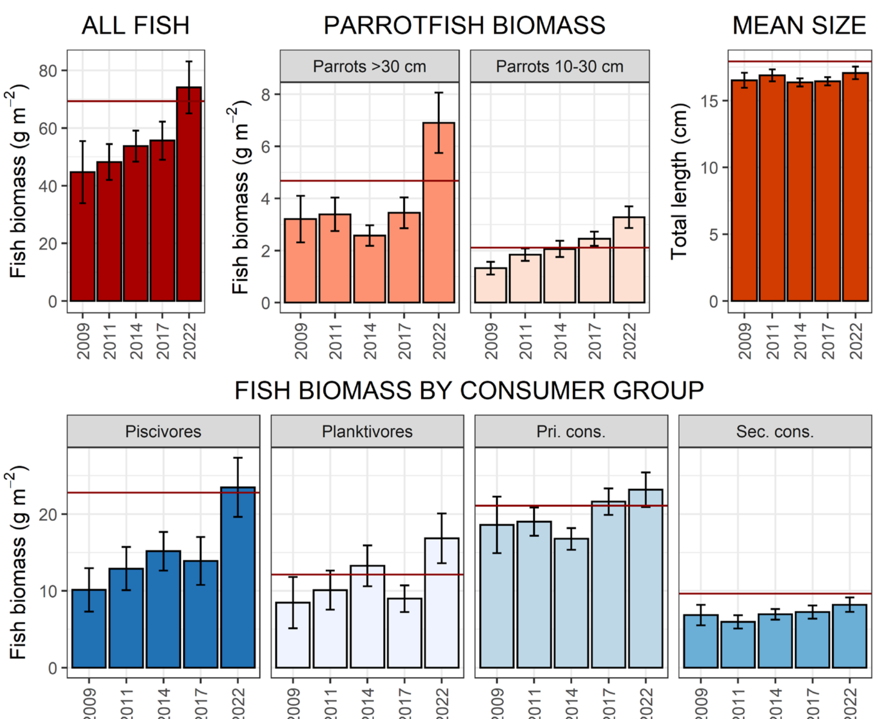

Figure 22. Maug Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top), and per consumer group (middle), as well as mean size (TL cm, top). The N. Mariana region mean estimates of fish biomass are plotted for reference (red line).

Pagan Island

Pagan Island was surveyed in 2009 (n = 21), 2011 (n = 29), 2014 (n = 43), 2017 (n = 40), and 2022 (n = 40).

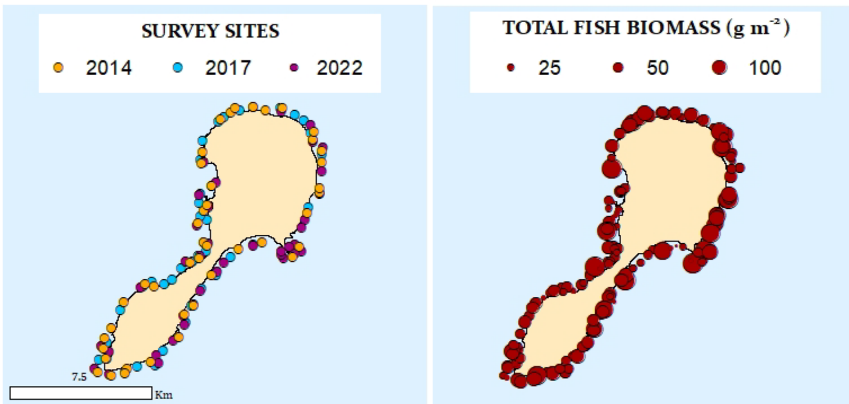

Figure 23. Pagan Island site survey data for 2014, 2017, and 2022. Site location identified by year and total fish biomass recorded at each site.

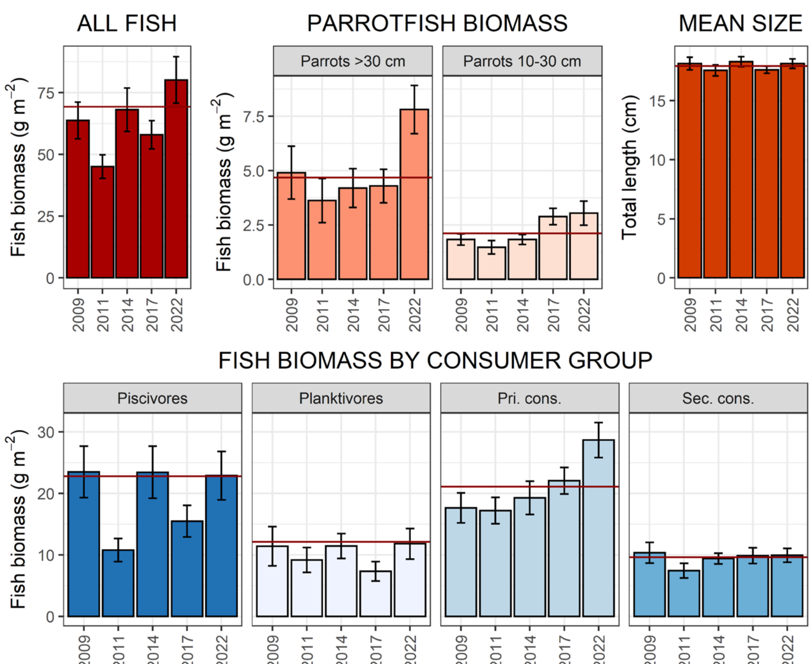

Figure 24. Pagan Island fish plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top) and per consumer group (middle), as well as mean size (TL cm, top). The N. Mariana region mean estimates of fish biomass are plotted for reference (red line).

Alamagan, Guguan, and Sarigan Islands (AGS)

These three islands were combined for analysis purposes due to proximity and small size. Alamagan, Guguan, and Sarigan Islands were surveyed in 2009 (n = 19), 2011 (n = 24), 2014 (n = 33), and 2017 (n = 18). These islands was not surveyed during 2022 due to time restrictions.

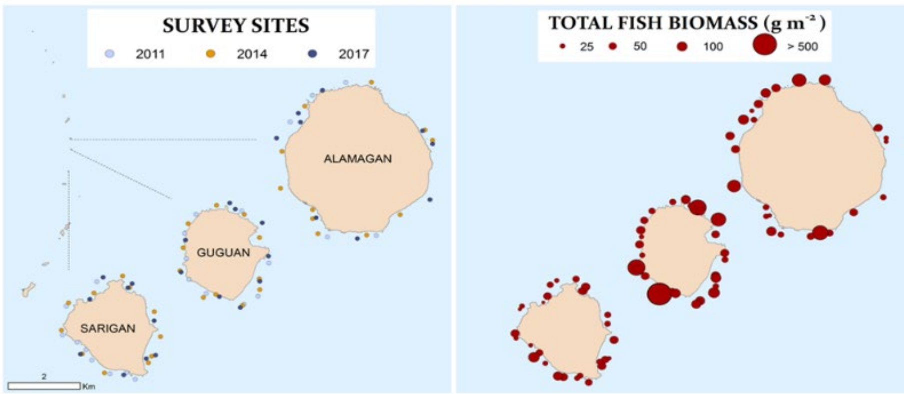

Figure 25. AGS Islands site survey data for 2011, 2014, and 2017. Site location identified by year and total fish biomass recorded at each site.

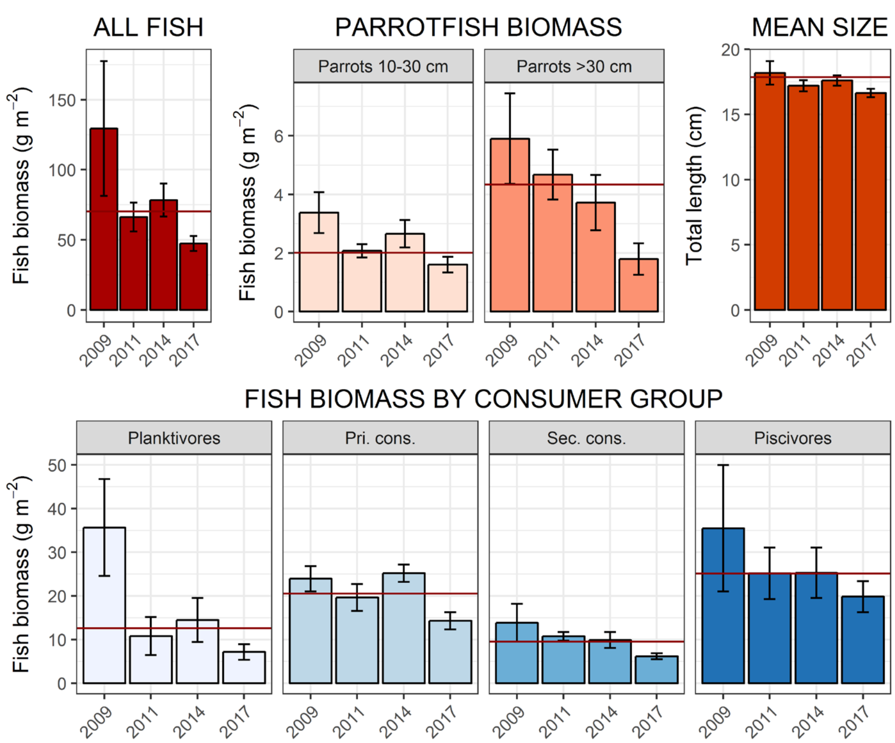

Figure 26. AGS Islands fish and benthic plots. Biomass (g m^{-2} ± SE) of all fishes observed, per parrotfish size class (top) and per consumer group (middle), as well as mean size (TL cm, top) and the percentage cover (± SE) of the benthos. The N. Mariana region mean estimates of fish biomass in 2017 are plotted for reference (red line).

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Appendices

Appendix 1: Surveys per region per year and method used

Table A1. 1. The number of belt transect and SPC sites surveyed per region per year. From 2000 to 2006 the belt transect method was used to survey coral reef fishes. During the calibration period that took place from 2006–2008, surveys were conducted using both the belt and the stationary point count (SPC) method. The SPC data collected prior to 2009 are not used in this report because sites were not selected based on the randomized depth stratified design (see Section: Methods). Furthermore, during the methods transition period, sites surveyed at the mid-depth strata in 2009 were the haphazardly selected, fixed sites selected in the previous years. Shallow and deep sites were randomly selected. Here we report all data from 2009 onwards, including the non-randomized mid-depth 2009 sites. In the future, these mid-depth sites should be excluded from any time series analysis.

Year	**2000-2005**	**2006-2008**	**2009**	**2011**	**2014**	**2017**	**2022**
Region| Method	**Belt**	**Belt & SPC**	**SPC**	**SPC**	**SPC**	**SPC**	**SPC**
N. Mariana	80	36	135	135	148	159	98
S. Mariana	59	60	116	219	198	172	197

Appendix 2: Sector maps

Guam

Guam is subdivided into sectors based on management status (marine preserve or not) and aspect (East or West): thus there are two open sectors: "Guam Open East" (areas outside of marine preserves on east side of Guam); and "Guam Open West." Grouping of marine preserve sites (i.e., whether to pool all into a single 'Marine Preserve' group or break out at a level of some or all individual marine preserves) depends on annual sampling density. Higher sampling density allows for each individual marine preserves to be a distinct sector. In 2014, we pooled MP sites into "Achang MP" (Achang Reef Flat Marine Preserve, due to intensive sampling efforts there) or "Marine Preserve" (being all other areas within Guam's Marine Preserve System; Figure A2.1).

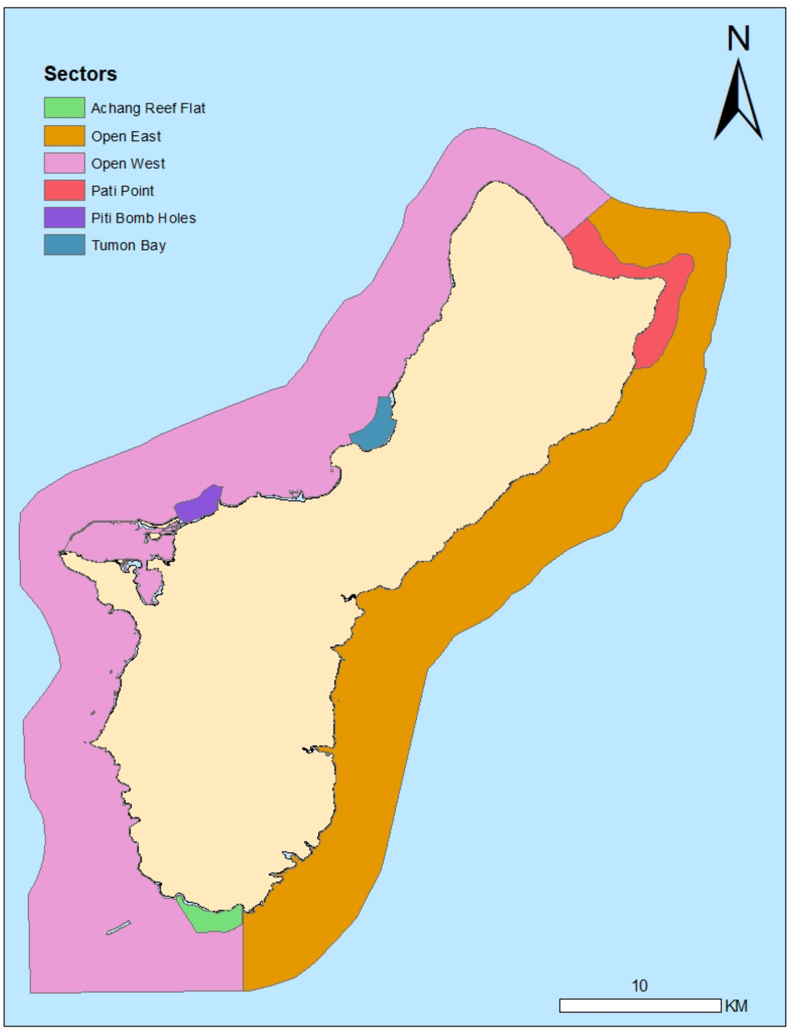

Figure A2. 1. Guam sectors. Sampling is stratified by habitat, depth and the additional sectors based on the pooled marine preserve system, and by the east and west side of the island.

Appendix 3: Samples per sector and strata in 2022

Table A3. 1. The number of sites surveyed per depth strata and the sector used to pool the data in island level parameter estimates. During the site selection process, the sector area from which site locations are randomly drawn for most islands are the islands themselves. In Guam, the island is broken down into smaller sectors. D = deep (>18–30 m), M = mid (> 6–18 m), S = shallow (> 0–6 m).

Region	Island	Sector	Deep	Mid	Shallow
S.MARIAN	Aguijan		6	5	4
S.MARIAN	Guam	Pooled Marine Preserves	14	14	11
S.MARIAN	Guam	Open East and West	17	22	15
S.MARIAN	Rota		5	6	5
S.MARIAN	Saipan		27	19	8
S.MARIAN	Tinian		8	7	4
N.MARIAN	Asuncion		3	9	3
N.MARIAN	Farallon de Pajaros		3	4	2
N.MARIAN	Maug		9	17	4
N.MARIAN	Pagan		18	13	9

Appendix 4: SPC Quality control: observer cross-comparison

Estimates are compared between dive partner pairs to check for consistency between observers. Though this can be done for any parameter estimated, total fish biomass, species richness (number of unique species counted), and hard coral cover estimates are highlighted here. These are three of the most frequently reported summary metrics from the stationary point count survey data. The difference between the estimates of each diver and those of their dive partner at each site is calculated and referred to as diver performance. Real differences between dive partners are expected, as divers survey adjacent, not the same cylinder area. However, if there is no consistent bias in the estimates made by a pair of divers, one would expect the median value of their performance to be close to zero i.e., 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 (1) a strong but general indication of relative bias; if there is no consistent bias, then the median differences between a pair of divers 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), it 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 A4. 1 Mariana Islands 2022).

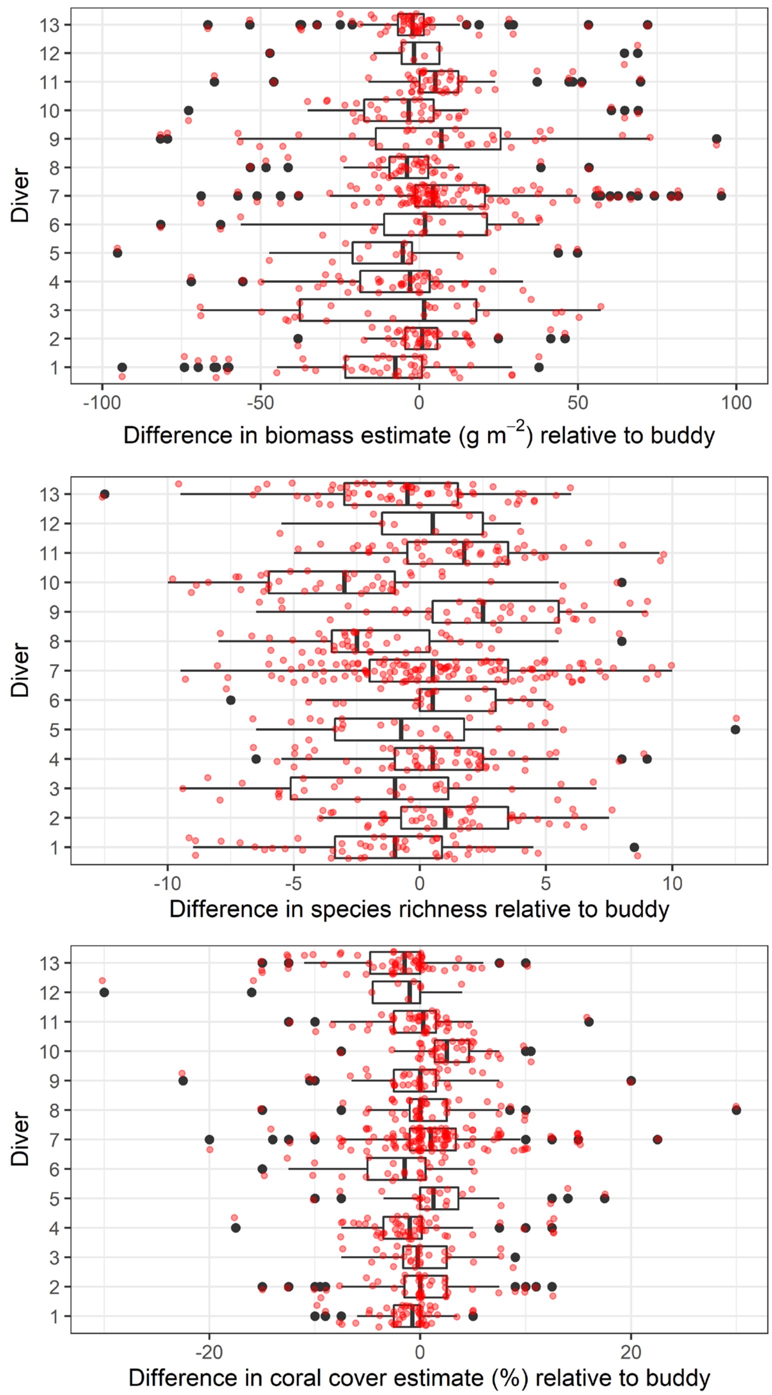

Figure A4. 1. Mariana Islands comparison of observer diver vs. diver partner estimates for total fish biomass, species richness, and hard coral cover during 2022 surveys. The boxplot shows the median difference (thick vertical line) in estimates for each diver. The box represents the location of 50% 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 5: Random stratified sites surveyed at each island per year

Table A5. 1. The total number of sites surveyed per island per year under the depth stratified random sampling design, using the stationary point count method to survey the fish assemblage. AGS = Alamagan, Guguan, and Sarigan Islands pooled

ISLAND	2009	2011	2014	2017	2022
Aguijan	6	13	10	17	15
Asuncion	13	20	21	19	15
Farallon de Pajaros	7	12	11	16	9
Guam	25	133	104	66	93
Maug	21	30	40	38	30
Pagan	21	29	43	40	40
Rota	14	24	28	28	16
Saipan	23	30	48	37	54
Tinian	14	19	19	24	19
Agrihan	14	20	-	19	-
AGS	19	24	33	27	-

Contact us

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: Tye.Kindinger@noaa.gov

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