# American Samoa JCR-FMP: PIFSC ESD analysis

Kurt Ingeman and Tye L. Kindinger

**U.S. DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
National Marine Fisheries Service
Pacific Islands Fisheries Science Center

August 2023

# American Samoa JCR-FMP: PIFSC ESD analysis

Kurt Ingeman[1,2] and Tye L. Kindinger[1]

[1] Pacific Islands Fisheries Science Center
National Marine Fisheries Service
1845 Wasp Boulevard
Honolulu, HI 96818

[2] Cooperative Institute for Marine and Atmospheric Research
University of Hawaii
1000 Pope Road
Honolulu, HI 96822

August 2023

**U.S. Department of Commerce**
Gina Raimondo, Secretary

National Oceanic and Atmospheric Administration
Richard W. Spinrad, Ph.D., NOAA Administrator

National Marine Fisheries Service
Janet Coit, Assistant Administrator for Fisheries

### About this report

The Pacific Islands Fisheries Science Center of NOAA's National Marine Fisheries Service uses the NOAA Technical Memorandum NMFS-PIFSC series to disseminate 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.

### Recommended citation

Ingeman K., Kindinger TL. 2023. American Samoa JCR-FMP: PIFSC ESD Analysis. U.S. Dept. of Commerce, NOAA Technical Memorandum NMFS-PIFSC-146, 1927 p. doi: 10.25923/7f0d-q794

### Copies of this report are available from

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
1845 Wasp Boulevard, Building #176
Honolulu, Hawaii 96818

### Or online at

https://repository.library.noaa.gov/

Cover photo credit: NOAA Fisheries

## Table of Contents

List of Tables iii

List of Figures iv

Executive Summary v

Introduction 1

How do these analyses support the development of the JCR-FMPs 1

Size structure 1

Herbivore biomass and diversity 2

Questions that this report addresses 3

Size structure of priority species 3

Herbivore biomass and diversity 3

Data collection 4

Survey design 4

Reef-fish survey methods 4

Calculating fish biomass 4

Analysis 5

Size structure of priority species 5

Herbivore biomass and diversity 5

Results 7

Size structure among priority species 7

Question S1: What is the overall characterization of species size distribution across American Samoa for the priority species? 7

Question S2: Are there important differences that should be considered between species and their size distributions at various survey depth strata? 8

Question S3: Does the size structure for priority species differ among islands? Is there variability over the jurisdiction (higher populated vs. sparsely populated)? 9

Question S4: Has the size structure of any of the priority species changed over time? 11

Question S5: Are there any direct management considerations (i.e., biomass change without size-structure change or vice-versa)? 11

Herbivore biomass and diversity 12

Question H1: What is the overall spatial distribution of herbivore fish biomass in terms of density and diversity in American Samoa? 12

Question H2: Does herbivore fish biomass and diversity differ among islands? Is there variability across the jurisdiction (higher populated vs. sparsely populated)? 13

Question H3: Has herbivore fish biomass and diversity changed over time? 14

| | |
|---|---|
| Acknowledgments | 18 |
| Literature Cited | 19 |

## List of Tables

Table 1. Priority Species and Species of Special Interest for the American Samoa JCR-FMP. .... 2
Table 2. Herbivore functional groups. .......................................................................................... 6
Table 3. Mean total length of the five priority species reported as being overfished per island in American Samoa. ................................................................................................................. 7
Table 4. Mean herbivore biomass by island. ................................................................... 13

## List of Figures

Figure 1. Size distributions of each of the original priority species for American Samoa. ........... 8
Figure 2. Depth-specific size distributions for representative priority species. .............................. 9
Figure 3. Aggregate size distribution for all priority species combined per island. ..................... 10
Figure 4. Size distribution for two priority species across island population levels. .................... 10
Figure 5. Size distribution through time for a priority species. .................................................. 11
Figure 6. Change in biomass without corresponding changes in size indicators. ......................... 12
Figure 7. Density and biomass per herbivore functional group through time in American Samoa. ........................................................................................................................... 13
Figure 8. Herbivore biomass and diversity (species richness) per island through time. .............. 14
Figure 9. Herbivore density, biomass, and species richness in American Samoa through time. . 14
Figure 10. Herbivore biomass at each island through time. ....................................................... 15

## Executive Summary

This report details the results of a series of analyses conducted by PIFSC staff to support the development of the American Samoa Jurisdictional Coral Reef Fisheries Management Plan (JCR-FMP). These analyses examine (1) status and trends in population size-structure of jurisdiction-specific priority species as provided by the Pacific Islands Regional Office (PIRO) Habitat Conservation Division (HCD), and (2) herbivore fish biomass and diversity.

We compiled size distributions for each of the priority species across the jurisdiction. We found reduced mean size of some species in American Samoa over time and corresponding reductions in the biomass of the largest size classes. Furthermore, we observed truncated size distributions in the highly populated islands compared to the less populated islands. Taken together, these findings suggest the potential for intact size distributions of the priority species in American Samoa to be restored to increase population productivity.

Among herbivore indicators, we found that mean herbivore biomass was somewhat lower in Tutuila compared to Tau and Ofu and Olosega. However, we observed an increase in herbivore biomass over time, a temporal trend that was relatively consistent across the islands of America Samoa. Furthermore, herbivore species richness was similar and temporally constant across the jurisdiction. Lastly, the herbivore functional groups, detritivore, excavator, and grazer, increased to their maximum values by 2018.

While direct assessment of population productivity is beyond the scope of the report, we found indications that American Samoa's reef-fish biomass has increased since 2011. Still, the size structure of particular species remains altered compared to unpopulated regions. These findings serve as a baseline to compare the effects of future management efforts and highlight an opportunity to improve these indicators towards enhancing population productivity of the priority species in American Samoa.

# Introduction

This report details the results of a series of analyses conducted by the staff of NOAA Pacific Islands Fisheries Science Center (PIFSC), Ecosystem Science Division (ESD) support the development of Jurisdictional Coral Reef Fisheries Management Plans (JCR-FMPs) in the U.S. Pacific Territories. The JCR-FMPs represent comprehensive resource management plans for each jurisdiction, focusing on coral reef fishery resources in territorial waters (0-3 nautical miles from shore). These plans are being developed by the territorial resources management agencies, in collaboration with local partners and stakeholders, with support from NOAA Pacific Islands Regional Office (PIRO) and other federal partners.

The overarching goals of the JCR-FMPs are to ensure sustainable nearshore coral reef fisheries in the territories, prevent overfishing, restore overfished species, and protect critical coral reef habitats. Specific targets have been identified to ensure sustainable fisheries of priority species (Table 1):

- Protect 20% of adult females
- Protect 30% of cumulative spawning potential

Various management options (e.g., bag limits, size limits, seasonal closures) were identified by American Samoa as potential tools for achieving these sustainable fisheries targets and sustainably managing priority species in this jurisdiction. Evaluating these proposed management controls in terms of their ability to achieve the targets for priority species is a key step in developing effective JCR-FMPs.

While a comprehensive evaluation of management options is beyond the scope of this report, analyses of existing fisheries-independent data from the National Coral Reef Monitoring Program (NCRMP), formerly known as the American Samoa Reef Assessment and Monitoring Program (ASRAMP), was identified as an important foundational step by providing critical baseline summaries of target populations and identify potential sensitive and relevant indicators of population productivity. The analyses include two broad sections:

- Status and trends in population size structure and size-related indicators toward biological targets for the jurisdiction-specific priority species
- Analysis of herbivore fish biomass and diversity towards ecological indicators of coral-reef habitat quality

## How these analyses support the development of the JCR-FMPs

### *Size structure*

The analysis of population size structure using existing fisheries-independent data from the NCRMP will clarify the present conditions of priority species, an important first step toward evaluating management controls using biological targets. Stock assessment and productivity models that can be used to evaluate management actions (e.g., size limits, bag limits) and their effects on cumulative reproductive potential require baseline population size distributions as important inputs. Nadon (2019) states that size structure and abundance data from fisheries-independent diver surveys are used for spawning-potential ratio (SPR) calculations (a major proposed biological target), and abundance data are used to derive total population biomass estimates for select species.

Further value of this analysis will be to establish a baseline for these important fishery parameters against which to measure possible future changes and, through monitoring, determine how well management actions are working and adapt accordingly (i.e., adaptive management).

### *Herbivore biomass and diversity*

Complex and "healthy" coral reef habitat is essential to maintaining the full carrying capacity of fish populations that support and maximize the sustainability of directed fisheries on priority species. Herbivorous fish are particularly important in maintaining quality habitat, as they forage on algae that can compete for habitat space and limit the recruitment and growth of corals and, consequently, reef fish. Expansive algal growth also contributes to reef degradation, resulting in rubble-type reefs with low rugosity/complexity. This further reduces shelter and habitat space for reef fish and, thus, limits their population sizes. Importantly, overall herbivory rates depend on both total herbivore biomass and the diversity of herbivores due to the complementary nature of various herbivore feeding strategies (Lefcheck et al. 2019).

This project will document the baseline abundance and diversity of herbivorous fishes, providing an important first step toward identifying any potential biomass and diversity thresholds necessary for maintaining healthy coral-reef habitat for healthy reef fish populations. Herbivore information can later be paired with detailed habitat-specific information to further develop thresholds specific to different reef types that occur within each jurisdiction.

**Table 1. Priority Species and Species of Special Interest for the American Samoa JCR-FMP.**

| Priority Species (initial list) | | Species of Special Interest |
|---|---|---|
| *Acanthurus lineatus** | *Lutjanus kasmira* | *Bolbometopon muricatum* |
| *Acanthurus guttatus* | *Monotaxis grandoculis** | *Caranx melampygus* |
| *Acanthurus nigricans* | *Myripristis berndti** | *Caranx sexfasciatus* |
| *Acanthurus xanthopterus** | *Naso unicornis* | *Cheilinus undulatus* |
| *Cephalopholis argus* | *Naso lituratus* | *Epinephelus lanceolatus* |
| *Chlorurus frontalis* | *Sargocentron tiere* | *Pristipomoides zonatus* |
| *Chlorurus japanensis* | *Scarus frenatus* | *Variola louti* |
| *Chlorurus microrhinos* | *Scarus rubroviolaceus* | |
| *Ctenochaetus striatus** | *Scarus niger* | |
| *Epinephelus melanostigma* | *Scarus globiceps* | |
| *Kyphosus cinerascens* | *Scarus oviceps* | |
| *Lethrinus rubrioperculatus* | | |

Identified species were provided by the PIRO Habitat Conservation Division (HCD) when the analyses in this report were conducted (summer 2022). An asterisk denotes species HCD reported as experiencing greater fishing mortality than natural mortality (i.e., an indicator of overfishing). Fishing levels for many of the remaining species are unknown.

## Questions that this report addresses

### *Size structure of priority species*

- What is the overall characterization of species size distribution across American Samoa for the priority species?
- Are there important differences that should be considered between species and their size distributions at various survey depth strata?
- Does the size structure for priority species differ among islands, especially with respect to varying harvest levels (to the degree known)? Is there variability over the jurisdiction (higher populated vs. sparsely populated)?
- Has the size structure for any of the priority species changed over time?
- Are there any direct management considerations (i.e., biomass change without size-structure change or vice versa)?

### *Herbivore biomass and diversity*

- What is the overall spatial distribution of herbivore fish biomass in terms of density and diversity in American Samoa?
- Does herbivore fish biomass and diversity differ among islands? Is there variability across the jurisdiction (populated vs. unpopulated)?
- Has herbivore fish biomass and diversity changed over time? Can any such changes be correlated with the timing of management interventions if effectively enforced?

# Methods

## Data collection

This analysis employs data from the NOAA National Coral Reef Monitoring Program (NCRMP) in American Samoa, formerly known as the American Samoa Reef Assessment and Monitoring Program (ASRAMP), conducted by NOAA PIFSC ESD. Specifically, surveys from 1134 forereef sites (≤ 30 m depth) were compiled across the islands of American Samoa.

While RAMP surveys have been conducted across the U.S. Pacific Territories since 2000, the survey design and monitoring methods were not standardized by national NCRMP protocols until 2010. Thus, we have restricted our analyses to surveys conducted in American Samoa from 2010 onward. Before 2010, the Pacific RAMP used different survey methods and statistical sampling design to assess fish populations, preventing the integration of data in an appropriate and rigorous manner. Surveys were typically conducted in the spring (end of February through early May), except surveys in the summer months of 2018 (mid-June through mid-July).

### *Survey design*

For NCRMP data, site selection and subsequent data pooling are hierarchical, using a stratified random design (StR) to ensure that reefs are surveyed as widely as possible to cover large areas in an unbiased manner. This goal is achieved by splitting the total area of hard-bottom habitat in each island (or sub-island sector for larger islands) into 'strata' based on depth (shallow = >0 – 6 m; mid = 6 – 18 m; deep = 18 – 30 m) and by reef zone (backreef, forereef, lagoon, protected slope). The target number of sites per stratum is determined by proportionally allocating total expected sites based on a weighting factor calculated from the size of the strata and the variance of the target output metrics (e.g., consumer group biomass and total fish biomass).

Summary statistics (e.g., mean and variances) of survey quantities (e.g., biomass) were calculated from the surveys within each stratum. To pool those up into larger units (e.g., island), we weighted each stratum by its relative size (i.e., if a stratum is 50% of the total area for each reporting unit [typically island or atoll] then the weighting factor will be 0.5, and a total of all weighting factors sums to 1. Per-strata mean and variance values were aggregated to a higher level (e.g., to island scale) using the formulas found in Heenan et al. (2017).

### *Reef-fish survey methods*

The number and size of all observable reef fishes (limited mainly to diurnal and non-cryptic species) were estimated using stationary point count (SPC) surveys. At each site, divers conducted simultaneous visual fish counts in two adjacent, visually-estimated 15-m diameter cylindrical plots that extend from the seafloor to the surface or the limit of vertical visibility. Depending on site-specific constraints (e.g., limited visibility), between one and occasionally, up to four cylinders were employed. In the first 5-min period, divers compiled lists of all species observed within the survey, then counted and estimated the size (total length [TL] to the nearest cm) of listed species present within the cylinder over approximately 30 minutes. Heenan et al. (2017) provides full details on SPC survey methods.

### *Calculating fish biomass*

Using the count and size estimate data collected per diver in each replicate cylinder survey, the body weight of individual fish was calculated using length-to-weight (LW) conversion parameters (total and fork length conversions as appropriate). Site-level estimates of abundance and biomass were calculated by taking the mean of the values from the adjacent diver-level counts conducted for each survey.

## Analysis

### *Size structure of priority species*

The overall goals for this section of the analysis were to (1) clarify present conditions (i.e., population size structure) of priority species toward evaluation of management controls using biological targets and (2) establish a baseline for these important size metrics upon which to measure possible future changes through monitoring.

To address these goals, for each of the 30 priority species identified, every observation of the species during the focal research period was compiled. These data were then analyzed at various spatial (i.e., island and jurisdiction) and temporal scales to calculate mean TL, maximum TL, and size quantiles. The size distribution of each species was visualized as both biomass within discrete size bins and continuous size distributions from individual observations. Summaries of these metrics were compiled for each species to evaluate size metrics for:

- jurisdictional populations
- island-scale populations
- groups of islands (higher populated vs. sparsely populated)
- changes over time

### *Herbivore biomass and diversity*

The overall goals of this section of the analysis were to (1) document the current baseline abundance and diversity of herbivorous fish toward identifying thresholds for maintaining healthy coral-reef habitat and (2) identify any “red flag” areas where herbivore biomass appears to be particularly low.

Using the statistical pooling methods described above, the overall herbivore biomass, biomass within functional group, and herbivore species diversity were compiled at the following scales:

- jurisdiction-wide
- per island
- per group of islands (higher populated vs. sparsely populated)

In addition, each metric (at each scale) was summarized per year to evaluate changes through time that may correspond to prior management interventions. Herbivores were subdivided into functional groups following standard NCRMP reporting categories. These include the following categories: grazer, scraper, browser, excavator, and detritivore. The definitions for each of these functional groups are shown in Table 2.

**Table 2. Herbivore functional groups.**

| Functional group | Feeding mode description | Example from jurisdiction |
|---|---|---|
| Browsers | Feed on fleshy and upright macroalgae and associated epiphytic material. | *Naso lituratus*<br>(Orangespine unicornfish) |
| Grazers | Feed intensely on epilithic algal turf (and associated detritus) without removing reef substratum. | *Acanthurus lineatus*<br>(Lined surgeonfish) |
| Scrapers | Consume epilithic algal turf (and associated detritus) and remove *small* portions of the reef substratum. | *Scarus oviceps*<br>(Dark-capped parrotfish) |
| Excavators | Feed on epilithic algal turf (and associated detritus), removing *substantial* amounts of the reef substratum. | *Chlorurus microrhinos*<br>(Steephead parrotfish) |
| Detritivores | Feed primarily on detritus but may occasionally consume turf algae. | *Ctenochaetus striatus*<br>(Spotted surgeonfish) |

Description of herbivore functional groups' feeding modes with an example from the jurisdiction. Epilithic algal turf refers to low-lying algae that grow on hard substrata.

## Results

We compiled size distributions for each of the priority species in American Samoa from 15,615 total observations across the jurisdiction over the survey period. Across all priority species, the mean total length (TL) was highest in 2018 (18.0 cm) and lowest in 2010 and 2015 (15.8 cm).

### Size structure among priority species

*Question S1: What is the overall characterization of species size distribution across American Samoa for the priority species?*

Size distributions aggregated across all 5 survey years (2010, 2012, 2015, 2016, and 2018) varied among priority species across the islands of American Samoa, with many species exhibiting the lowest mean sizes at Tutuila (Table 3). In contrast, the mean TL of each priority species reported as being overfished was substantially higher at Tau and Ofu and Olosega.

For most of the priority species at the jurisdictional scale, large sample sizes provided relatively precise estimates of size indicators (i.e., narrow distributions in Figure 1), except for *Cheilinus undulatus,* which was not frequently observed. Therefore, these data provide a reasonably sensitive baseline from which to compare responses to future management interventions.

**Table 3. Mean total length of the five priority species reported as being overfished per island.**

| | Mean total length (cm) | | | | |
|---|---|---|---|---|---|
| **Species** | **Tutuila** | **Tau** | **Ofu and Olosega** | **Swains** | **Rose** |
| *Acanthurus lineatus* | 14.0 | 16.6 | 15.8 | 16.8 | 18.2 |
| *Acanthurus xanthopterus* | 30.8 | 36.3 | 33.4 | 36.1 | *NA* |
| *Ctenochaetus striatus* | 14.4 | 14.8 | 15.2 | 13.4 | 14.5 |
| *Myripristis berndti* | 17.0 | 18.0 | 18.1 | 19.1 | 13.6 |
| *Monotaxis grandoculis* | 23.7 | 26.3 | 28.5 | 31.1 | 21.1 |

One important caveat to the interpretation of population size structure from these data is that both NCRMP site selection (limited to hard-bottom habitats) and the SPC methodology bias the data toward capturing adults and larger individuals over juveniles, especially for species that undergo habitat shifts across their post-settlement life cycle (e.g., where juveniles occupy mangrove or seagrass habitats). Therefore, comparing these size distributions to data collected by other means is not advised.

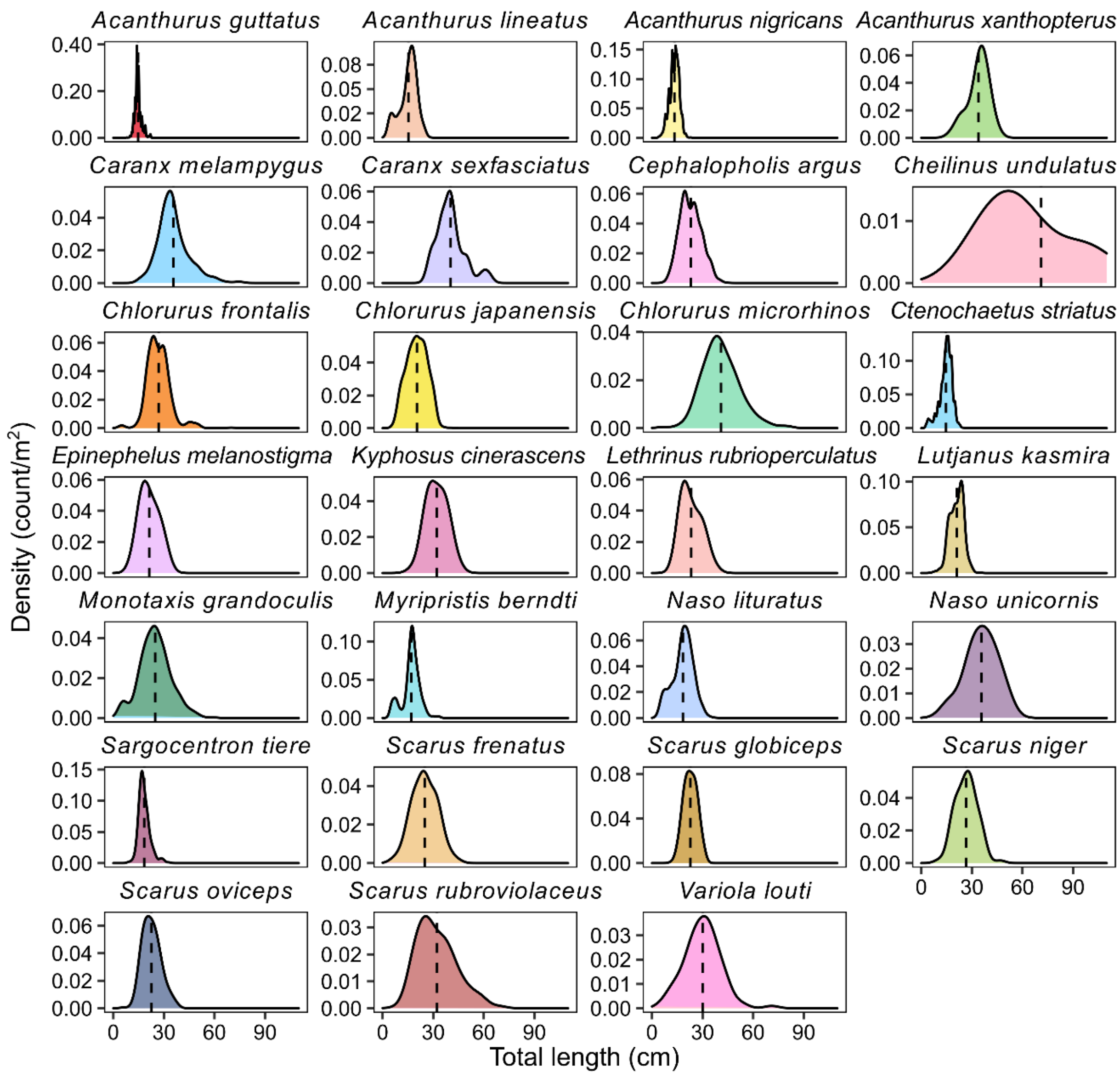


**Figure 1. Size distributions of each of the priority species for American Samoa.**

Dashed vertical lines indicate the mean TL per species. Note that the scales of y-axes differ among plots.

### *Question S2: Are there important differences that should be considered between species and their size distributions at various survey depth strata?*

Several priority species showed clear depth-specific differences in size metrics. For example, *Acanthurus lineatus* and *Epinephelus melanostigma* showed major differences in both mean TL and the overall distribution of large individuals (Figure 2). In both cases, the deeper sites showed substantially higher mean sizes compared to moderate or shallow sites.

However, differences in distributional patterns for these two species may indicate that these depth-specific size differences originate from different mechanisms (Figure 2). In the case of *Acanthurus lineatus*, large individuals occur across depths, and differences in mean TL appear to result from juveniles preferentially occupying shallow habitats. In contrast, the largest individuals of *Epinephelus melanostigma* are only rarely observed outside of deep habitats, potentially indicating a depth refuge for this species.

Regardless of the mechanism, the strong signal of depth in several priority species indicates that this factor is a critical consideration for setting and measuring progress toward any size-based conservation targets and identifying appropriate management interventions.

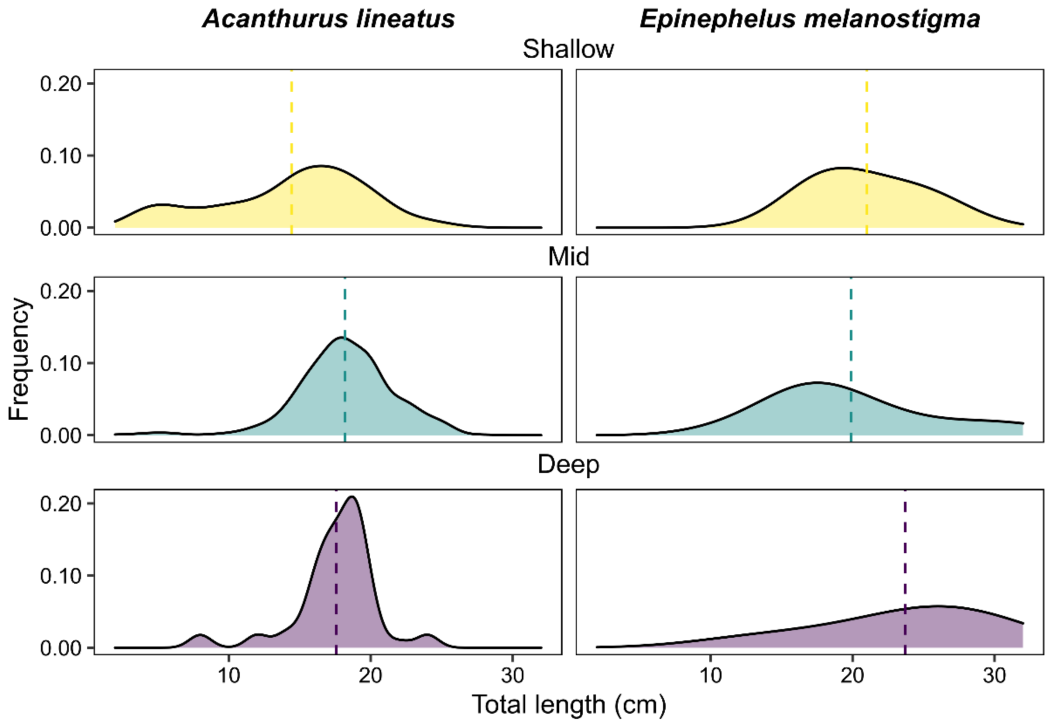


**Figure 2. Depth-specific size distributions for two example priority species.**

Dashed vertical lines indicate the mean TL per species.

### *Question S3: Does the size structure for priority species differ among islands? Is there variability over the jurisdiction (higher populated vs. sparsely populated)?*

There are weak indications of island-specific differences in size indicators when comparing highly populated vs. less populated islands in American Samoa. Within particular species, however, we found indications of larger mean sizes corresponding with lower human populations.

Aggregated across priority species, the mean TL is similar across all islands, except Swains Island, which had a greater proportion of large individuals compared to the other islands (Figure 3). Ranking islands by aggregate size metrics, Tutuila ranked lowest overall, but aggregate size differences among the highly populated and moderately populated islands were minimal.

Taking two examples, *Scarus rubroviolaceus* at unpopulated islands have a substantially higher mean and max TL than at populated islands (Figure 4). In contrast, species such as *Sargocentron tiere* show no such disparities. While the relative intensity of fishing among priority species was not included in this analysis, linking fishing pressure to size disparities among islands merits future investigation. Nevertheless, it is apparent that at least some of the priority species show a truncated size distribution at islands with human inhabitants, with implications for population productivity (see Discussion).

Size distributions according to density and overall mean total length of all priority fish species combined at each island of the jurisdiction.

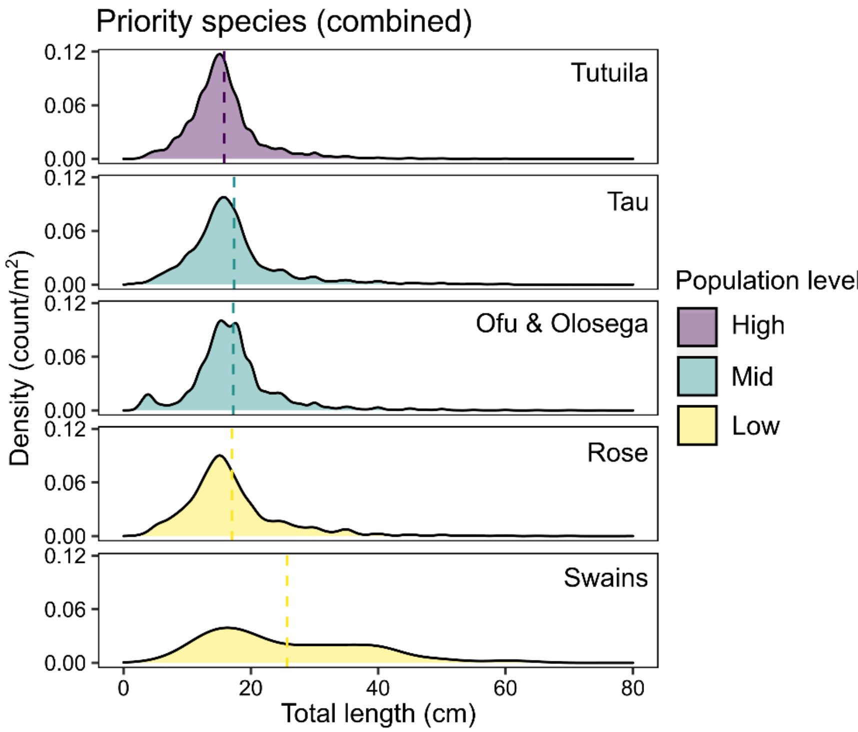


**Figure 3. Aggregate size distribution for all priority species combined per island.**

Colors indicate relative population level. Dashed vertical lines indicate the mean TL.

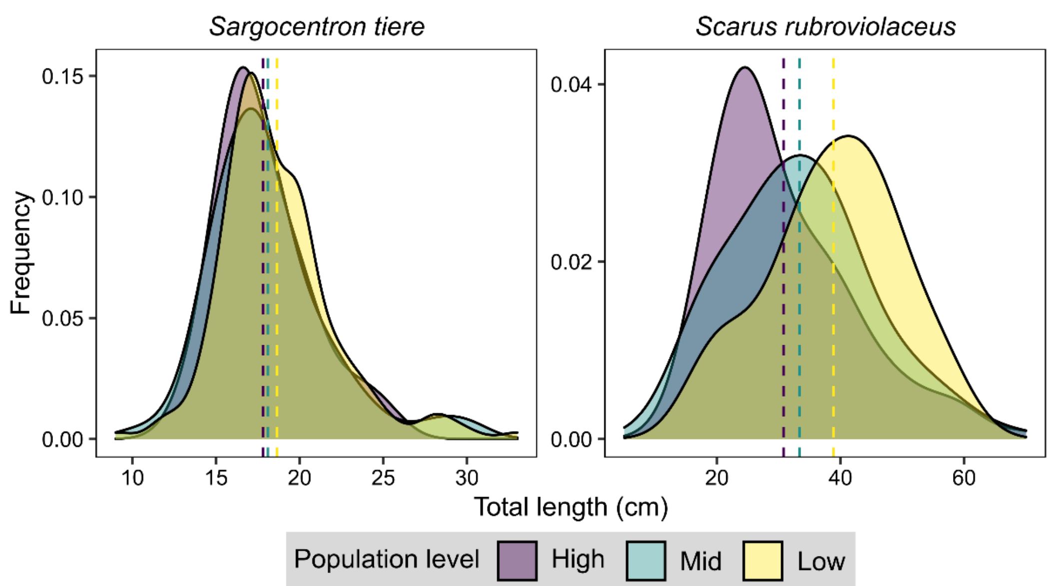


**Figure 4. Size distribution for two priority species across island population levels.**

Colors indicate relative population level. Dashed vertical lines indicate the mean TL. Note that the scales of axes differ between plots.

### *Question S4: Has the size structure of any of the priority species changed over time?*

Aggregating across all priority species, there is no clear evidence of size increases or decreases through time in American Samoa. In contrast, individual species show differences in size distribution over time, with truncated size distributions in 2018 compared with earlier data (2010 –2015).

For example, *Scarus rubroviolaceus* shows a decline in mean TL and an increase in the proportion of biomass from individuals smaller than 20 cm TL through time (Figure 5). Although the overall biomass of the species increased between 2016 and 2018, the biomass represented by individuals >30 cm showed little change, whereas the biomass of small individuals increased disproportionately. As larger individuals provide major contributions to population productivity, this increase in the proportion of small individuals (but not large individuals) could have implications for overall productivity.

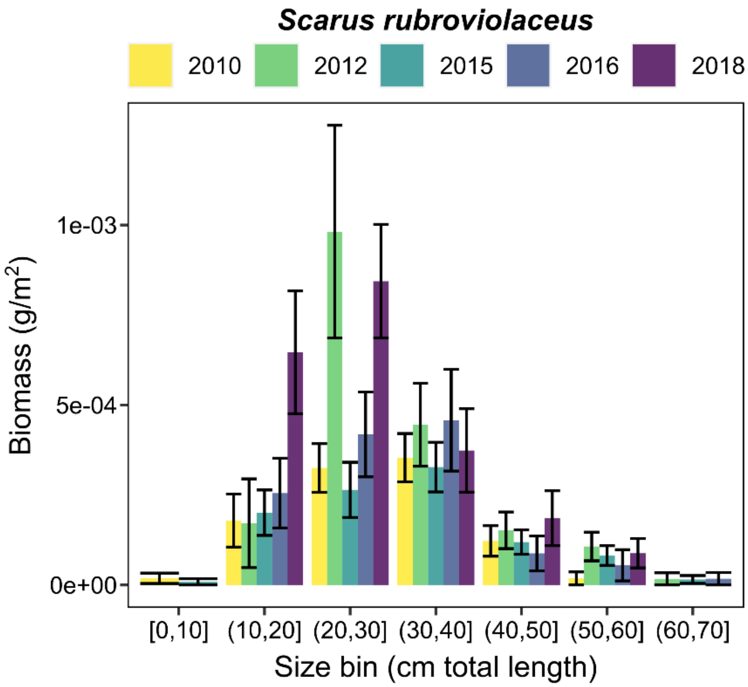


**Figure 5. Biomass of 10-cm size bins through time for a priority species.**

Dashed vertical lines indicate the mean TL. Error bars are the standard error of the mean (SEM). Note that the scales of y-axes differ among plots.

### *Question S5: Are there any direct management considerations (i.e., biomass change without size-structure change or vice-versa)?*

It is important to note that mean TL captures only a single dimension of population health and productivity assessment. Indeed, we observed species with average sizes that remained relatively stable through time but showed important changes in other indicators.

For example, the mean TL of *Acanthurus lineatus* remained largely unchanged from 2010 to 2018 (Figure 6). However, this masked an overall increase in biomass from 2010 to 2018. This result underlines the importance of assessing the effects of management interventions on the health and productivity of priority populations using a diversity of metrics that include, but are not limited to, population size indicators.

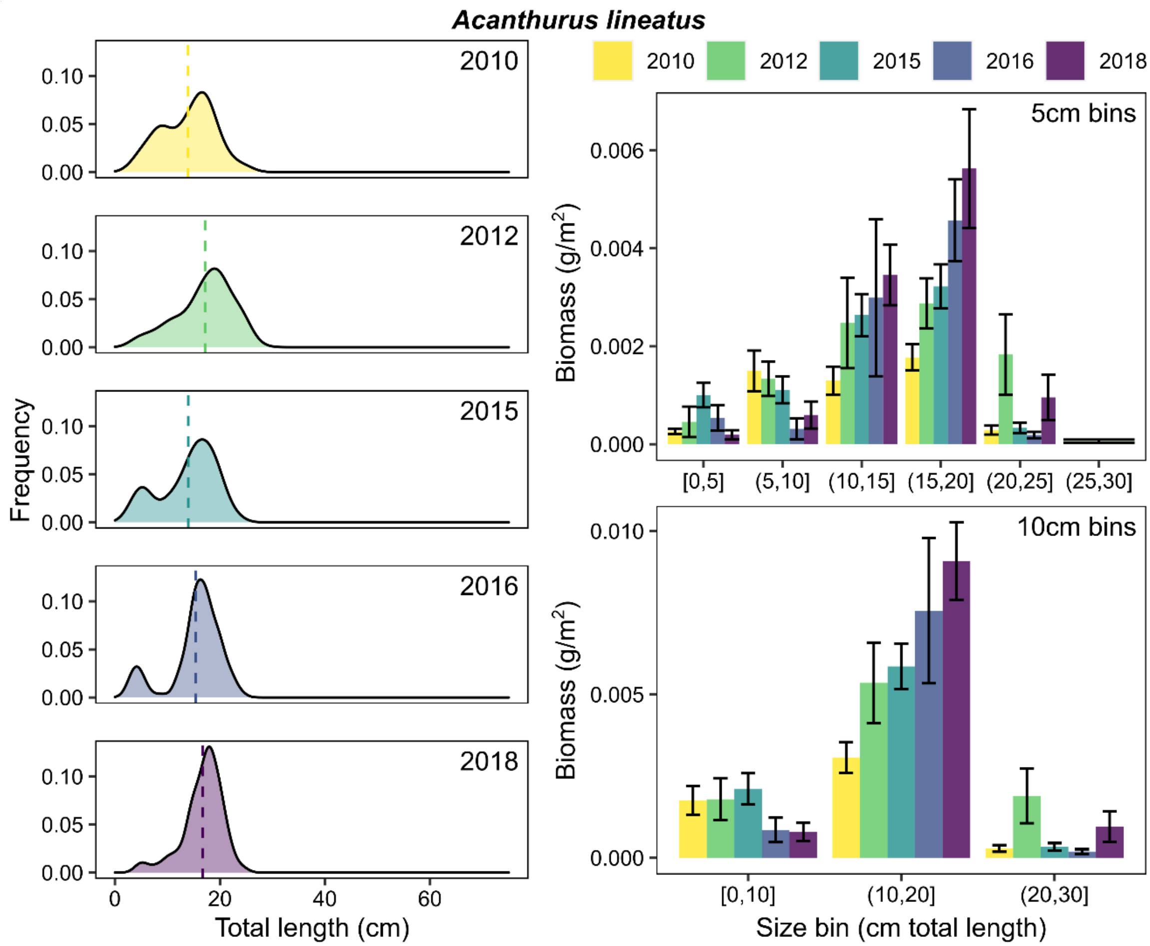


**Figure 6. Change in biomass without corresponding changes in size indicators.**

Dashed vertical lines indicate the mean TL. Error bars are the standard error of the mean (SEM). Note that the scales of axes differ among plots.

## Herbivore biomass and diversity

### *Question H1: What is the overall spatial distribution of herbivore fish biomass in terms of density and diversity in American Samoa?*

Across American Samoa, mean herbivore biomass (averaged across years) ranged from 16.9 g/m$^2$ at Ofu and Olosega to 6.8 g/m$^2$ at Swains (Table 4). Tutuila ranked 3rd among the islands regarding overall herbivore biomass with 11.6 g/m$^2$.

Overall, herbivore density was not distributed evenly among functional groups, with grazers representing the highest proportion of individuals in American Samoa (Figure 7). Across the jurisdiction, grazers, detritivores, and excavators provide similar levels of biomass, whereas scrapers and especially browsers contribute smaller proportions to overall herbivore biomass.

**Table 4. Mean herbivore biomass by island.**

| Island | Mean herbivore biomass (g/m$^2$) |
|---|---|
| Swains | 6.8 |
| Rose | 7.6 |
| Tutuila | 11.6 |
| Tau | 14.1 |
| Ofu & Olosega | 16.9 |

Mean total herbivore biomass averaged across observation years. Islands are ordered (top to bottom) from lowest to highest mean total biomass.

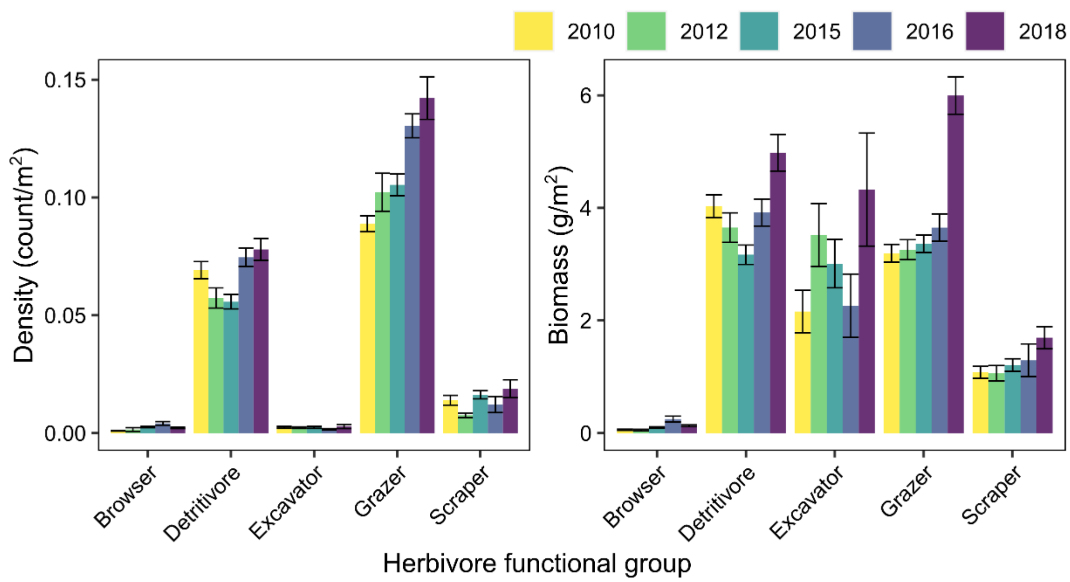


**Figure 7. Density and biomass per herbivore functional group through time in American Samoa.**

Error bars are the standard error of the mean (SEM).

### *Question H2: Does herbivore fish biomass and diversity differ among islands? Is there variability across the jurisdiction (higher populated vs. sparsely populated)?*

There were clear differences in herbivore biomass among islands, but these differences did not align with highly populated versus less populated islands (Figure 8).

While we observed inter-island variability, herbivore biomass was greatest at moderately populated islands, and this distinction remained through time. However, the discrepancy in herbivore biomass between Tutuila and the moderately populated islands diminished by 2018, when Tutuila exhibited the highest mean biomass observed at that island throughout the survey period. Finally, species richness – a less sensitive signal of variance among communities –

showed relatively modest differences among islands, with a less pronounced difference between populated and unpopulated islands.

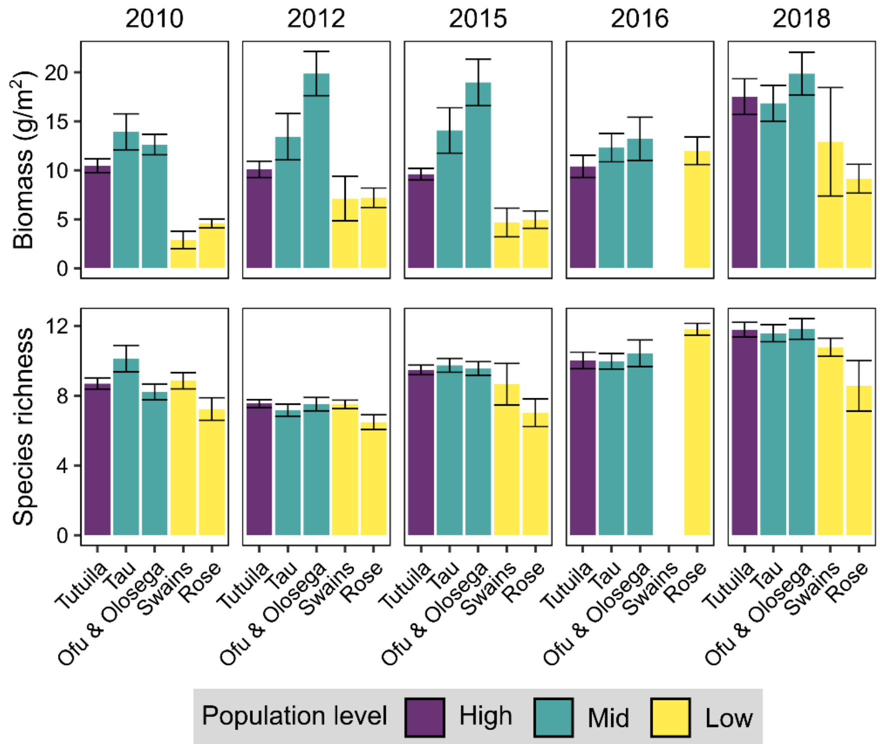


**Figure 8. Herbivore biomass and diversity (species richness) per island through time.**

Islands are color-coded according to relative population level. Error bars are the standard error of the mean (SEM).

### *Question H3: Has herbivore fish biomass and diversity changed over time?*

Across the islands of American Samoa, herbivore abundance, biomass, and species richness were highest in the most recent survey year, 2018 (Figure 8). This increasing trend through time was also consistent at each island assessed except for Rose Atoll (Figure 9).

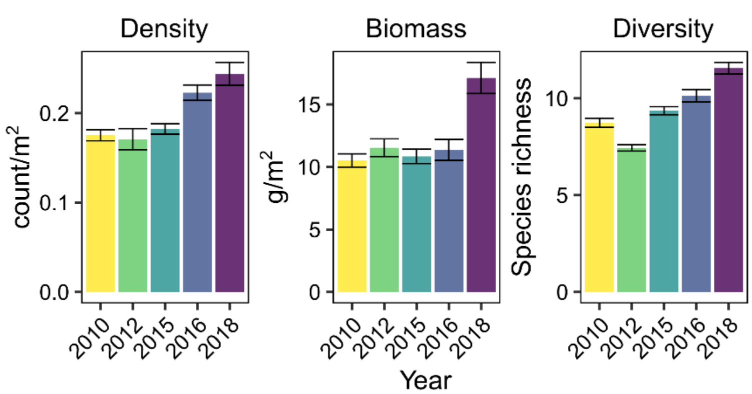


**Figure 9. Herbivore density, biomass, and species richness in American Samoa through time.**

Error bars are the standard error of the mean (SEM).

This increase in herbivore biomass in American Samoa occurred across functional groups, with the highest biomass for every functional,group except for browsers occurring in 2018 (Figure 7). However, the increase in detritivores, excavators, and grazers was most pronounced.

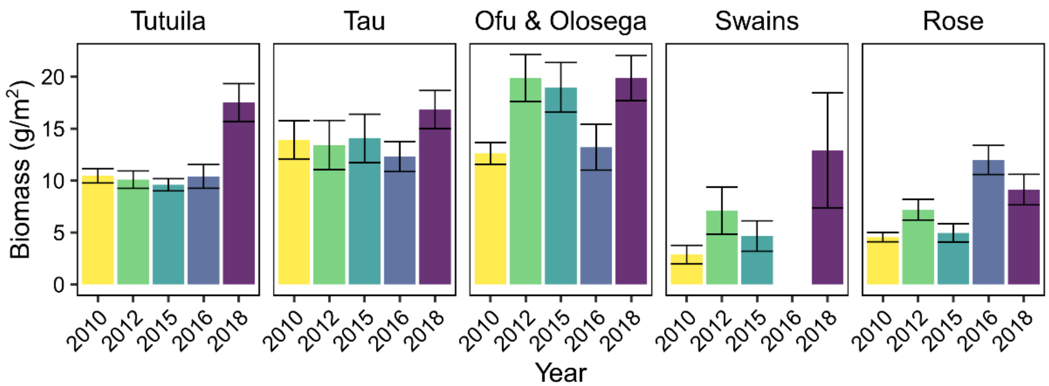


**Figure 10. Herbivore biomass at each island through time.**

Error bars are the standard error of the mean (SEM).

## Discussion

This assessment focused on two primary categories of reef-fish indicators (priority-species size structure and herbivore biomass and diversity) as foundational steps toward evaluating the impact of management interventions on population productivity and habitat quality. While direct assessment of population productivity is beyond the scope of this report, we found indications of important differences in size structure among islands in American Samoa and increases in herbivore biomass through time. This finding represents an opportunity to compare the effects of future management efforts in the populated areas of the jurisdiction to the current baseline, with the corresponding changes in reef-fish indicators at the uninhabited islands serving as temporal controls.

In the first category (size metrics), we found reduced mean sizes of certain reef fish in American Samoa through time and corresponding increases in the biomass of the smaller size classes. Furthermore, we observed truncated size distributions (i.e., missing the largest individuals) at the highly populated islands compared to the less populated islands. These findings suggest that restoring intact size distributions of the priority species in American Samoa may increase population productivity. However, the links between size distribution, population productivity, and particular management controls are complex. While the largest size classes often produce disproportionately more offspring (and higher quality larvae) than smaller mature females across a wide variety of teleost fishes (Hixon et al. 2014), the absolute abundance of medium-sized reproductive individuals means that intermediate size-classes may be responsible for much of the larval replenishment in many reef-fishes (Lavin et al. 2021).

In the second category, we found that mean herbivore biomass was somewhat lower at Tutuila compared to Tau and Ofu and Olosega. However, we observed an overall increase in herbivore biomass over time in American Samoa, a temporal trend that was relatively consistent across the remaining islands. Herbivore species richness was similar and temporally constant across the jurisdiction. Finally, the herbivore functional groups, detritivore, excavator, and grazer, all increased to their maximum mean values of density and biomass by 2018.

Herbivore grazing of marine algae serves as a critical ecosystem function that helps improve coral-reef resilience in the face of various stressors (Graham et al. 2013). Thus, closing the observed gap in overall herbivore biomass between Tutuila and the moderately populated islands represents an opportunity to improve habitat for other coral-reef associated fishes indirectly. Due to the complementarity of herbivore feeding strategies (i.e., targeting different algae growth forms and employing various feeding apparatuses), overall herbivory rates depend on the diversity of herbivores present as well as their density and size. Particularly notable was the increase in reef 'excavators' over time in American Samoa. These large herbivores are critical for their importance in bioerosion and clearing substrate to create settlement habitat for coral recruits (Green and Bellwood 2009). Compared with other territories (data from other regions not included here), the 'browser' functional group was particularly low. This is notable because 'browsers' feed on upright or fleshy macroalgae, and their low abundance and biomass may indicate that fleshy macroalgae remains at low levels across the territory.

Two important caveats should be noted here. First, in evaluating the potential for increased herbivore biomass at the island scale, it is important to consider habitat quality as a driver of – and not merely a response to – herbivore population levels. Thus, comparing herbivore biomass and diversity levels among islands may indicate differences in underlying habitat characteristics and the effects of human activities such as fishing. Second, herbivore populations can increase in response to degradation in habitat with corresponding increases in algae (food resource), so high densities of herbivores may not be an indicator of broader ecosystem health.

## Acknowledgments

This work was funded by the Pacific Islands Regional Office (PIRO) and summarized fish data collected by the Coral Reef Conservation Program (CRCP) National Coral Reef Monitoring Program (NCRMP; CRCP Project #743).

## Literature Cited


Graham NA, Bellwood DR, Cinner JE, Hughes TP, Norström AV, Nyström M. 2013. Managing resilience to reverse phase shifts in coral reefs. Frontiers in Ecology and the Environment. 11(10):541–548. doi:10.1890/120305.

Green AL, Bellwood DR, editors. 2009. Monitoring functional groups of herbivorous reef fishes as indicators of coral reef resilience: a practical guide for coral reef managers in the Asia Pacific region. 2009 edition. Gland, Switzerland: International Union for Conservation of Nature.

Heenan A, Williams ID, Acoba T, DesRochers A, Kosaki RK, Kanemura T, Nadon MO, Brainard RE. 2017. Long-term monitoring of coral reef fish assemblages in the Western central pacific. Sci Data. 4(1):170176. doi:10.1038/sdata.2017.176.

Hixon MA, Johnson DW, Sogard SM. 2014. BOFFFFs: on the importance of conserving old-growth age structure in fishery populations. ICES Journal of Marine Science. 71(8):2171–2185. doi:10.1093/icesjms/fst200.

Lavin CP, Jones GP, Williamson DH, Harrison HB. 2021. Minimum size limits and the reproductive value of numerous, young, mature female fish. Proceedings of the Royal Society B: Biological Sciences. 288(1946):20202714. doi:10.1098/rspb.2020.2714.

Lefcheck JS, Innes-Gold AA, Brandl SJ, Steneck RS, Torres RE, Rasher DB. 2019. Tropical fish diversity enhances coral reef functioning across multiple scales. Science Advances. 5(3):eaav6420. doi:10.1126/sciadv.aav6420.

Nadon MO. 2019. Stock assessment of Guam coral reef fish, 2019. NOAA Technical Memorandum NMFS-PIFSC-82. doi:10.25923/pyd6-7k49.