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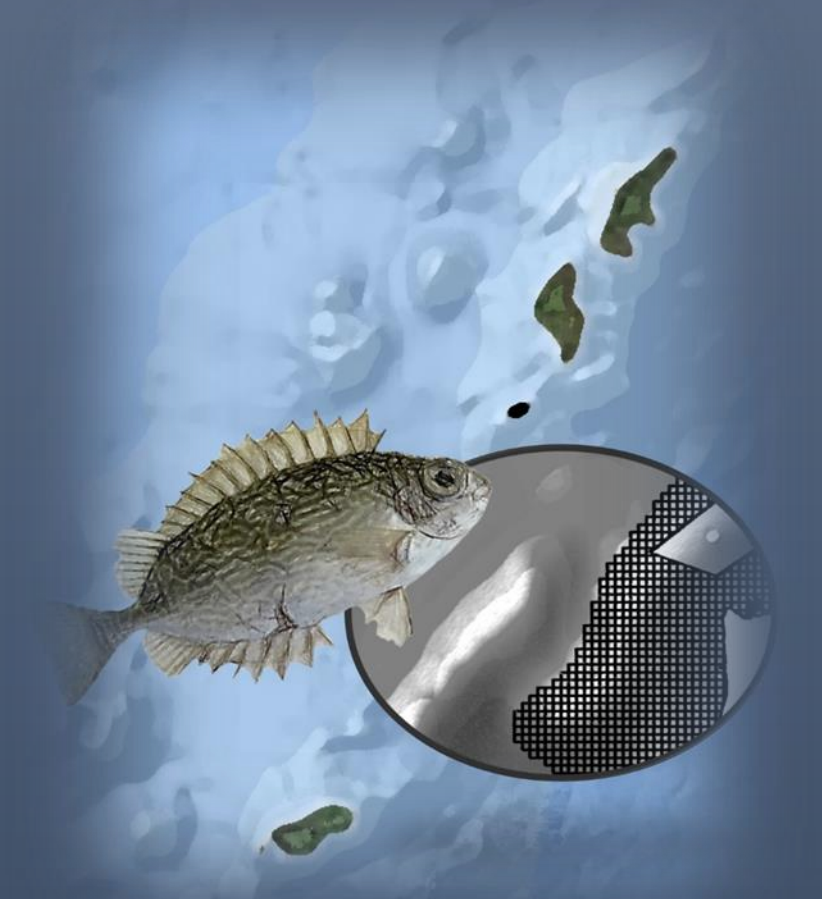

Mapping the Coral Reef Fisheries of the Mariana Islands

AN ATLAS OF CNMI'S REEF FISHERIES

PRODUCED FOR THE WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL

PACIFIC COASTAL RESEARCH & PLANNING | SAIPAN, MP 96950

Mapping the Coral Reef Fisheries of the Mariana Islands

An Atlas of CNMI's Reef Fisheries

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About the Project

In order to better understand the coral reef fisheries of the Pacific Islands region a concerted effort must be made to leverage the knowledge of those who know those fisheries best. Within the setting of nearshore and inshore areas, this means capturing the expertise of local fishing communities. Information gathered from such efforts can be a useful tool for resource users and managers alike, particularly where knowledge is spatially referenced and subsequently rendered compatible with a growing suite of area-based management tools. This project constitutes one such effort. This study and its associated products are intended to supplement existing fisheries data in the Marianas with a range of geographic datasets that were derived from the experiences of the local fishing community. This project was first implemented in 2016 on the island of Guam and then replicated in 2017 in the CNMI on the islands of Saipan, Tinian, and Rota. Using multiple participatory mapping techniques, this project resulted in a wide range of spatial data that tells a geographically explicit story. This report describes the process and outcomes of this process as implanted in the CNMI.

Use Limitations

The results presented in this report and the accompanying *CNMI Reef Fisheries Map Atlas* are intended to provide a general portrait of CNMI fisheries and fisheries-related issues, as understood by resource users. Given the participatory nature of the processes involved in the project, conclusions drawn from the data and maps should take into account the primarily qualitative manner in which information was gathered. Project outcomes and products should not be used for navigation or as a guide in identifying various areas for fishing. The resolution of spatial data on project maps has been intentionally broadened to a resolution that is not intended for policy or litigation at the parcel level (e.g. decision-making within property boundaries), but rather can be used as broader guidance in determining management priorities or areas for further study. Likewise, this product should not be used as a sole resource in making fishery management decisions, as additional fisheries and natural resource data can be leveraged to provide a more comprehensive foundation for understanding the issues facing CNMI's fishing community.

Acknowledgements

Thanks and gratitude are due to the individuals and organizations that provided ongoing assistance and input throughout the duration of this project. Specifically, this project could not have occurred without the support and participation of the members of the CNMI fishing community on Saipan, Tinian, and Rota. Thank you to all those who attended the workshops and provided invaluable feedback and information, particularly those who served as citizen scientists in collecting global positioning system (GPS) data for validation purposes.

Thanks is also due to the government entities who provided data and support to this project including the Division of Fish and Wildlife at CNMI Department of Lands and Natural Resources, the Mayors' Offices of Saipan, Tinian and Rota, NOAA's Coral Reef Conservation Program, the Pacific Islands Fisheries Science Center, Western Pacific Fisheries Information Network, and the Western Pacific Regional Fishery Management Council.

Executive Summary

In 2017 CNMI's fishing community and aquatic resource stewards were engaged in a participatory mapping project to both identify and fill knowledge gaps pertaining to CNMI's coral reef fisheries, specific to the islands of Saipan, Tinian, and Rota. The project consisted of three phases that were designed to weave input from the fishing community with data development and analysis. A mixed-methods approach was taken, using the tools and information that have traditionally been used in quantitative fisheries studies and integrating local and traditional knowledge with them. This approach was implemented in three phases, which included:

Stakeholder engagement and data collection: Creel data that was collected sporadically in the 1980s and 1990s, and more consistently since 2000 and other relevant fisheries information were joined in a geographic information system to identify the spatial coverage of fisheries data and delineate areas that might have potential knowledge gaps. Members of the fishing community and other key stakeholders were identified and engaged through the dissemination of project goals and objectives. Stakeholders were invited to take part in a series of participatory mapping and data validation workshops on each of the three islands as a way of geo-referencing local knowledge.

Data processing and GPS data collection: Data collected from the three initial participatory mapping workshops was edited and processed to match existing geographic boundaries of nearshore fisheries data. Attribution for that data was developed in a manner that would be compatible with existing analytical tools. In addition, GPS units were distributed to a total of 13 citizen science volunteers in order to document boat-based fishing effort over a three month period from June to September. Five fishermen participated on Saipan, three on Tinian, and five on Rota.

Data validation, revisions, and follow-up: Participatory mapping information was further refined through a validation workshop, follow-up discussions, and processing of GPS field data. The participatory GIS data that was developed in the project was used to generate map-based visualizations of various coral reef fishery issues, including accessibility, seasonal species presence, spatial variation in fishing methods and frequency, and geographic distribution of impacts to reef fisheries from a variety of sources. Geospatial products from the project are expected to be a useful tool for members of the fishing community and resource managers in their ongoing stewardship efforts.

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Introduction

Purpose and Intent

If one were to frame first-hand experience and field-based knowledge as the primary metric for understanding issues related to natural resources, then local fishing communities would likely rank far and above any other institution or group of experts. The body of knowledge harbored by resource users, and particularly those who rely on a resource as a primary source of well-being or identity, may be unmatched in terms of breadth and depth. Unfortunately, this knowledge is not always well known to those who manage those resources. In some cases, local or traditional knowledge is simply not transferrable to the frameworks and tools employed by managers. This project is intended to address this issue through the participatory mapping of various aspects of CNMI's coral reef fisheries and fishing effort.

Based directly upon the robust, experience-based knowledge that CNMI's local fishing community offers, the processes, results, and visual output that are highlighted in the following pages aim to communicate information that will supplement existing and future fisheries studies, and the plans and policies that those efforts inform. As a product of community input, this project is also proposed as a tool for CNMI's fishing community to use in conveying a wide range of issues and patterns that may impact their current and future activities. In addition, there is potential for the results presented here to spur further inquiry, as generalizations which are at the core of mapping can raise questions and elevate curiosities around apparent spatial patterns. With these expectations in mind, the following approach and methods were employed.

Project Approach and Methodology

At its core this project was a participatory mapping initiative that assumed that structured discussions about CNMI's reef fisheries could be channeled into a spatial framework and ultimately fill gaps in knowledge. With the dual intent of engaging the fishing community to instill local ownership of project output as well as developing spatial data that would be of use to resource managers, the project was characterized by an ongoing, iterative process in which knowledge was continuously gathered and simultaneously integrated with geographic data. Project phases and milestones are briefly outlined here, but it should be noted that the approach was intentionally flexible to accommodate a more seamless incorporation of stakeholder input with refined datasets.

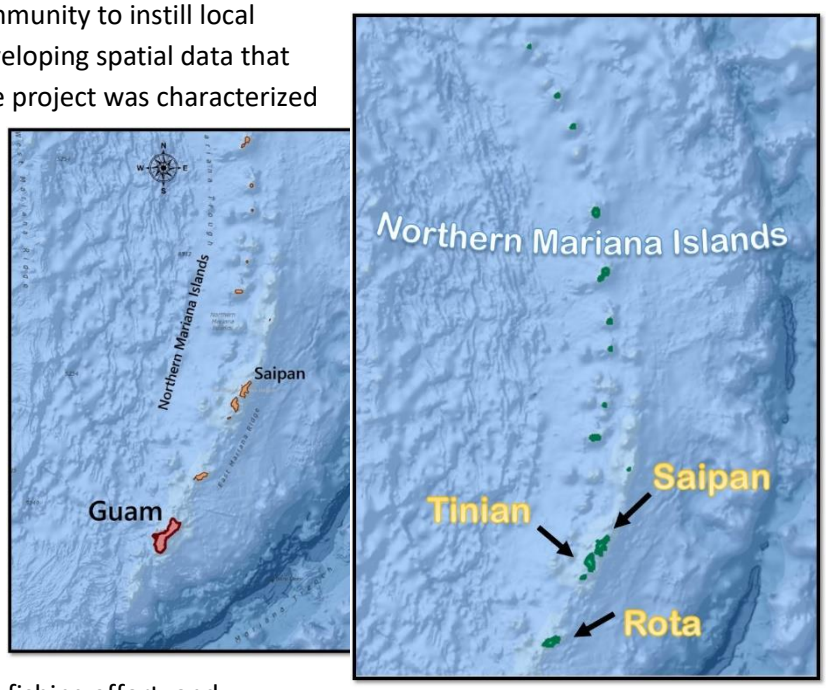

Figure 1: Context map of the Mariana Islands

The first phase of this work centered on stakeholder engagement and review of existing reef fisheries data to better understand CNMI's nearshore and inshore fishing effort, and how the community has been involved in the past. Creel data

that was collected sporadically in the 1980s and 1990s and more consistently since 2000 was provided by NOAA's Pacific Islands Fisheries Science Center. These datasets were linked within a geographic information system (GIS) to examine historical fisheries data and better identify potential knowledge gaps and limitations to that data. This process is detailed further in the next section of this report.

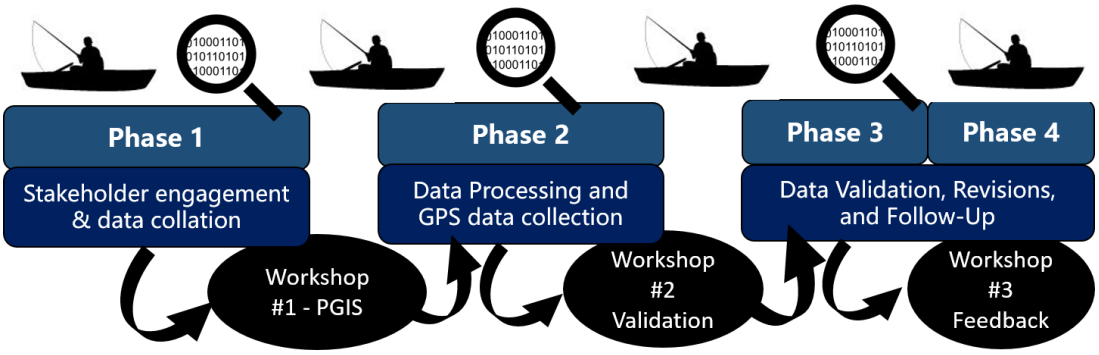

Figure 2: Diagram of project sequence

At this same time members of the fishing community on each of the three islands as well as local liaisons to the Western Pacific Regional Fishery Management Council were engaged in a stakeholder outreach effort. Given the sensitive nature of mapping nearshore fishing grounds that would be, at least in part, accessible to the broader community, awareness of the project was critical. Summaries of the project goals, approach, and intended products were distributed throughout different organizations and entities within the communities, along with invitations to one of three initial participatory mapping workshops that hinged on having sufficient representation from the community. This representation was not conceptualized as *quantity* of participants, but rather as having participants that had comprehensive knowledge of the local reef fisheries and the distribution of local geographies that they represented. In pursuit of the latter, outreach materials and workshop invitations were distributed to key community liaisons, posted at local markets and fishing shops, and provided to the Mayor's offices of each of the three islands.

The second phase of the project encompassed the initial participatory mapping workshop that would serve as the primary means of geo-referencing community knowledge and subsequently processing workshop results as spatial data. This process is described in detail in its own section of the report, however it is important to note that the data collected during this workshop was loosely structured in a manner similar to creel survey data. This was done intentionally in order to ensure that participatory spatial data contained information in a format that is familiar to managers as well as community members that may have been surveyed or aware of survey protocol.

Following the mapping workshop, coarse data and gaps in attribution related to specific fishing areas were filled with detailed notes that accompanied each feature that was mapped. The data was then cleaned to match consistent study area boundaries, and serve as a foundation for incorporating additional feedback throughout the project.

This phase also included the distribution of GPS units to citizen science volunteers. Accompanying field data protocol and instructions outlined the operation and data collection specifications for volunteer fishermen to document their effort over a three month period, roughly centered on the period of June through September. Participatory GIS (PGIS) processing and field data collection occurred concurrently.

The third phase of the project focused on refinement and validation of data. This was accomplished through the presentation of PGIS results to the community members on each of the three islands that were involved in the first mapping workshop, and conducting both live editing and post-processing of the data. This phase also included the processing of citizen scientists' GPS data, and analyzing it with respect to its general alignment with geographic information that was edited after the validation workshop.

Following this refinement process, follow-up discussions were held to identify some of the limitations to this work from the fishing community's perspective, and derive topics or threads of research that might be of use as supplemental work in the future. A final presentation of results to participants was given, followed by any remaining changes or revisions that were requested.

Through this iterative approach it is expected that the data and maps resulting from this project reflect with reasonable accuracy the input that members of the fishing community graciously offered. Details regarding the work and results of each phase are detailed in the following sections of the report.

Creel Data and Spatial Gaps in Fishery Information

Given that a primary driver of the project was to fill geographic gaps in reef fishery information, a cursory examination of existing reef fisheries data for CNMI was necessary. The most cohesive set of data available for this project existed in the CNMI's creel surveys and data collection program. While this program has led to a fairly significant amount of reef fishery information over the last couple of decades, this material has rarely been organized or examined through a spatial lens. Application of such a lens was precisely what was needed to begin an assessment of data gaps. This was accomplished by linking the boundaries of CNMI creel survey zones and interview points with survey records pertaining to both participation and species, and developing thematic maps to understand the relative configuration of where data has been coming from. The survey data, linkages to spatial information, and resulting map-based observations of information gaps are summarized here.

Creel data was obtained through the Pacific Islands Fisheries Science Center (PIFSC) and CNMI Division of Fish and Wildlife (DFW), the latter of which manages the creel data collection program for CNMI. The purpose of the boat-based creel data collection program has been to quantify fishing participation, effort, and catch originating with vessels in CNMI's waters through survey and analytical applications, and ultimately establish a long-term historical database of species caught through boat-based methods. Similarly, the shore-based creel program aims to estimate the total annual shore-based participation, effort, and harvest of CNMI's inshore fisheries, establishing a robust source of historic reef fisheries data. While the resulting datasets are substantial, there have been issues given inconsistent allocation of time, expertise, and resources during the implementation of the programs.

Boat-based (BB) data collection began on Saipan in 1988, but data from the first eight years (through 1996) was excluded from this project's examination of data due to a lack of standardized methods. Shore-based (SB) data collection on Saipan was active in 1984, and from 1990-1994, though methods were not standardized and surveys were terminated due to limited resources. Due to lack of funding, no data collection occurred from 1994 until it began again in April 2000. Data processing also began in 2000 and was assisted by the Western Pacific Fisheries Information Network (WPacFIN). Data collection and processing has been more consistent over the past decade.

To provide geographic context for this information, all BB survey points, BB fishing zones, and SB survey zones were digitized in a GIS using existing data such as geo-referenced location names, prominent boat access features identified in satellite imagery, and map images provided by WesPacFIN and NOAA (Figure 3 through Figure 6).

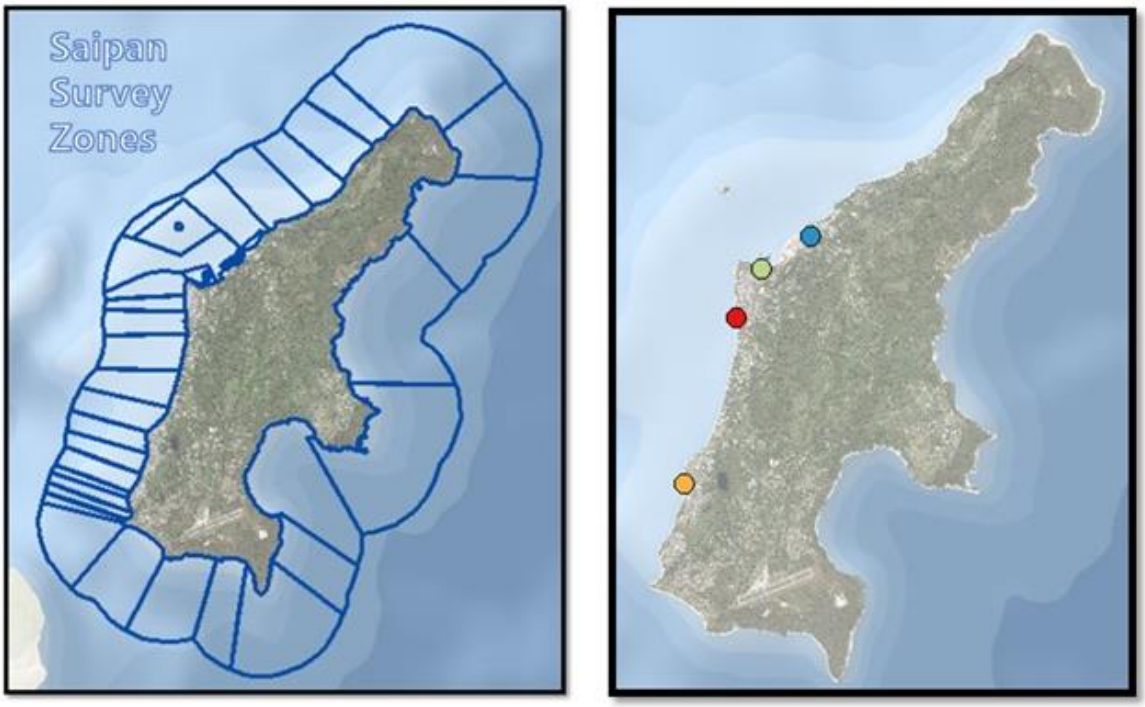

Figure 3: Saipan creel survey locations, shore-based (zones, left) and boat-based (points, right)

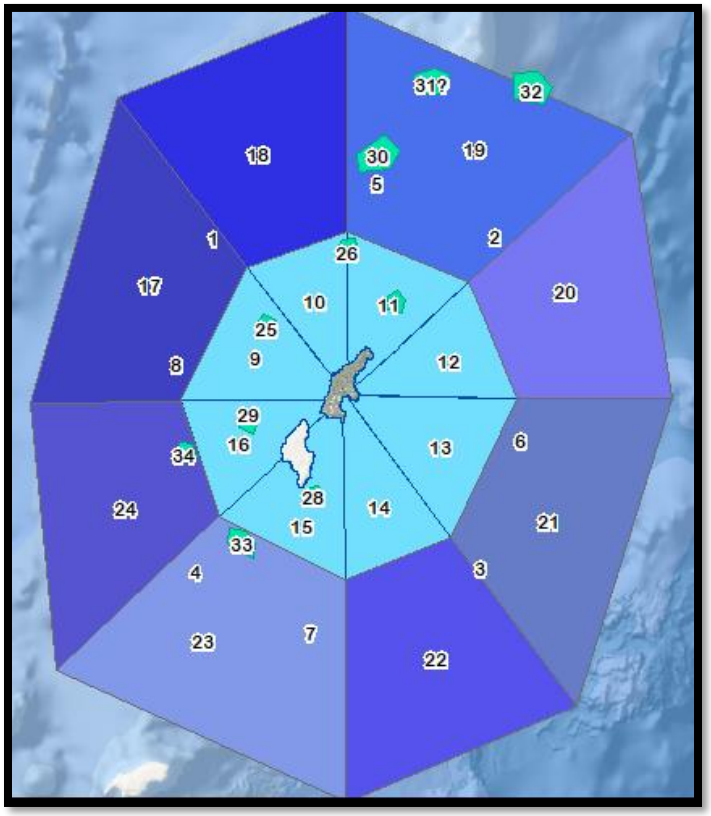

Figure 4: Saipan boat-based fishing zones, digitized in GIS.

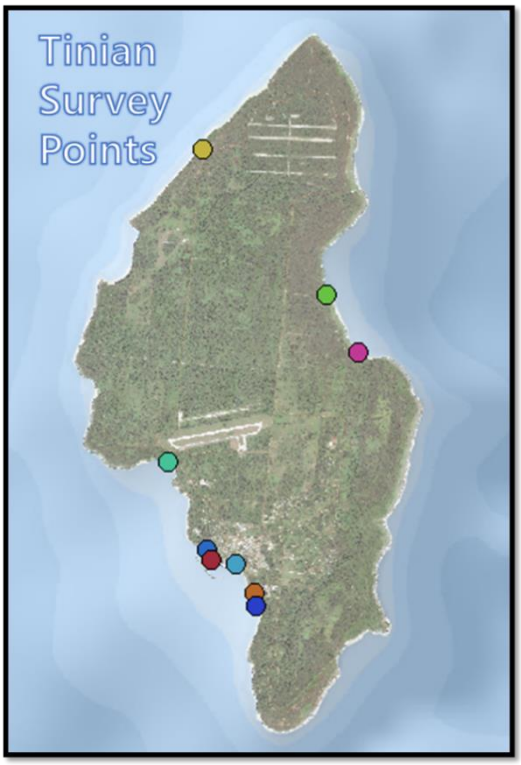

Figure 5: Shore-based survey locations on Tinian

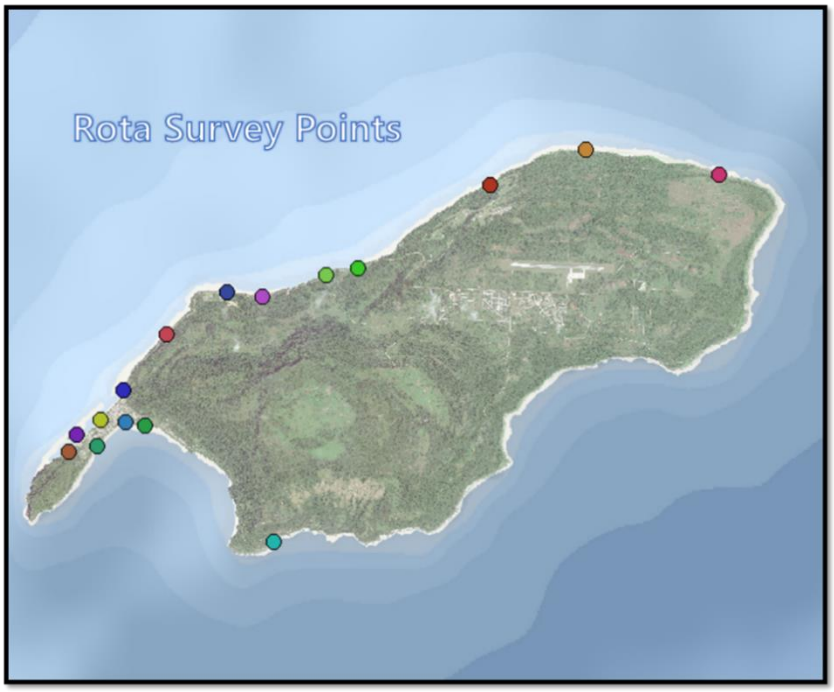

Figure 6: Shore-based survey locations on Rota

Creel data tables were imported into the GIS environment and query tables were built to join the spatial features with the creel data. Priority species for each island were selected from the tables, and exported into individual spatial datasets. To assist in visualizing a broad overview of the creel data collection, summary statistics were used to provide total catch (kg) per survey zone and point, and total sum of surveys by survey zone and point.

Spatial Gaps in Data

Saipan's SB survey zones encompass the entire island (Figure 7), extending approximately 4 km offshore, but very few surveys were collected on the eastern side of the island (Figure 8). Therefore species, methods used, and catch are largely unknown for this area.

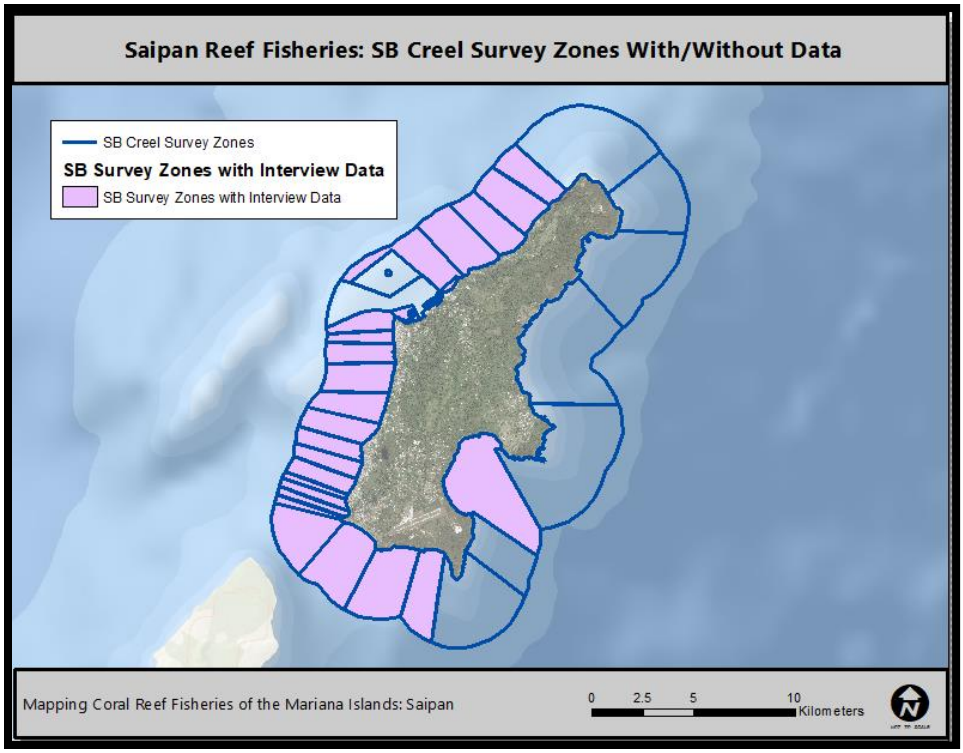

Figure 7: Saipan shore-based creel survey zones, with and without interview data.

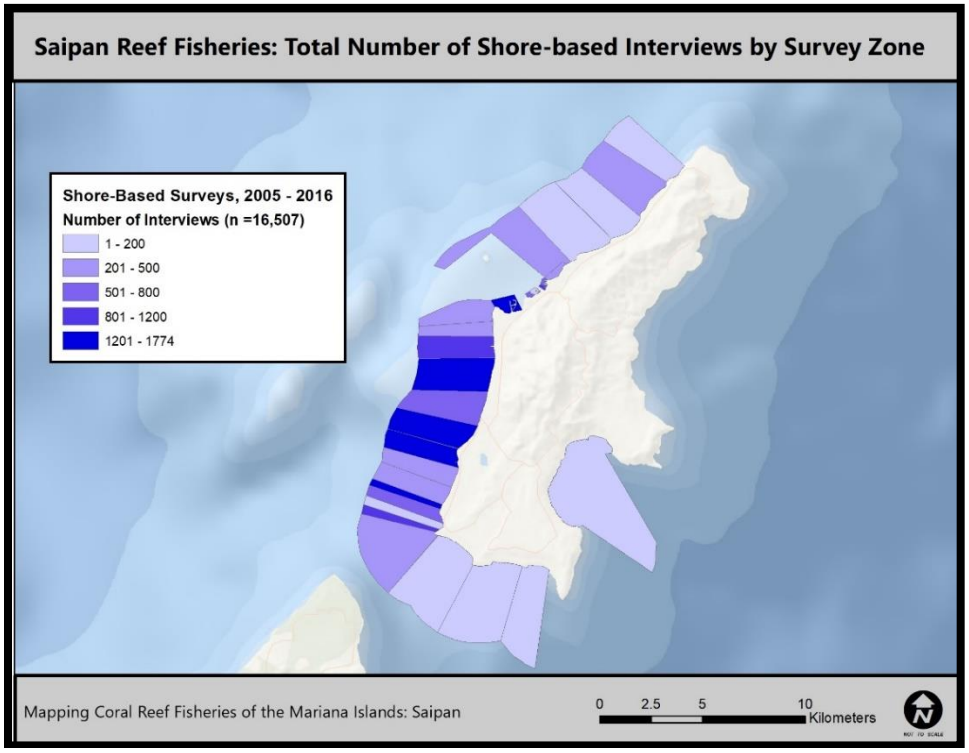

Figure 8: Total number of Saipan shore-based interviews by survey zone.

Similarly, large areas of both Tinian and Rota went un-surveyed, such as the south-eastern side of Rota and the mid-western side of Tinian. For Rota and Tinian, the largest proportion of interviewing occurred near the ports and largely excluded areas that were difficult to reach due to lack of roads or difficult terrain (Figure 9 and Figure 10.

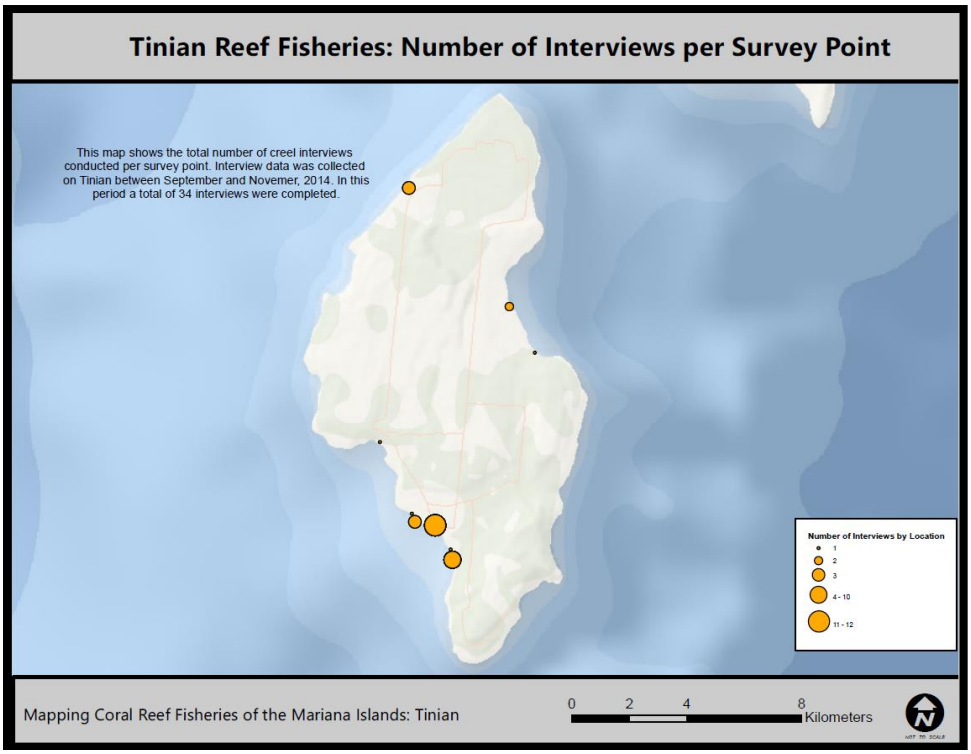

Figure 9: Total number of Tinian shore-based interviews by survey point.

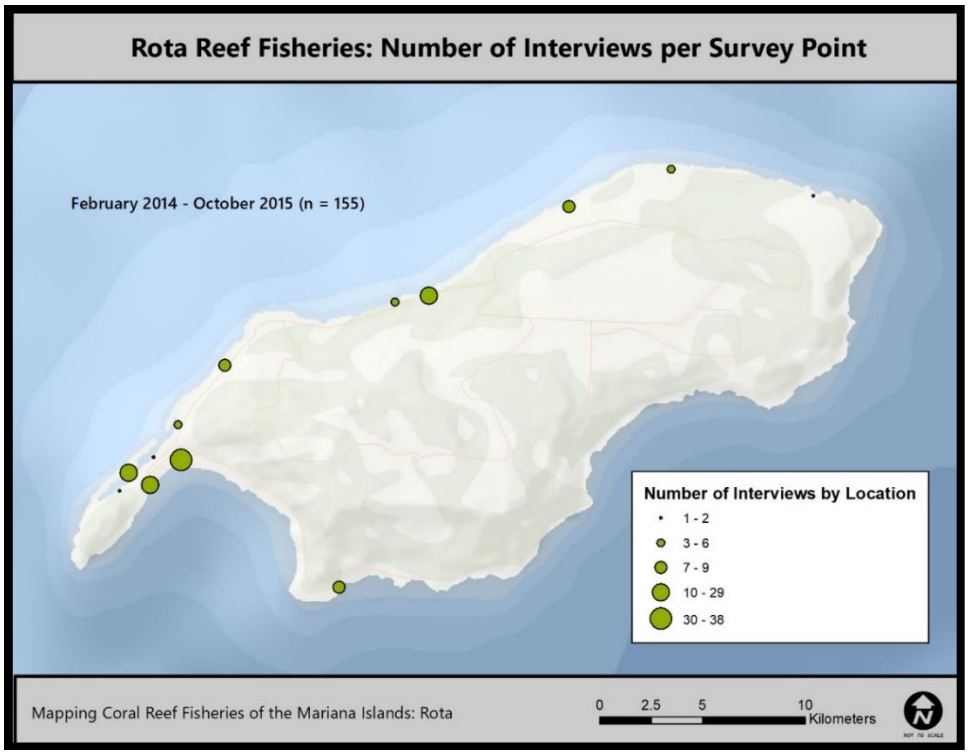

Figure 10: Total number of Rota shore-based interviews by survey point.

Workshop interviews conducted during this project; however, highlighted the prevalence of fishing in some of these hard-to-reach areas. For Saipan, interview surveys were most prominent in the central lagoon and less so in the south and the north portions of that feature, but interview data suggests that these less centralized areas are regarded as prime fishing spots. Additionally, as described in the creel data methodology, interviews are intended to occur representatively throughout the day. However, only 913 of 16,538 Saipan shore-based interviews, or 5.5%, occurred between 9:00 pm and 5:00 am, indicating that a significant portion of the community's nighttime effort may be unaccounted for.

Boat-based data, collected only on Saipan, included surveys conducted at six established boat launches: Sugar dock, Smiling cove, DFW, Fishing base, Charlie seaplane ramp, and Tanapag. Almost all of these surveys were performed at Fishing Base, Smiling Cove, and Sugar Dock, with only 9 out of 24,902 of the total surveys conducted at one of the other three locations. Both the Seaplane Ramp and Tanapag were omitted completely from the BB data. Smaller vessels and paddled watercraft launching from beaches are not captured in the BB data (Figure 11).

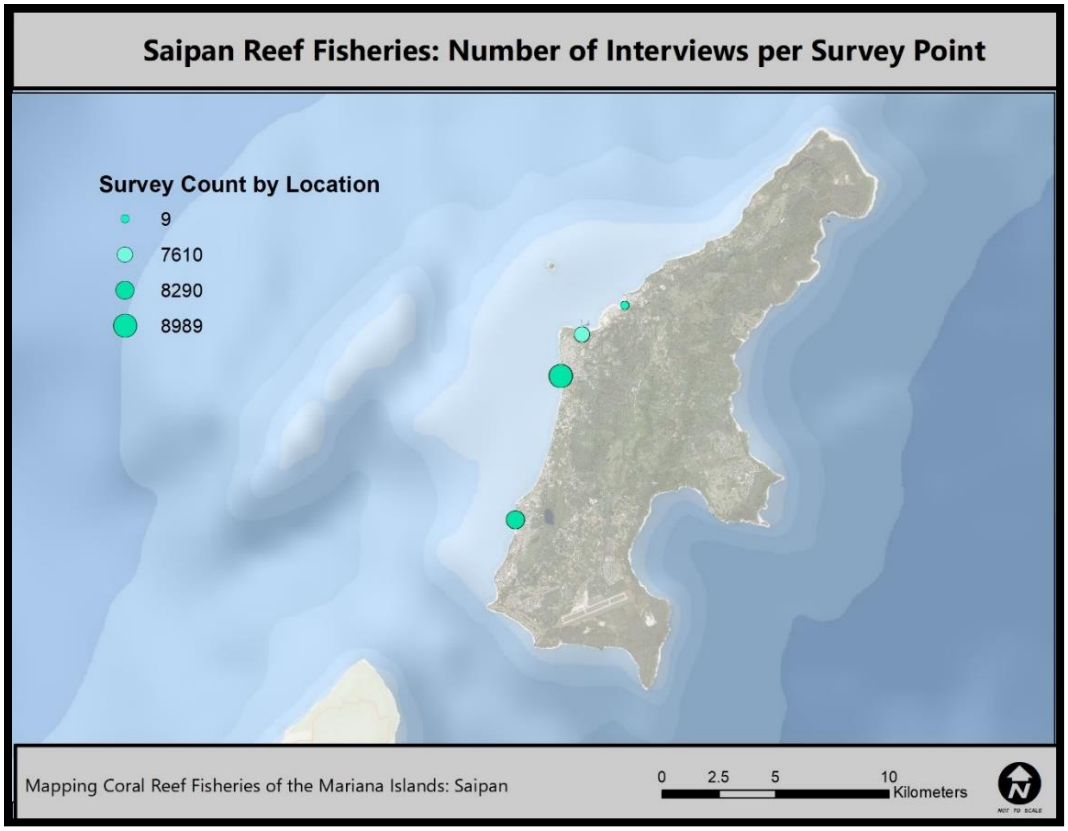

Figure 11: Total number of Saipan boat-based interviews by survey point.

For the purposes of assessing geographic distribution of BB fishing, the use of BB zones was slightly more helpful, though the zones were relatively large (beyond the extent of depth contours defining Saipan's reef fishery), and boundaries were drawn in a manner to maintain quadrants and equal sub-divisions of these zones, though not necessarily reflect the coverage or route of typical fishing trips (Figure 4). Additional information regarding the collection of data that reflects actual BB fishing spatial patterns is discussed in later sections of this report (see Citizen Science and Field Data Collection).

Saipan SB data that was processed and analyzed includes interview and participation surveys from May 2005 to December 2016. Boat-based interview and boat log data was available for Saipan, dating from April 2000 to November 2016. The resulting maps can be found in Appendix A of this report (Figure A-1 through Figure A-10).

Data from Rota and Tinian was collected as part of a pilot project in 2014-2015 to determine whether long-term surveying in these communities is feasible. Rota SB data includes data from February 2014 to October 2015, and Tinian's SB data is confined to the limited period from September 2014 to November 2014. The data from these trial survey studies was processed under this project and is represented in the creel maps for Tinian and Rota found in Appendix A (Figure A-11 and Figure A-12 for Tinian, Figure A-13 through Figure A-18 for Rota).

Because of this limited amount of data for Tinian and Rota, there are limitations to what can be extrapolated from such short-term data. For example, only a single priority species is noted in the Tinian data, and only five of the ten priority species are present in Rota data. Additionally, boat-based efforts were not captured for either of these islands. Shore-based survey points also left large areas of each island unattended, indicating the potential for large data gaps and inaccurate representations of fishing effort. Regardless of these limitations, creel data from all three islands is useful in gathering general observations regarding overall catch and locations where there may be high concentrations of priority species harvested.

Participatory Mapping

Initial Participatory Mapping Workshops were held on each of the three primary CNMI islands: Tinian was held on May 31, 2017, Rota was held on June 9, 2017, and Saipan on June 17, 2017. Given the potential merits of various participatory mapping techniques (NOAA Office for Coastal Management, 2015), the workshop was designed to include both a facilitated participatory GIS (PGIS) exercise using digital whiteboard technology (E-Beam) and printed mapping (hard copies). This allowed for both direct (digital whiteboard) and indirect (paper maps) translation of fishermen input and contributions related to fishing effort into spatial data. A total of 31 fishermen attended these initial workshops. Sixty-eight unique fishing areas were mapped in the PGIS exercises, with 19 fishing zones for Rota, 24 for Tinian and Aguigan (Goat Island), and 25 for Saipan. Data related to fishing frequency, gear type, access, species, habitat, and issues of concern were captured for each of these areas. Detailed notes were taken during this process with a note taking template that matched the fields and attribute scheme of the GIS features. These notes were cross-referenced with the GIS data that was captured during the workshops, helping to validate the live capture of attribute information during the facilitation and mapping processes.

The hands-on mapping component of the workshop involved the use of printed base-maps of each island, including inset and detail maps illustrating particular portions of the coast that were identified by members of the fishing community as focal points. Print maps resulted in 106 unique polygons across all three study areas. Upon digitizing this information, much of the data involved overlap with the digital results, requiring further processing to merge the digital and print map results. Similar attribution for these areas was captured in a "notes" section on the printed base maps.

Printed Mapping, Digital Data Capture, & GIS

Workshop exercises attempted to mesh a semi-structured discussion around fishing effort and concerns with real-time spatial data capture. Two facilitators were responsible for (1) leading discussion and assisting participants in sketching fishing areas on an interactive digital map; and (2) editing the attribution for each

sketch in a GIS and manipulating the interactive map. Discussions about each sketch or fishing area were structured to match the themes and categories discussed in the following pages.

While the participatory mapping workshops captured 174 distinct features, many of these were redundant in terms of duplication between digital and paper mapping. In other cases there simply wasn't enough information recorded for the feature. Additional features referenced "special issue" areas, with a focus on limitations to access/property boundaries, sources of land-based pollution, hazardous seas, and multi-use conflict or high boat traffic. These themes were added as values within a separate "issues" field in the feature attribution.

The spatial data fields that were developed for real-time data capture during the PGIS exercises were analyzed for comparative potential to existing creel data. Additional fields and attribute values were added to allow for matching categories within the two spatial datasets. This development of comparable domains is intended to provide spatial data in a format familiar to managers and the fishing community but not necessarily to encourage detailed comparative analysis between creel and PGIS data, which are built on very different survey mechanisms and data capture platforms.

Print base-maps and their features were manually digitized and features were edited to match the PGIS results. Attribution for printed map polygons were derived from the hard-copy input (participant notes on print base maps) as well as any PGIS polygons that either contained or overlapped more than ~80% of the print polygon feature. For example, a printed base map feature might encompass 90% of Laolao Bay, so the print map polygon for that feature would derive benthic characteristics and fishing effort attributes from the PGIS feature for Laolao Bay.

Both print and PGIS features were edited and "cleaned" to be consistent with high resolution shoreline data for each island and the 150-meter depth contour, which participants had suggested as an applicable cutoff for most bottom-fishing activities in their boat-based trips. Please note that on Tinian, at the request of the workshop participants, the study area for pelagic fishing extended past the 150-meter contour in order to include Fish Aggregating Devices (FADs). Following the assumption that fishing does not occur within no-take CNMI Marine Protected Areas (MPAs), MPA polygons with no-take restrictions were used to erase the portions of each fishnet that overlapped with the MPAs.

The cleaned results of both PGIS and print-based mapping served as the basis and foundation for final project output and spatial data. The original fishing zone polygons and associated attribution derived from workshops were referenced to a 250-meter resolution grid of polygons, referred to herein as a "fishnet". This step essentially transferred all mapping workshop data into a consistent grid, therefore obscuring the specific and potentially sensitive boundaries of fishing zones that participants had drawn and allowing all workshop information to be contained within a single feature class.

The fishnets developed for Saipan, Tinian, and Rota cover the entire study area out to the 150-meter depth contour and serve as the final geospatial data format for the project's participatory mapping information. The fishnets provided a consistent medium for ongoing revisions and are illustrated in the maps on the following pages (Figure 12 through Figure 14).

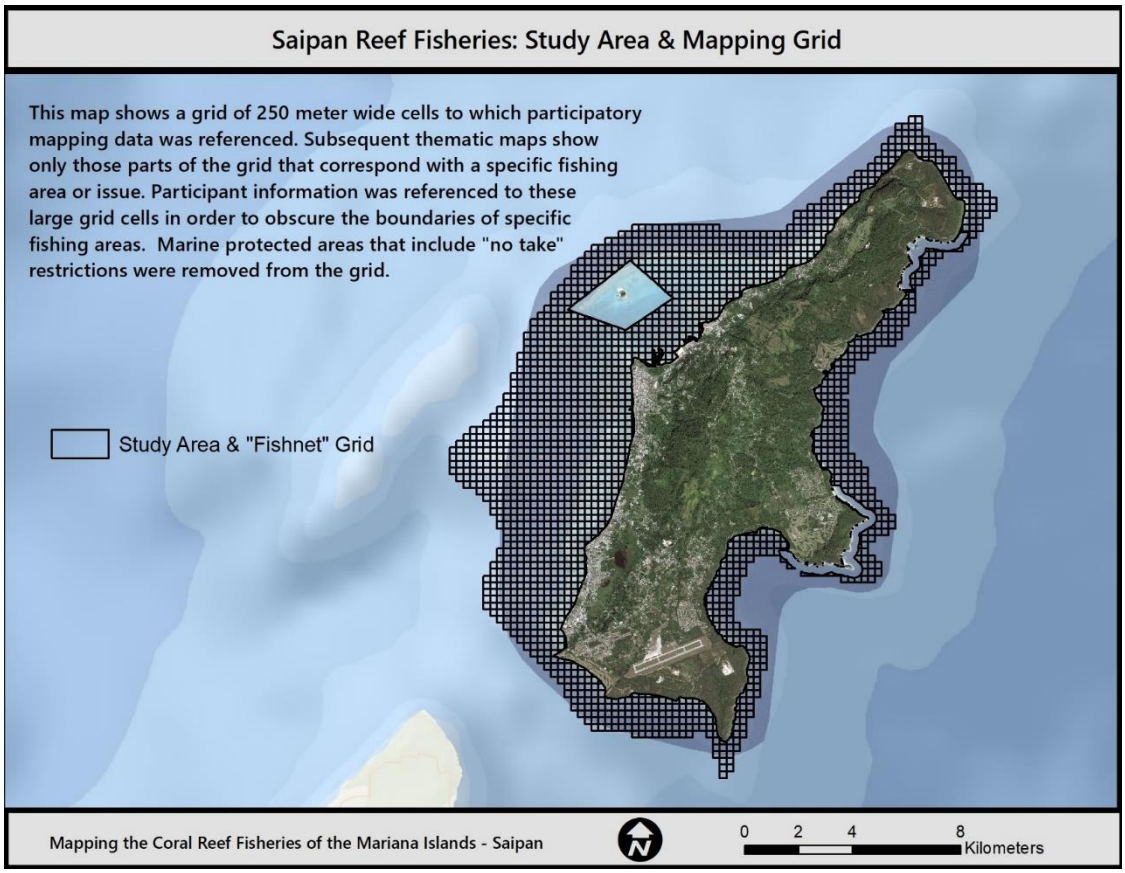

Figure 12: Saipan PGIS study area and mapping "fishnet" grid.

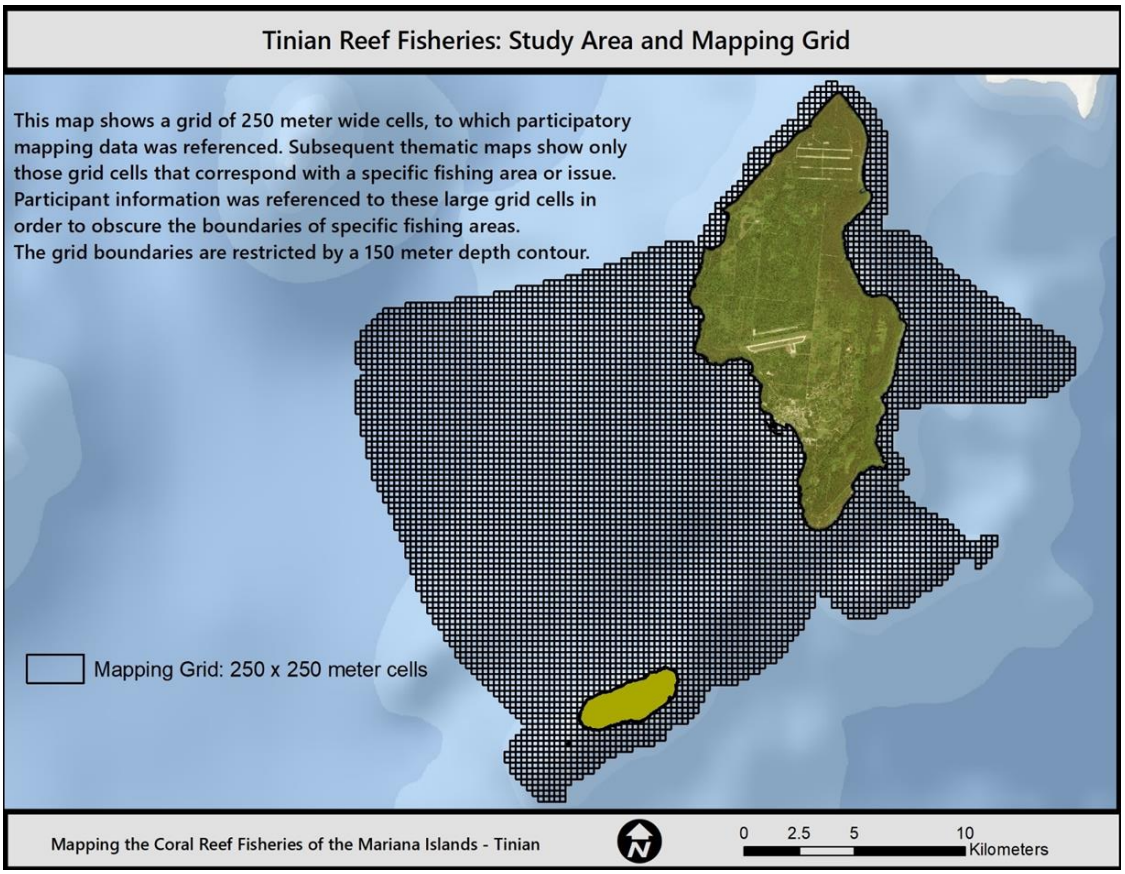

Figure 13: Tinian PGIS study area and mapping "fishnet" grid.

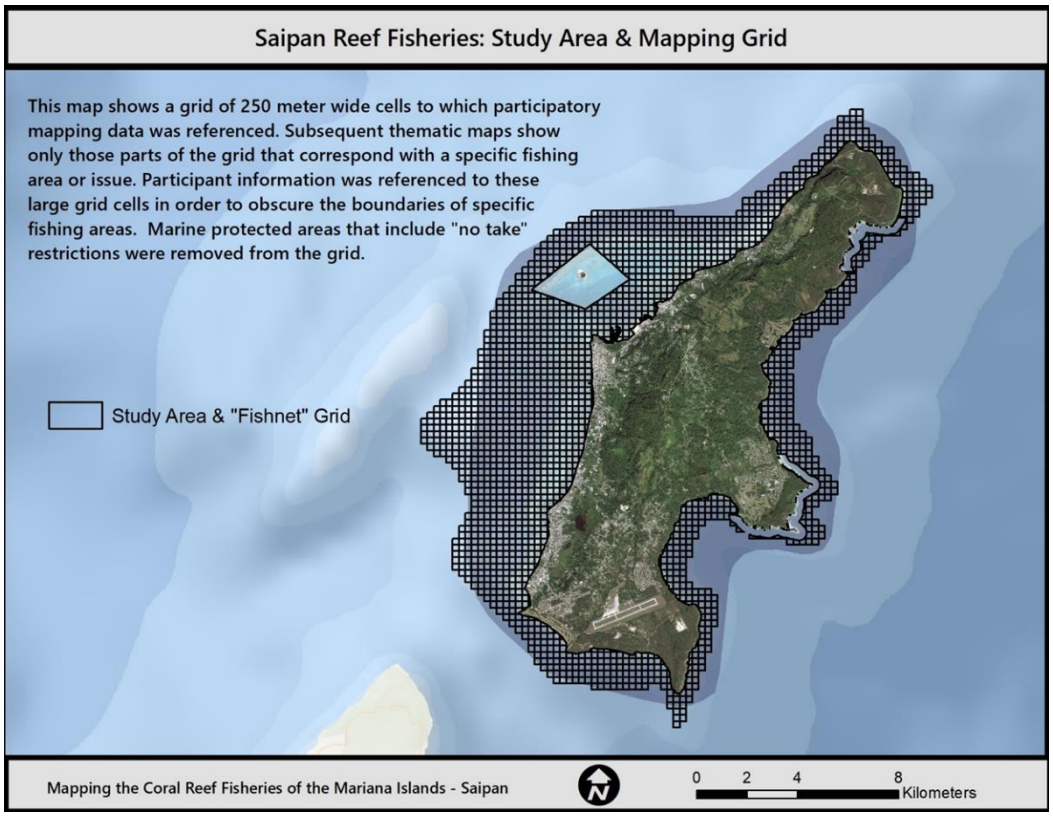

Figure 14: Rota PGIS study area and mapping "fishnet" grid.

Results and Discussion

The final spatial data resulting from the participatory mapping exercises matches the following fields and domains:

CNMI Reef Fisheries Mapping - Participatory GIS Data		
Field	**Description**	**Domain (Range & Coded)**
Access Type*	How fishermen access certain areas of nearshore and inshore waters (shore or boat). The default value for this category is "both"; however, if access by shore or boat is fairly restricted in a certain area, it may be described as "predominantly" boat or shore-based.	'Boat Based', 'Shore Based', 'Both'
Frequency*	How often a certain area is accessed and fished. Based on workshop participant discussion, this category was split between "Dominant" and "Limited", and then further split into values of seasonal dominant or limited depending on whether ocean conditions had a major influence during certain times of the year.	'Dominant', 'Limited', 'Seasonal-Dominant', 'Seasonal-Limited'
Gear-Method*	The types of fishing methods that are in use in a certain area. While larger spaces that are inclusive of many reef environments (e.g. reef slope, channel, reef flat, lagoon, etc…) may be subject to all fishing methods, smaller delineations in specific habitats favored particular methods and gear.	'Cast', 'Gill', 'Spear', 'Bottom' (boat-based), 'Line' (Shore-Based), 'Hand' (gleaning), 'Troll', 'Cliff'.

Shift	Whether fishing effort is occurring primarily during daylight hours or at night. This category proved to be homogenous throughout CNMI's shoreline and coastal waters, as participants noted that both fishing shifts occur in most areas.	'Day', 'Night', 'Both'
Habitat	The benthic habitat and nearshore environment that characterizes a certain fishing area. This description was derived from facilitated discussion with participants and resulted in a more simplified classification scheme than the authoritative cover and structure data published by NOAA.	'Sand', 'Lagoon', 'Cliff', 'Reef Flat', 'Caves', 'Fringing Reef', 'Steep Dropoff', 'Gradual Slope'
Species *	The common English names of fish species, genus, or family that may be targeted or abundant in a particular area. Values in this category were determined by structured discussions during participatory mapping workshops, wherein participants highlighted areas that were particularly "good" for certain fish. In some areas only a broad grouping of species was mentioned (e.g. "pelagics"), and rarely did discussions filter down to the species level. Broader taxa dominated workshop input.	'Bigeye Scad', 'Emperor', 'Unicorn', 'Parrotfish', 'Goat', 'Rabbit', 'Jobfish', 'Trevally', 'Barracuda', 'Rudderfish', 'Jack', 'Lobster', 'Octopus', 'Snappers', 'Tuna', 'Milkfish', 'Surgeon', 'Onaga', 'Wrasse'
Issues*	Concerns about various external influences on reef fisheries that were a consistent topic of discussion during mapping workshops. "Issues" were primarily related to pollutants, safety considerations, and limitations to access. The values in this category are broad topics that encompass a wide range of influences on specific fishing grounds and each could be a focal point of additional research. Of particular interest was the presence of non-local fishermen, which often coincided with instances of illegal scuba spearing.	'Pollution', 'Runoff during large storms', 'Marine Debris', 'Rough Ocean Conditions', 'Problems with Access' (e.g. dangerous terrain), 'Private Property', 'Jellyfish', 'Sharks', 'Dead Coral', 'Foreign Fishers', 'Scuba Fishing'
Season*	Instances in which fishing effort may focus or increase during certain times of the year based on ocean conditions.	'Summer-Calm', 'All'
Seasonal_Species* Runs	Areas in which there tend to be particularly abundant seasonal runs of certain species, especially culturally significant groups (e.g. Manahak or Ti'ao)	'juv rabbit', 'juv goat', 'juv mullet', 'juv skipjack', 'juv bluespine unicorn'
*Notation: * Category or theme highlighted in CNMI Fishery Atlas*		

Many of the fields within the table above are noted for their inclusion in the thematic maps from the *CNMI Reef Fishery Map Atlas* that accompanies this report. Because the values within those fields are largely derived from coding of semi-structured and open discussions around each PGIS feature, there are numerous assumptions that are inherited in the data, and thus instilled in the maps and Atlas. These assumptions and caveats are summarized in the following table.

Theme	Caveats and Assumptions
Access Type	During PGIS exercises participants were asked to discuss whether a certain area was primarily characterized by 'boat-based access', 'shore-based', or 'both'. In many areas where the discussion leaned toward "shore" or "boat" it was also noted that depending on seasonal ocean conditions, those areas could see more of a balance between "shore" and "boat". Therefore, there was greater than 90% overlap in the values for "Access Type" in the initial stages of data collection. In the final data and maps, areas marked "boat access" or "shore access" do not necessarily exclude the other but are assumed to be the more dominant means of access. There remain very few areas where both types of access are not included, the exception being stretches of open water greater than 250 meters from the shoreline, where shore-based methods were not included in the fishnets.
Frequency	Participants were asked to discuss how frequently an area is fished. There was no quantitative scale imposed on this discussion as fishing effort can vary greatly by season and shifts in accessibility. Without forcing an arbitrary number on the topic of "frequency", participants simply differentiated between "dominant" (very frequent) and "limited" (less frequent). In many areas, especially on the islands' eastern and northern shorelines, it was noted that under calm ocean conditions an area might experience far more fishing effort than it would under more hazardous, storm or trade wind-induced conditions. In these areas a value of "seasonal-dominant" was assigned. While these values are fairly broad generalizations, they were appropriate to the manner in which fishing areas were discussed, and can prove useful in combination with other mapping layers such as "Access Type". Frequency attributes that were established in this project's spatial data are not a substitute for more objective creel data related to effort; however, the participatory data does fill gaps in the geographic distribution of that information.
Gear-Method	Discussion around the type of gear or fishing methods that are employed in a certain area were generally characterized by a lumping of most methods. Participants suggested that just about all methods are employed in all accessible areas throughout the islands, with the exception of deeper, open water zones. As mapping exercises progressed, participants were asked to specify if a certain method was used within a given area more than others, or if a particular method was defined by certain environmental parameters such as shoreline and shallow water constraints on talaya. These parameters, while subjective, have proxies in other spatial data such as benthic habitat and structure, and were deemed appropriate to refine method-specific areas following validation workshops. In viewing maps that illustrate this topic, it should be acknowledged that the association of a specific area with a specific fishing method does not mean a total absence of other methods, but rather a scarcity of their use in that area.

Theme	Caveats and Assumptions
Species	The topic of "species" in the participatory data is wrought with generalizations and simplified assessments of fish species, genus, or families in a given area. As semi-structured discussion of individual fishing areas moved to different stretches of shorelines, lagoons, or large zones encompassing multiple methods, participants were asked to point out areas that might yield particularly abundant and high-quality catches of types of reef fish, but different taxa were not used in the event that they would restrict discussion. The focus on the "species level" was broadened from the outset to include participant input on genus, families, or even larger groupings that are present in an area. For example, references to a reef flat and shallow area of unconsolidated sediment that is "good" for Manahak under particular seasonal conditions might fall within a large polygon that was also noted as part of a stretch characterized by an entire range of "parrots", "goatfish", and "surgeons". In the largest polygons a common suggestion was simply "reef fish". The latter is not helpful in terms of distinguishing different fishing areas from one another, but speaks to the wide range of methods and types of access available in most spaces. For the purposes of this project, this does not necessarily pose a problem as it reflects the manner in which the fishing community perceives various fishing grounds. Nevertheless, the mixed classifications of fish within the PGIS features are less structured than CNMI's other fishery data, particularly creel and in-water surveys which distinguish more precise groupings. Analyses that can be conducted using the latter datasets cannot be applied to this project's geospatial products for any rigorous comparative analysis.
Seasonality and Seasonal Runs	In the context of the participatory mapping discussions, seasonality was a particularly important topic as it provided a mechanism for breaking down some generalizations about fishing effort on a temporal basis. Areas with limitations to access generally coincided with rough seasonal ocean conditions, and this phenomenon gave way to participants identifying other fishing area characteristics that were defined largely by timing. Seasonal runs of certain species, and particularly early life stage catches were the primary focus of these temporally sensitive discussions. In reviewing spatial data related to seasonal ocean conditions and seasonal abundance of species at certain life stages, it becomes clear that these themes need to be explored in conjunction with layers related to accessibility, and issues such as "runoff from storms". For example, large congregations of Bigeye Scad in Lao Lao Bay may occur within the summer monsoon period, offering an opportunity to overlay data related to both seasonal catch and seasonal issues. Despite the early summer Monsoon's generally calm ocean conditions, high accessibility for shoreline methods, and abundance of some seasonal catches, there may also be extended periods of poor water quality in areas vulnerable to land-based sources of pollution.
Issues	The categorization of "issues of concern" was an effort to include some of the most prominent topics of discussion during mapping workshops. Participants were encouraged to have open discussion concerning any barriers or challenges to healthy reef fisheries in their area. This encouragement was largely based on participatory workshops on Guam, where the community enriched the semi-structured mapping approach by delving deeper into the character of particular fishing areas. The primary caveat with layers pertaining to issues such as "Marine Debris" or "Multi-Use Conflict" is that these issues have immense levels of nuance to them, and are related to problems that may have their own separate geographic patterns. Each one of these issues could be, and in some cases is, the focus of immense research efforts. Connecting the results of issue-specific projects with reef fishery studies will be critical for effective management.

Keeping these assumptions in mind, participatory mapping data was subjected to a series of revisions concerning the precision of the information that was associated with different features, as well as the spatial accuracy of where that information appeared on maps. CNMI fishermen, and particularly those who consistently participated throughout the project process, provided essential feedback on the themes touched upon, and the appropriateness of the attributes that were ascribed to different fishing areas. The following section describes this data review and validation process, as well as the steps taken to visualize the data in a consistent manner.

Data Validation and Final Spatial Representations

While the entire project involved multiple iterations of participatory data in a fairly fluid sequence, the later stages of the data validation process can be broken down into three primary components:

- Adjustments based on feedback from data validation workshops in September (Rota) and October (Tinian and Saipan) 2017
- Data comparisons between GPS field data and PGIS data
- Final adjustments based on feedback from map-based presentations on each island in November 2017

While this lineage of quality control does not render the final project output as infallible, it was an important effort to better reflect the input of those community members that contributed time and sensitive knowledge to the data. Given that one of the main components of this project is the development of spatial data and associated process documentation, any substantial changes to the CNMI's reef fisheries or community perceptions of particular fishing area characteristics could conceivably be integrated into the data at a later point in time. In other words, the process of data validation, with respect to this project's output, is flexible and lends itself to cyclical improvements in the future, as opposed to terminating as a static end product.

Validation Workshop Results and Adjustments

Data validation workshops were held on Rota (September 29), Tinian (October 4), and Saipan (October 7). Digital maps were used to revise the results of initial participatory mapping, suggest edits to those results, and facilitate a discussion around outstanding issues that might need additional focus in the final products.

In preparation for each workshop, the fishnet data that contained all information from the initial mapping workshops were exported into individual maps based on individual fields and ranges of attribute values. These maps were grouped into five overarching categories: Gear-Method, Species, Access & Frequency, Seasonal Runs, and Issues. A total of 54 maps were produced for Saipan, 44 for Tinian, and 39 for Rota.

Almost all maps that were presented to the meeting attendees were revised in some way, although some revisions were based on broad comments about a topic, as opposed to specific sketches related to a particular attribute or area. Some maps were deleted due to redundancy or lack of relevance, while a large percentage of revisions simply involved refinement of fishing areas for specific topics where large generalizations had been made initially. The map below highlights a typical revision, in which Saipan participants narrowed the geographic focus of "cliff fishing" down to areas where the shoreline was actually characterized by accessible cliffs (Figure 15).

Figure 15: An example of a revision from one of the validation workshops.

A few additional maps were added to capture specific concerns that could not be addressed in the initial workshops. Following these revisions, additional data validation was conducted through comparisons with field data derived from fishermen who had volunteered to collect spatial data via global position systems (GPS) during the middle part of the project lifecycle. Processing of field data and comparisons with PGIS maps is described in the following section.

The final maps were presented to the fishing community on each of the three islands through Final Workshops, held on Rota on November 9, Tinian on November 14, and Saipan on November 18. In addition to receiving final feedback on the PGIS maps, these workshops focused on more in-depth discussions about issues of concern to each island's fishing community. A summary of these issues is included in the Discussion section of this report.

Citizen Science and Field Data Collection

As a broad, and evolving approach to data capture, participatory mapping can be conducted through a variety of methods. Each offers a suite of strengths and weaknesses, as well as potential avenues for complementing other datasets that may cover a similar topic. This project was largely centered around structured community workshops with facilitated digital and print-based mapping activities, yet additional methods offered opportunities for validating the workshop data. Data validation for CNMI was partially accomplished through additional geographic data collection using global positioning system (GPS) technology in a voluntary citizen science exercise. While the data collected through the volunteer GPS method did not include data related to fish taxa or reef fishery issues encountered on individual trips, it remained a useful set of information to assist in visualizing overall effort around Saipan, Tinian, and Rota.

Thirteen GPS units were distributed to volunteering members of the fishing communities on Rota, Tinian, and Saipan, along with tutorials and instructions on basic GPS operation. Units were pre-configured to collect waypoints at regular intervals whenever the unit was turned on.

The volunteer "citizen scientists" left their GPS units turned on for each of their boat and shore-based fishing trips for a three-month period, following the initial participatory mapping workshops on each island. Data collection throughout CNMI began on June 6, 2017, and continued through August and part of September, depending on the individual's fishing efforts.

Data recovery from the GPS units began at the data validation workshops in September 2017. Data in the form of GPX waypoints was recovered and subsequently processed in a GIS environment. A total of 197 GPX files were initially collected from most of the participating fishermen who returned to the validation workshops, while follow-up meetings with individuals yielded a final count of over 200 waypoint files. In general, each file represented a set of waypoints constituting the track of an individual fishing trip. Exceptions to this rule

occurred in instances where a GPS unit was not turned off after a trip, or where the unit was mistakenly switched on and off outside the period of fishing effort.

Considering these potential errors, the GPX files were further processed in GIS to distinguish between individual fishing trips. Inspection of timestamp attribution for each GPS waypoint allowed for accounting of duplicate tracks, or run-on files that encompass multiple trips. Visual inspection of waypoints with respect to the shoreline, inland features, and anomalous locations outside the CNMI Coastal Zone allowed for further identification of erroneous data.

Cumulatively the data represents 203 individual fishing trips during the data collection period. Rota and Tinian fishermen logged 96 and 71 boat-based trips respectively, while Saipan participants collected waypoints from 16 boat-based trips and 20 shore-based trips.

Based on follow-up communication with the volunteers on Saipan, it appears that the shore-based gear-method was composed primarily of talaya and spear. The lack of shore-based trip data from Rota and Tinian is suspected to be a product of the type of fishing preferred by those members of the community who volunteered, and cannot be used to reach any conclusions about prevalence of boat or shore-based methods around any of the islands. In addition, the data collection period from June to September coincides with relatively calm waters in the Marianas, allowing for greater opportunity for boat trips and increased fuel efficiency.

The GPS data was converted to a native GIS format (geodatabase feature classes), and incorporated into a geodatabase. Each fisherman was randomly assigned a number to preserve anonymity. A naming convention was then applied to document the volunteer and date that the trip occurred. All waypoints corresponding with inland travel or boat trailering, or launching activities within marinas or docks were removed. This included the generation of features representing launching and marina operations at each island, and distinguishing shoreline at marinas or launch locations that might also be used for talaya or other shore-based methods. Following the removal of all data that was not representative of fishing effort, the waypoints were merged by island to represent cumulative effort among each community.

An area of analysis was generated for each island by generating a polygon around the merged waypoint features using a rectangular minimum bounding geometry. This boundary encompassed the extent of all boat and shore-based fishing effort from participants in the field data collection phase. Because there were clear distinctions made between shore-based and boat-based effort in the Saipan field data, a rectangular bounding geometry was generated for both shore-based and boat-based fishing on Saipan.

Using these fishing effort boundaries, a waypoint density analysis was conducted for each island. Raster data surfaces were created for each island at 250-meter resolution (matching PGIS workshop data resolution), with raster cell values defined by “waypoints per square kilometer” (Figure 16). The analysis employed a circular search radius of 1 kilometer, allowing the output to capture a broad representation of fishing effort in the area, as opposed to simply mirroring the individual waypoints from each trip.

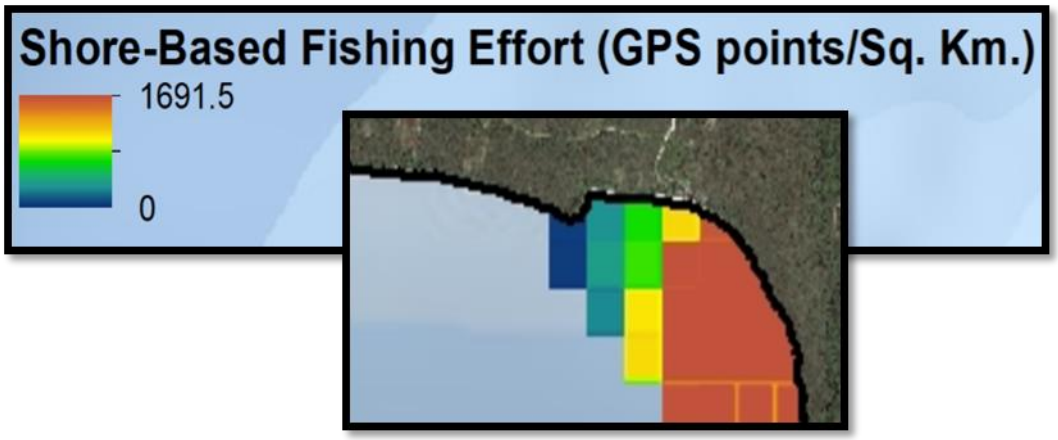

Figure 16: An example of the "hot spot" density analysis for the GPS citizen science study.

The individual fishing trip waypoints, merged trip data, and results of point density analyses, were organized in a file geodatabase, along with accompanying ISO 19115 metadata, and will remain confidential. The primary value of the data lay in its interim purpose as a means of comparison with other participatory information, and in some cases validation.

Because the field data collection period occurred during the Western North Pacific's wet season, ocean conditions remained fairly benign with light to non-existent trade winds on many days and very little cyclonic activity in the region. These calm conditions are assumed to be conducive to island-wide access to both shore and boat-based fishing, with very few days of severe weather and craft advisories. Field data and subsequent waypoint densities reflect these opportunistic conditions, particularly on Rota and Tinian where effort was extended to portions of the coast and near shore environment that might otherwise be prohibitively rough under periods of strong trade wind and swell.

Notably, much of the boat-based field data around the three islands corresponded with PGIS and workshop data that delineated "seasonal dominant" areas, or areas that experience fairly high levels of effort under temporary, calm seasonal conditions. The north end of Saipan, as well as the southeast portions of Tinian are highly characteristic of this, being noted in workshops as 'seasonal-dominant', and having strong validation in the GPS data. Tinian field data also matched well with workshop descriptions of regular trips to and from Aguigan, and anecdotal information concerning particular hot spots around Aguigan.

Shore-based GPS data on Saipan suggests strong preference among participants for particular spots that were also highlighted in the PGIS workshop, with high concentrations of effort occurring along the northern extents of the Saipan Lagoon, across the southern stretches of shoreline adjacent to the Tinian Channel, and within the protected portions of Laolao Bay.

Interpretation of the field data is fairly limited due to the sample size and lack of accompanying data related to specific effort or catch metrics, as well as an inability to extrapolate the data to other seasonal ocean conditions. Nevertheless, specific components of the PGIS and participatory mapping workshop information was able to be verified. Perhaps of greater importance is that the voluntary involvement in field data collection constitutes a successful instance of engagement with CNMI fishing communities through a citizen science approach. This type of approach could be augmented in the future with alterations to capture additional metrics of the reef fishery, aside from time (effort) and spatial distribution.

Final Adjustments to Participatory Information & Spatial Data

Following the data revisions from the validation workshops and visualization of GPS field data, a final round of adjustments was administered to the spatial data. These revisions focused on fine-tuning the extent of certain methods, and discerning the spatial distribution of various activities specifically around the Saipan Lagoon.

Of particular note was the use of benthic habitat data to better define the spaces in which shore-based methods might occur. The polygons in the fishnet grids that contained attribute values for 'cast net' were restricted to habitat types associated with shoreline, reef flats, and other shallow-water environments. In addition, large portions of the fishnet grids that noted shore-based spearfishing were originally derived from very large sketches at the participatory workshops. These needed to be reduced to grid cells within reasonable distances from shoreline access points. Meanwhile, grids for some boat-based methods required removal of grid cells that overlapped shallow water benthic environments and reef crests that would prohibit navigation of any vessels.

Given a series of adjustments such as those described here, the participatory data represents both subjective perceptions of reef fishery characteristics provided by the community, as well as more objective, authoritative environmental parameters in the form of rigorously studied geospatial information. This combination of input in the final product may serve as an extensible template for more broadly integrating stakeholder concerns and input into the tools and information that fishery managers use, which are often in need of greater community perspective.

A description of the maps produced through this effort can be found in the following section, and a sample of key maps can be found in Appendix B of this report. The complete collection of PGIS maps for all three islands can be found in the *CNMI Reef Fisheries Map Atlas* that accompanies this report.

Discussion

The maps produced through this project depict a story of fishing patterns that follow certain trends and themes. At the final workshops, after a final validation of the PGIS results, the facilitators led the fishermen in a more qualitative conversation about fishing habits, trends, and issues. Many of these themes and issues were consistent across all three islands, others were specific to just one or two. These are summarized below, with references to specific maps in Appendix B where appropriate.

Fishing Patterns & Habits

Seasonality

Seasonality of fishing patterns on all three islands followed a similar trend as that on Guam. Year-round fishing primarily occurs on the leeward (west) side of the three islands, where the coastlines are relatively protected from easterly swells. Dangerous ocean conditions are generally found on the eastern sides of the islands (Appendix B, Figure B-15). During the periods of calmer seas and lighter trade winds, generally the summer months, fishermen will venture more towards the more exposed areas of the islands (Appendix B, Figure B-12). These patterns of condition-based accessibility seemed to also hold true for day versus night shifts as represented on Tinian, where remoteness, difficult shoreline access, and rough seas generally limit any east side fishing activities to the daytime (Appendix B, Figure B-6). These sheltered areas were also listed as the most important "training grounds", where fishermen can teach and train the next generation in safe conditions (see below).

Familiarity

One of the striking differences between the heavily populated island of Saipan (population of approximately 50,000) and the more rural islands of Tinian and Rota (each with populations of about 2,500) was the prevalence of fishing "territories". As on Guam, Saipan fishermen tend to revisit fishing locations that they are familiar with, locations where they grew up fishing or had significant learning experiences, and areas that are close to their particular village. For example, fishermen from the village of Tanapag located on the coast of the northern Saipan Lagoon often responded with "I don't know because I don't fish down there" to questions about fishing along the southern coast or Laolao Bay. Understanding these constraints may be important for appropriate management decisions, as losing one key fishing area may disproportionately affect certain populations of the fishing community more than others.

In contrast, fishermen on Tinian and Rota seemed less "territorial" than those on Saipan. The phrase "everything is caught everywhere" was a common response to most questions about reef species (Appendix B, Figure B-13). This may be due to the fishermen's desire to keep specific fishing spots secret, but is also likely due to the contextual realities of these two islands as compared to Saipan. Both Rota and Tinian have significantly smaller populations. Rota is also geographically smaller than Saipan. Tinian is similar in size to Saipan (40 sq. mi. versus 45 sq. mi.), but has significantly more cliffline, fewer shore-based access points, and only one boat launch location. On these islands fishing locations followed distinct patterns of depth, benthic habitat, and distance from shore (Appendix B, Figure B-7). However, even on Rota and Tinian the fishermen expressed a common desire to fish in areas that were close in proximity to their home or to a boat launch. The desire to minimize the cost of fuel, both car and boat, often came up as a concern for the fishermen on all three islands.

Perceived Accessibility

Certain fishing spots are more or less popular based largely upon the safety of the fishing spot, perceived difficulty of access, and proximity to safe parking and boat launches. Ease of access was particularly discussed on Tinian, which has a large portion of its coastline marked by sheer cliffs and small pocket beaches. The implications that perceived accessibility has for management will be discussed in relation to specific issues below.

Issues and Concerns

Through the PGIS workshops, the fishing communities on each of the three islands highlighted areas of concern that they hoped would be included in this project's report. These issues were explored further during the discussion at the final workshops. The concerns expressed below are PCRP's attempt at accurately and impartially conveying the concerns of the fishing community.

"Training Grounds" for the Next Generation

The ability to pass on fishing techniques and the fisher lifestyle is an important aspect of cultural preservation in the Marianas and an area of concern for many members of the fishing community. One member of the Saipan fishing community even expressed the belief that they may be "the last generation of local fishermen". Such concern seems warranted when you compare the areas listed as the most important "training grounds" for the next generation with areas of potential tourism development and military expansion. As expected, the prime youth training grounds on Saipan (Appendix B, Figure B-3), Tinian (Appendix B, Figure B-9), and Rota occur in sheltered and shallow nearshore areas. On Saipan many of these areas align with locations that are under high pressure from tourism development. On Tinian, as represented in Figure B-9, almost all of the prime training ground areas are located at pocket beaches on the military leasehold area (see "Military closures" below).

Should these areas become closed to the public, there would be limited opportunities to teach the next generation how to fish.

Development and Crowding

On Saipan particularly, the issue of overdevelopment and overcrowding often came up as a concern that affects fishing behavior. As mentioned above, many coastal areas along the western Saipan Lagoon are under development pressure from expanding tourism, which may impact the fishing community's ability to access prime fishing grounds and youth training areas. Crowding with commercial marine sports was also discussed as a safety concern, particularly around the central and southern lagoon (Appendix B, Figure B-4). Light and noise pollution along the shores of the lagoon was also listed as a concern, as these may affect the habits and behavior of food fish species, particularly at night. Conflicts between fishermen and recreational SCUBA divers, particularly at the popular dive site at Laolao Bay, was also listed as a growing concern as tourism on Saipan increases.

Military Expansion and Development

On Tinian the biggest concern for the fishing community was that of the proposed expansion and development by the U.S. Military. The U.S. Military has a permanent leasehold on the northern two-thirds of Tinian. This area has, for the most part, been open to the public for most of the year, only closed for a few days sporadically throughout the year for military training exercises. There are discussions, however, of a military buildup which could result in the closure of this area for much of the year if not permanently. Most of the shore-based fishing areas and youth training grounds are located on this military leasehold area (Appendix B, Figure B-9); one pocket beach (Chiget Beach) has already been closed due to the presence of unexploded ordnances. Figure B-8 in Appendix B clearly shows how limited the shore-based fishing access would become if the military leasehold area were closed to the public.

Water Quality and UXOs

A common concern on all three islands was that of diminishing water quality and its impact on fish habitat and the fishing experience. These episodes of low water quality tend to correspond with heavy rain events; many fishermen attribute the low water quality to the recent rise in upland development (Appendix B, Figure B-5). On Tinian, fishermen often find unexploded ordnances leftover from World War II near their fishing spots (Appendix B, Figure B-11). The fishermen expressed concern both about the safety of these UXOs, as well as the affect they may have on the water quality or the safety of the food fish that live in the area. Pieces of white phosphorus are often found underwater or on beaches. Several fishermen expressed an interest in obtaining baseline water quality data around key fishing areas on Tinian to identify any heavy metals or toxins from these UXOs or runoff before any additional military development occurs.

SCUBA-Spearfishing

On both Tinian and Rota, fishermen have observed what they believe to be the presence of spearfishing using SCUBA equipment, which is illegal in the CNMI. This activity is often observed on the northeastern coastlines of the islands, which on both Rota and Tinian are far away from village centers or boat launch areas (Appendix B, Figure B-10). On both islands, fishermen expressed the belief that these SCUBA spearfishermen were not local. Both communities expressed a desire for additional boat-based enforcement support from the local Divisions of Fish & Wildlife in an effort to combat this illegal fishing activity.

Stagnant Sales Prices

Fishermen on all three islands, but especially Saipan, expressed concern over the stagnation of fish sales prices. On Saipan, where the cost of living has increased dramatically over the last five years, fish prices have not changed in many years. Many fishermen expressed concern that this was driving an increase in overfishing in an attempt to cover the costs of fuel and time. The development of a community-focused fishermen's co-op was an idea that many fishermen supported.

Marine Protected Areas

On all three islands the fishing community expressed support for the idea of Marine Protected Areas (MPAs), however all were concerned and confused over actual implementation of MPAs in the CNMI. Most were unsure as to why certain areas were selected over others, expressing the belief that the selection process was random or for economic (tourism) reasons rather than biological ones. Many fishermen also felt that concerns of the fishing community were ignored or overlooked during the designation process. Examining the effectiveness of each of the MPAs and revisiting their designation was suggested. Another suggestion that received overwhelming support on all three islands was the idea of "rotating" MPAs.

Recommendations and Next Steps

This study highlighted both the importance of fishing to the CNMI community and the challenges faced by the fishing community in the face of continuously changing circumstances and economic development. While the results of the PGIS mapping are by no means conclusive, they do highlight areas that managers and future research can focus on. They also highlight the importance of continuing to engage the fishing community in management decisions as the CNMI continues to grow.

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Appendices

Appendix A: Creel survey summary maps for Saipan, Tinian, and Rota

The maps in this appendix are the results of the data processing and analysis of the creel survey data acquired for the islands of Saipan, Tinian, and Rota.

Table of Maps

Saipan creel survey summary maps

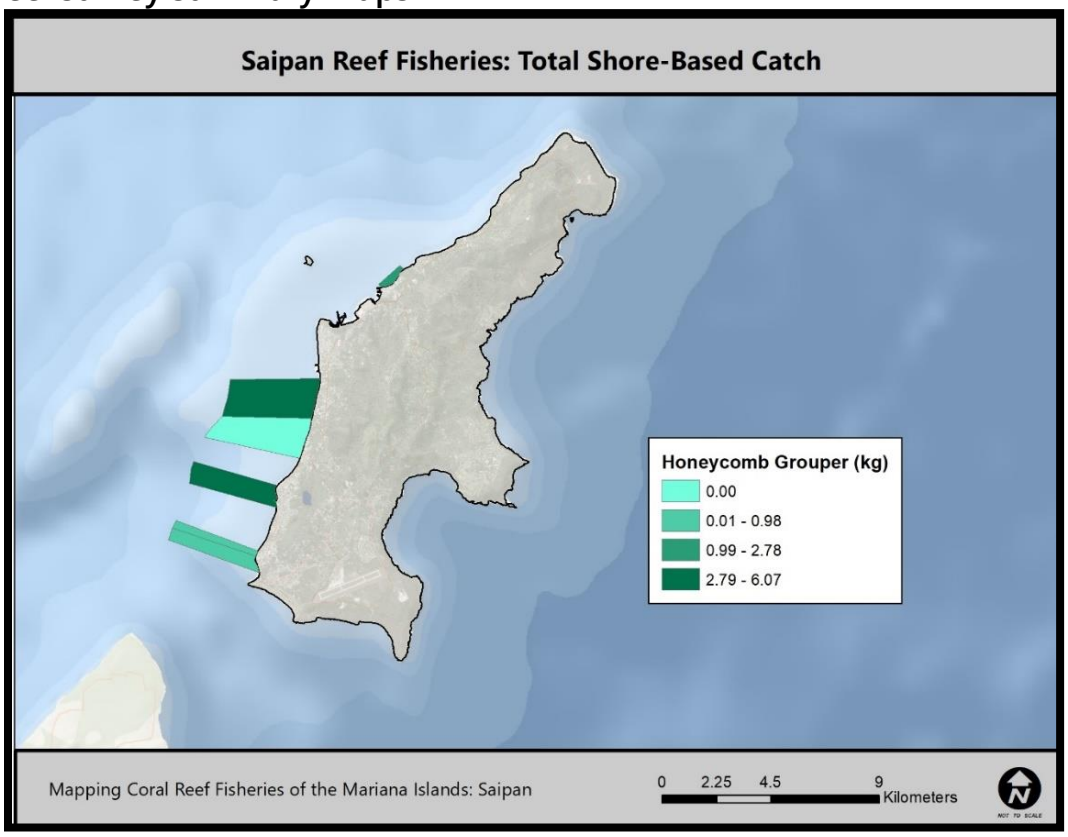

Figure A-1: Saipan total shore-based catch: honeycomb grouper (kg).

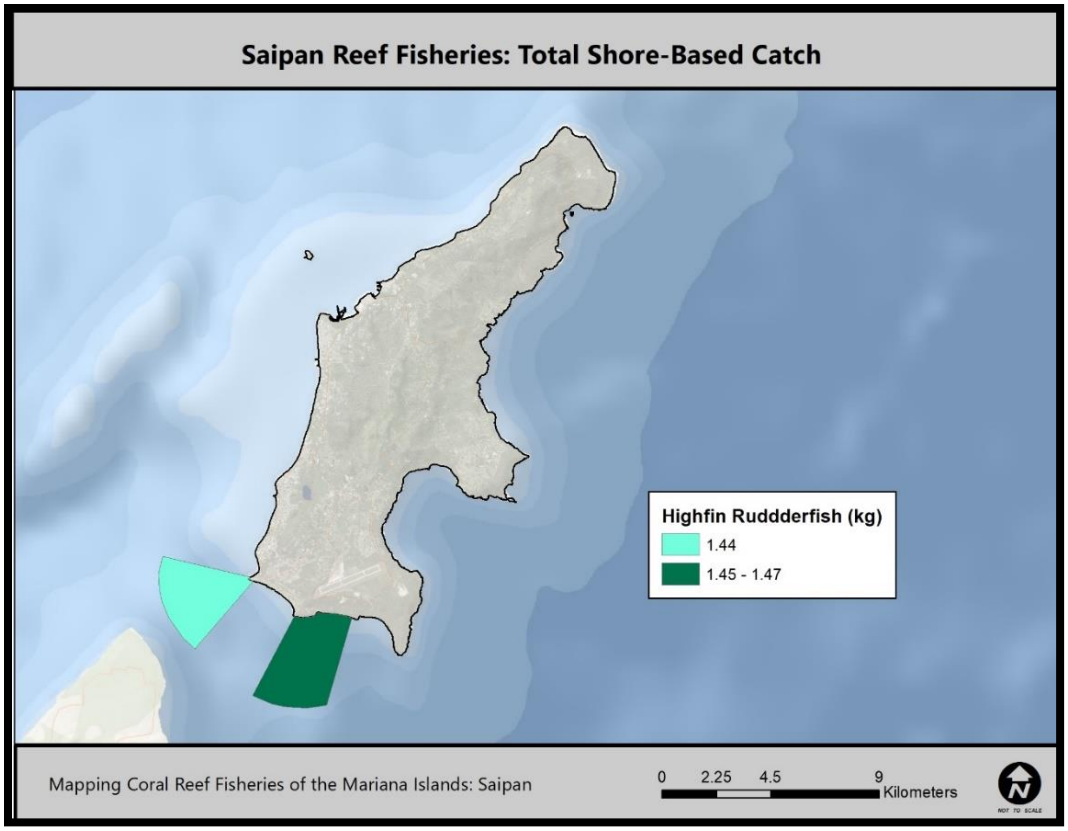

Figure A-2: Saipan total shore-based catch: highfin rudderfish (kg).

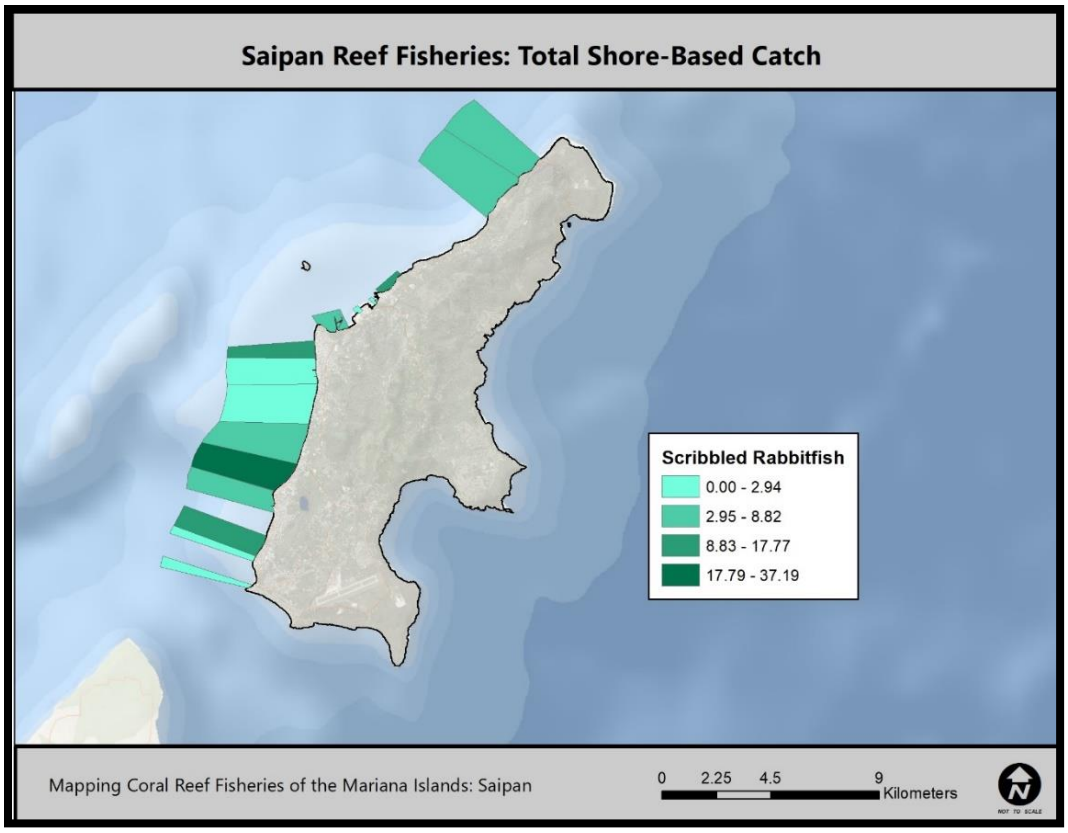

Figure A-3: Saipan total shore-based catch: scribbled rabbitfish (kg).

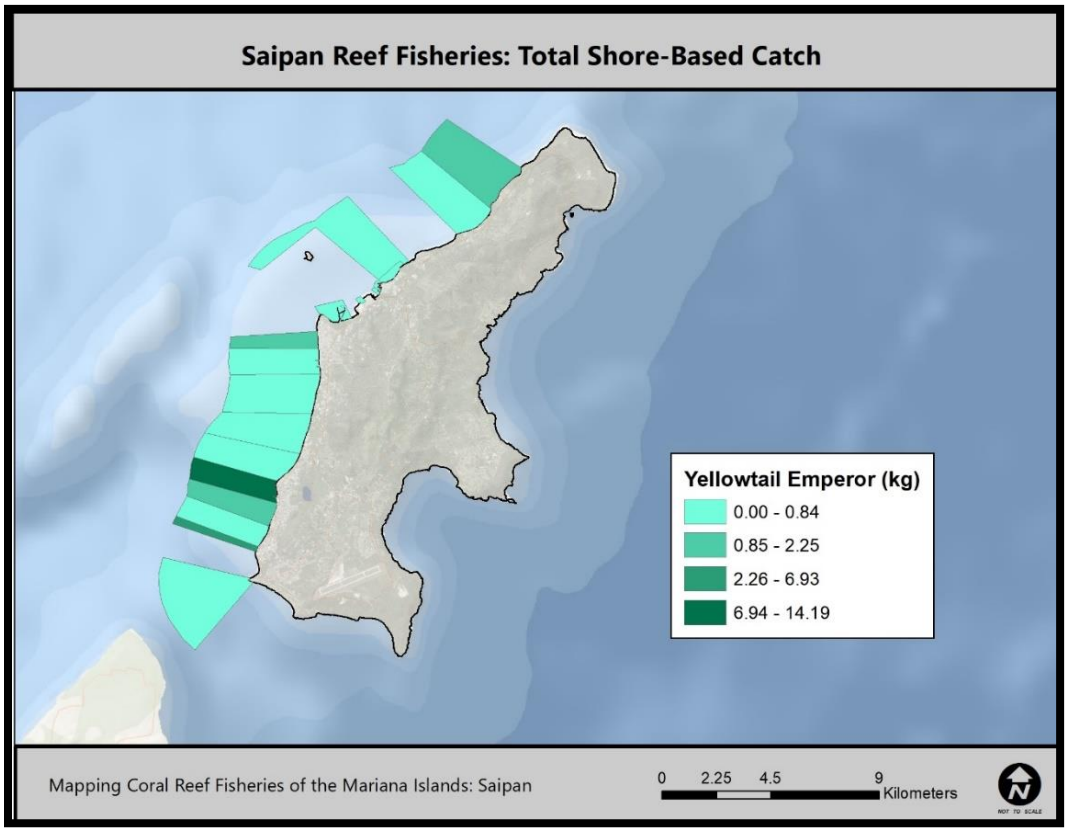

Figure A-4: Saipan total shore-based catch: yellowtail emperor (kg).

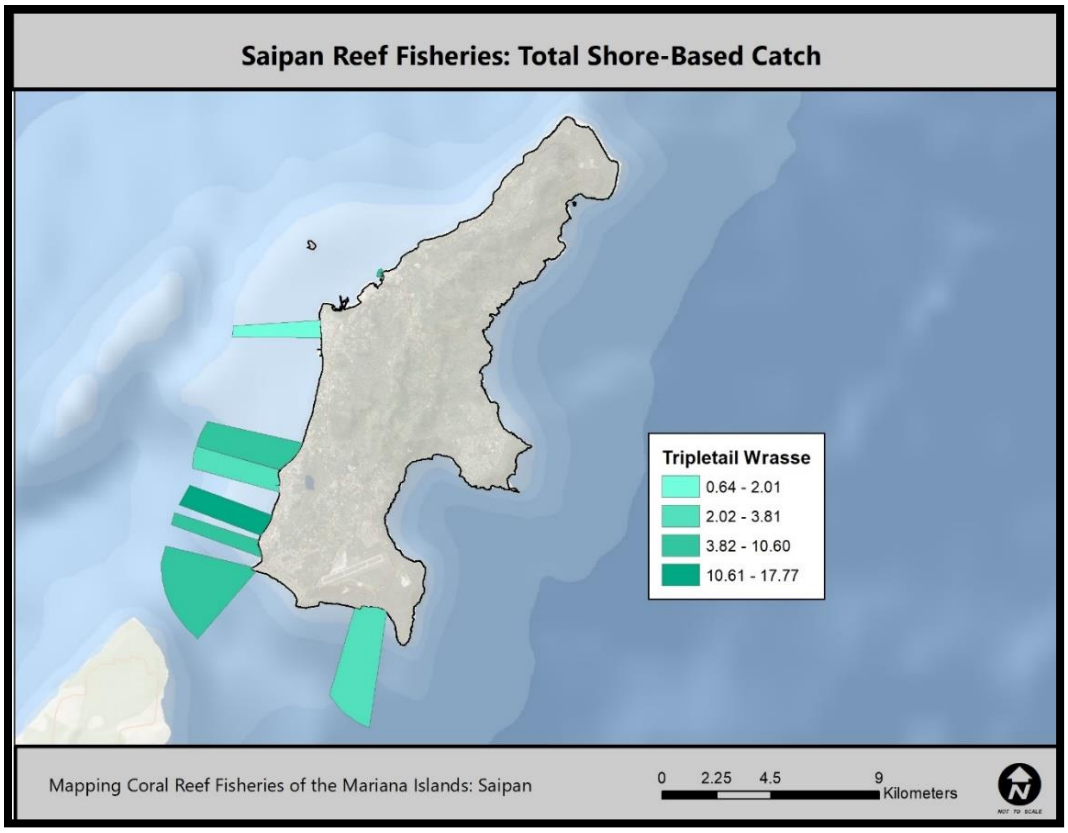

Figure A-5: Saipan total shore-based catch: tripletail wrasse (kg).

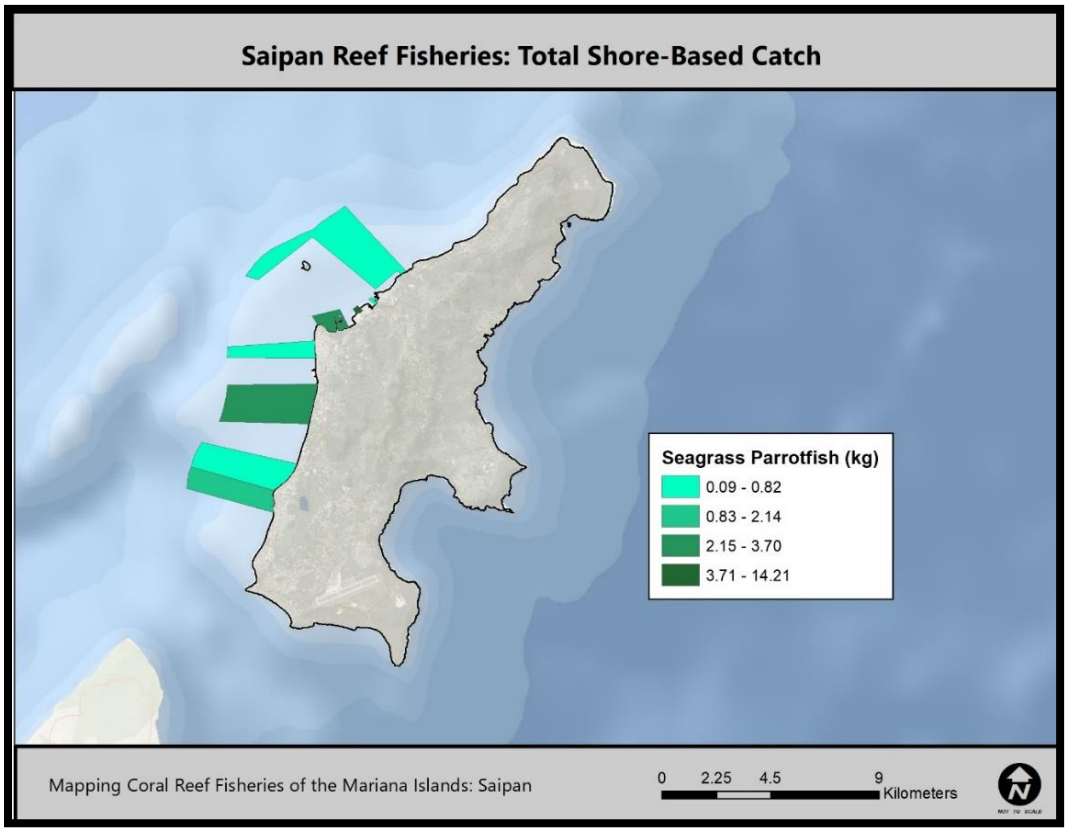

Figure A-6: Saipan total shore-based catch: seagrass parrotfish (kg).

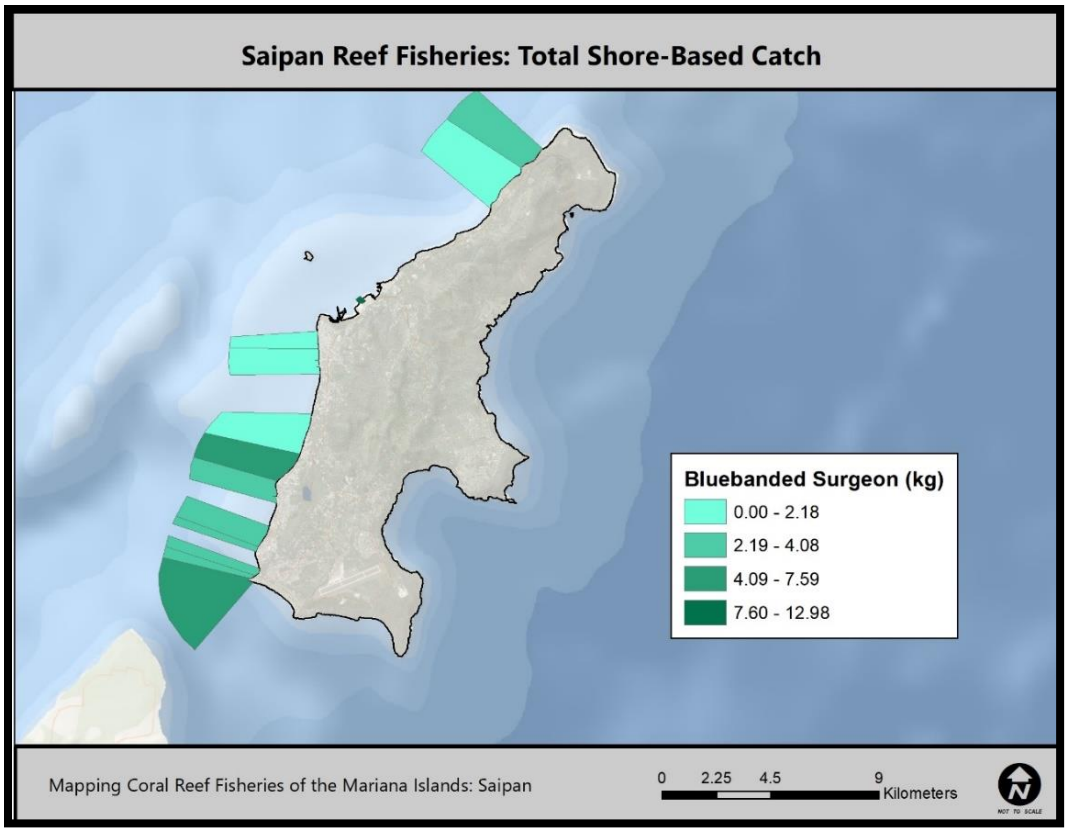

Figure A-7: Saipan total shore-based catch: bluebanded surgeon (kg).

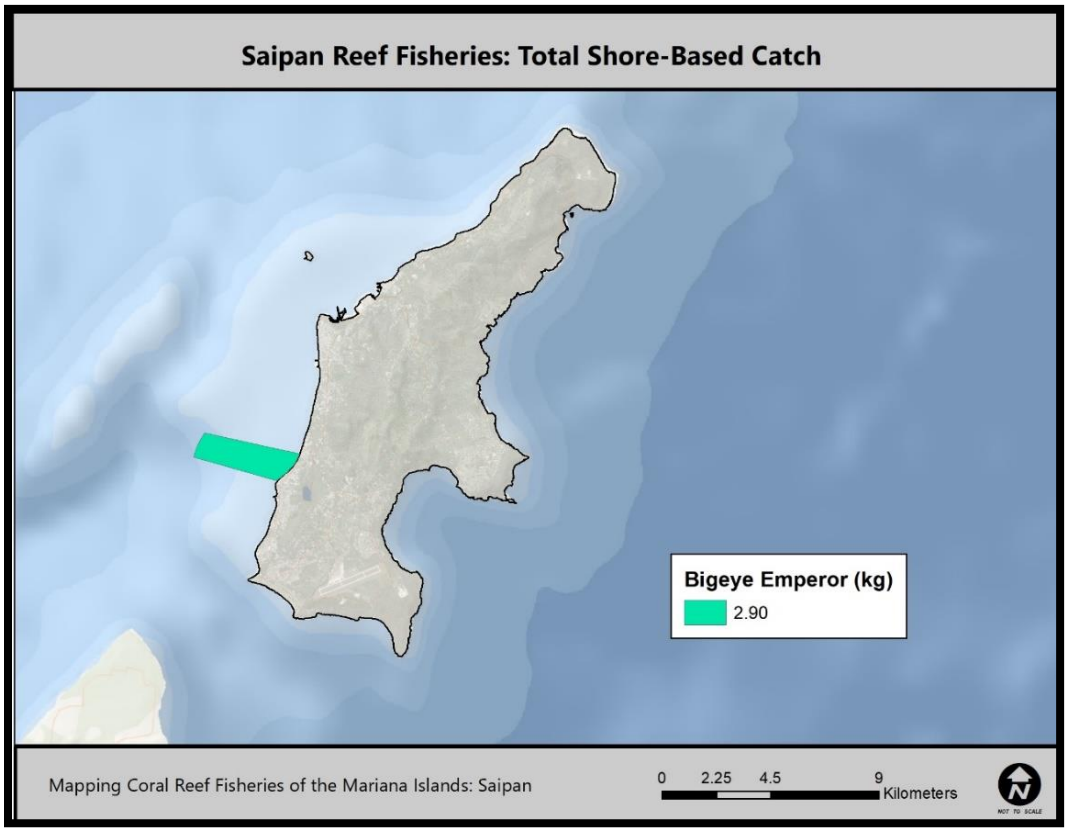

Figure A-8: Saipan total shore-based catch: bigeye emperor (kg).

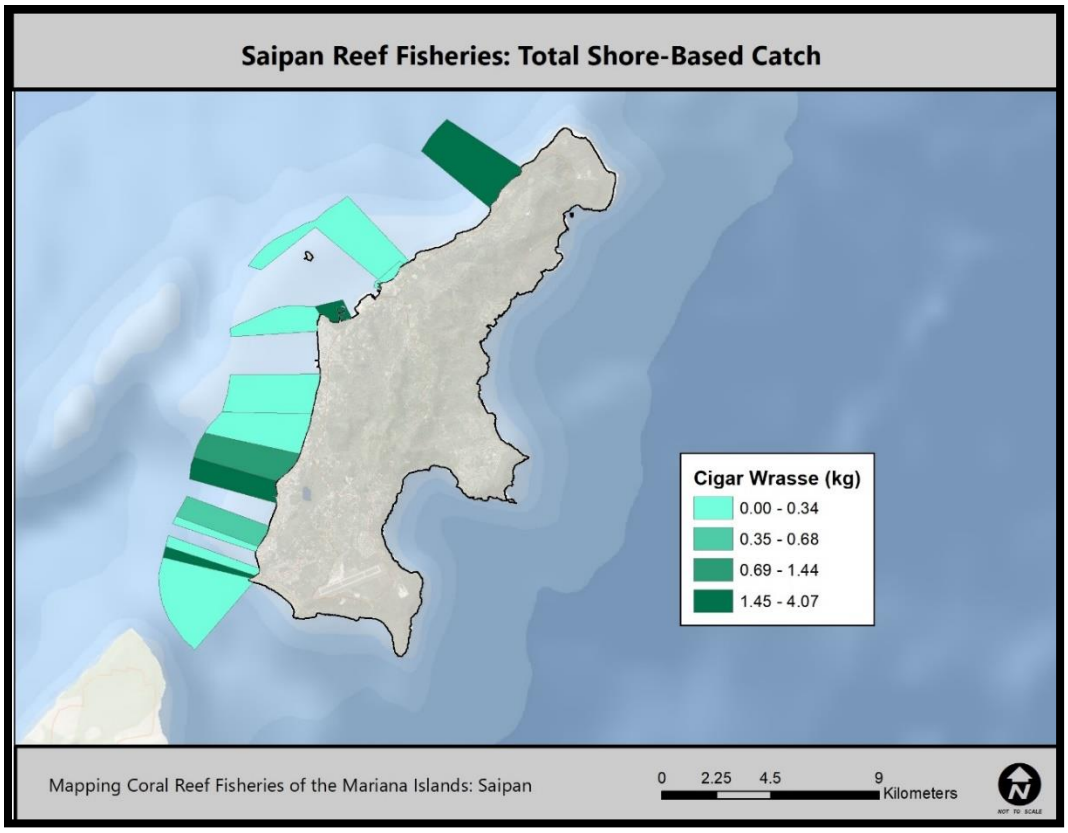

Figure A-9: Saipan total shore-based catch: cigar wrasse (kg).

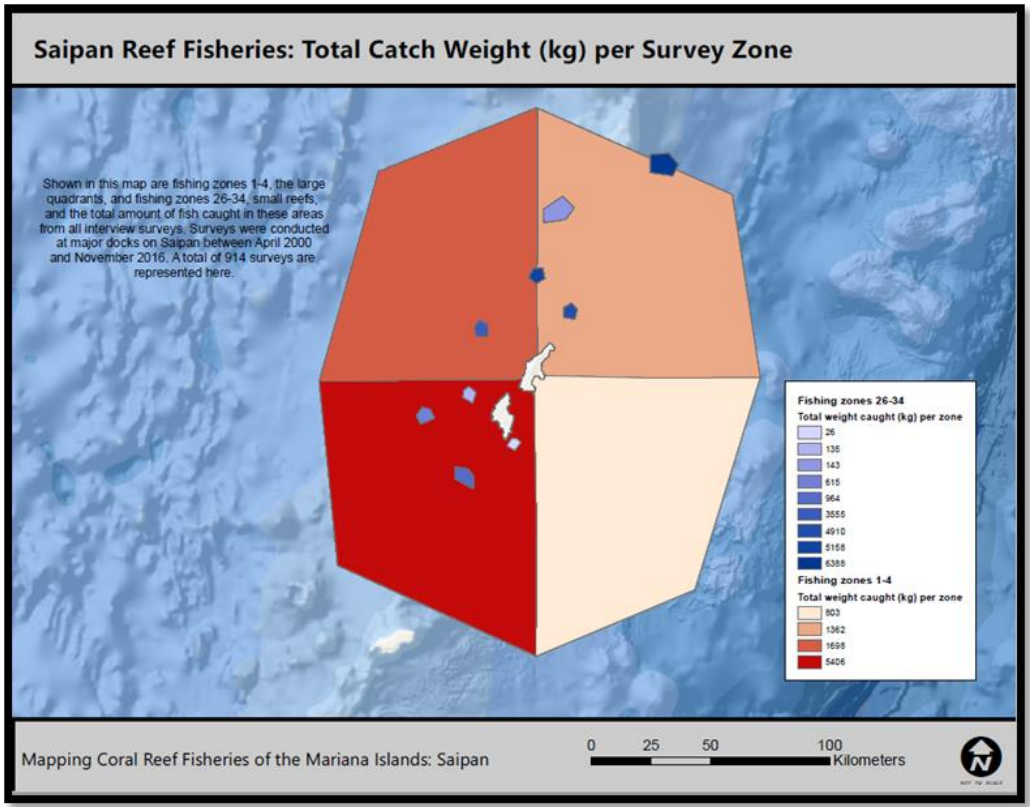

Figure A-10: Saipan total catch weight (kg) per survey zone.

Tinian creel survey summary maps

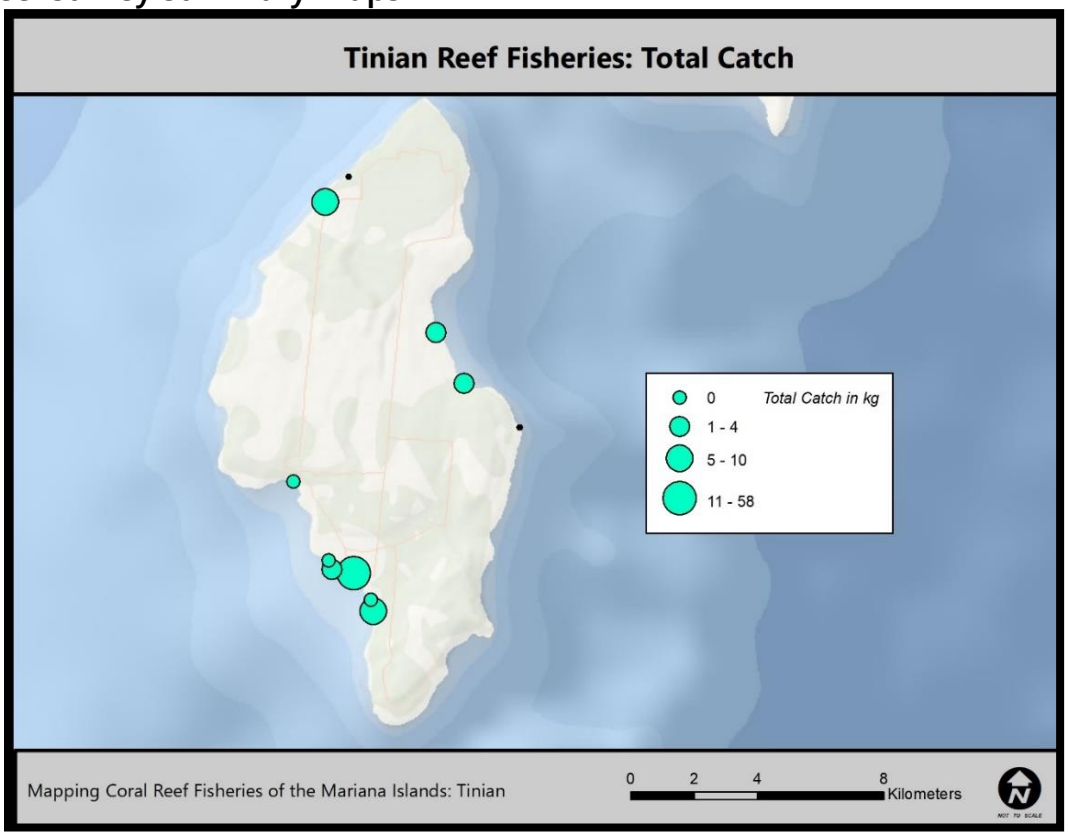

Figure A-11: Tinian total catch weight (kg) per survey point.

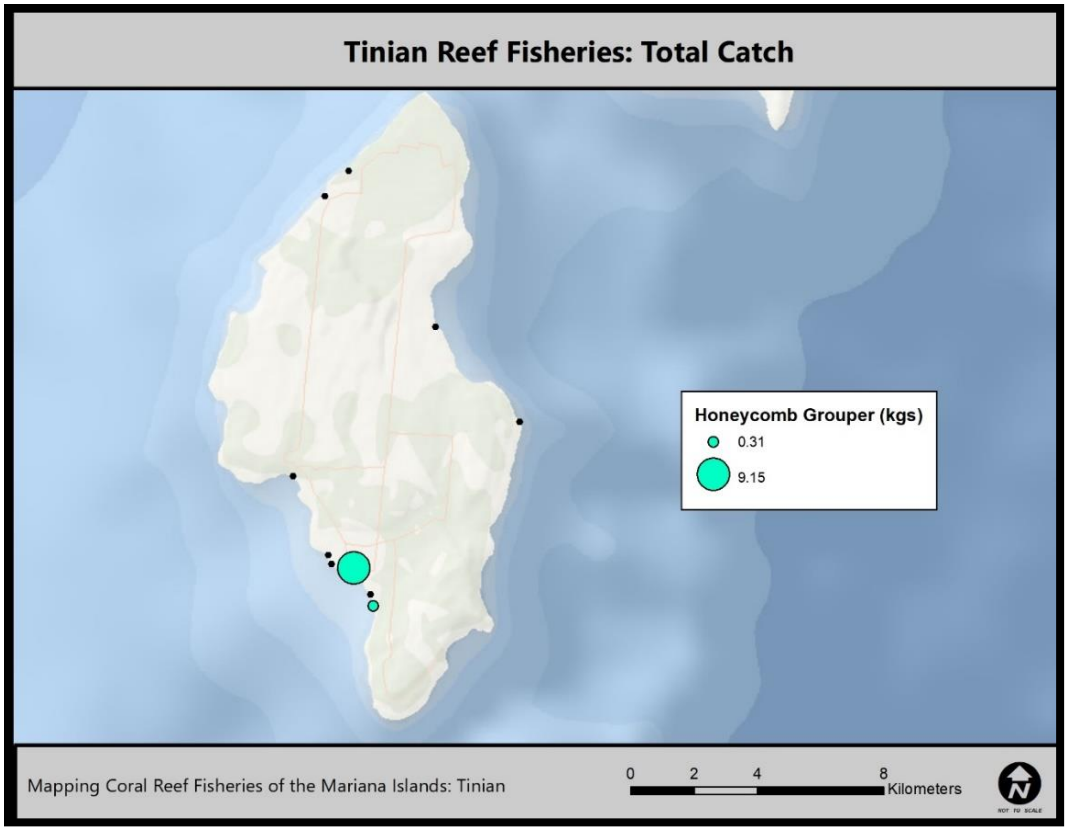

Figure A-12: Tinian total shore-based catch: honeycomb grouper (kg).

Rota creel survey summary maps

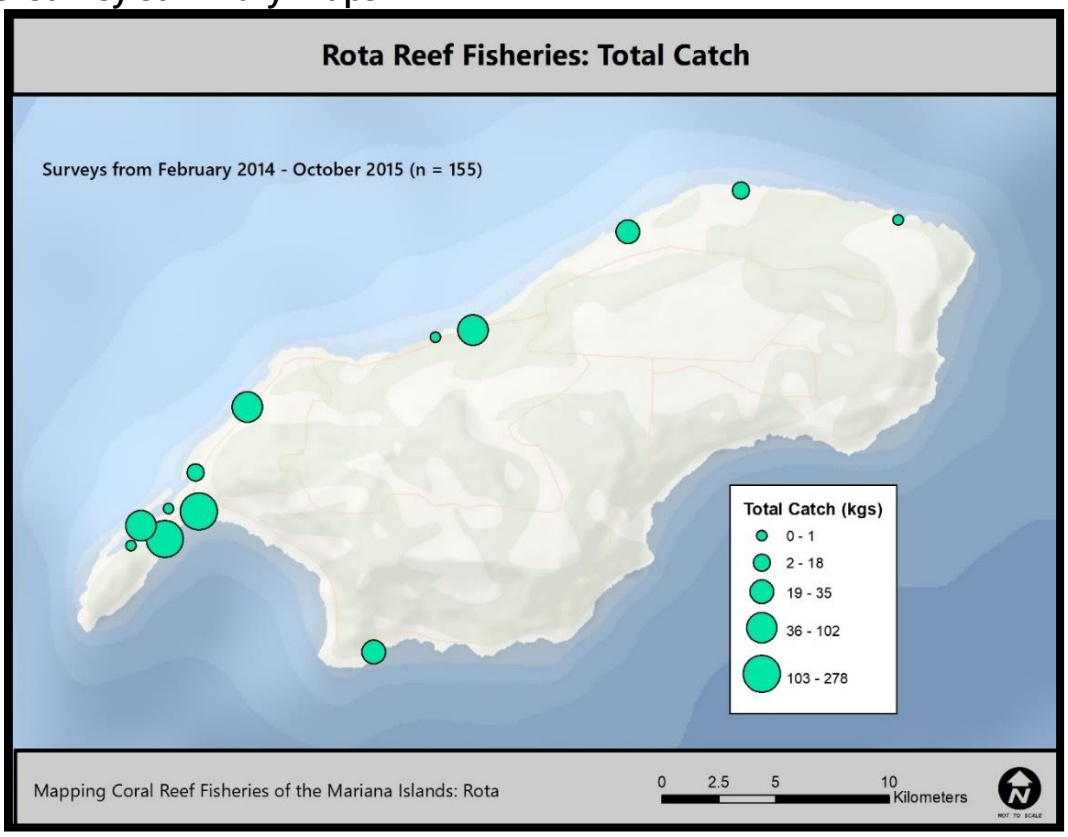

Figure A-13: Rota total catch weight (kg) per survey point.

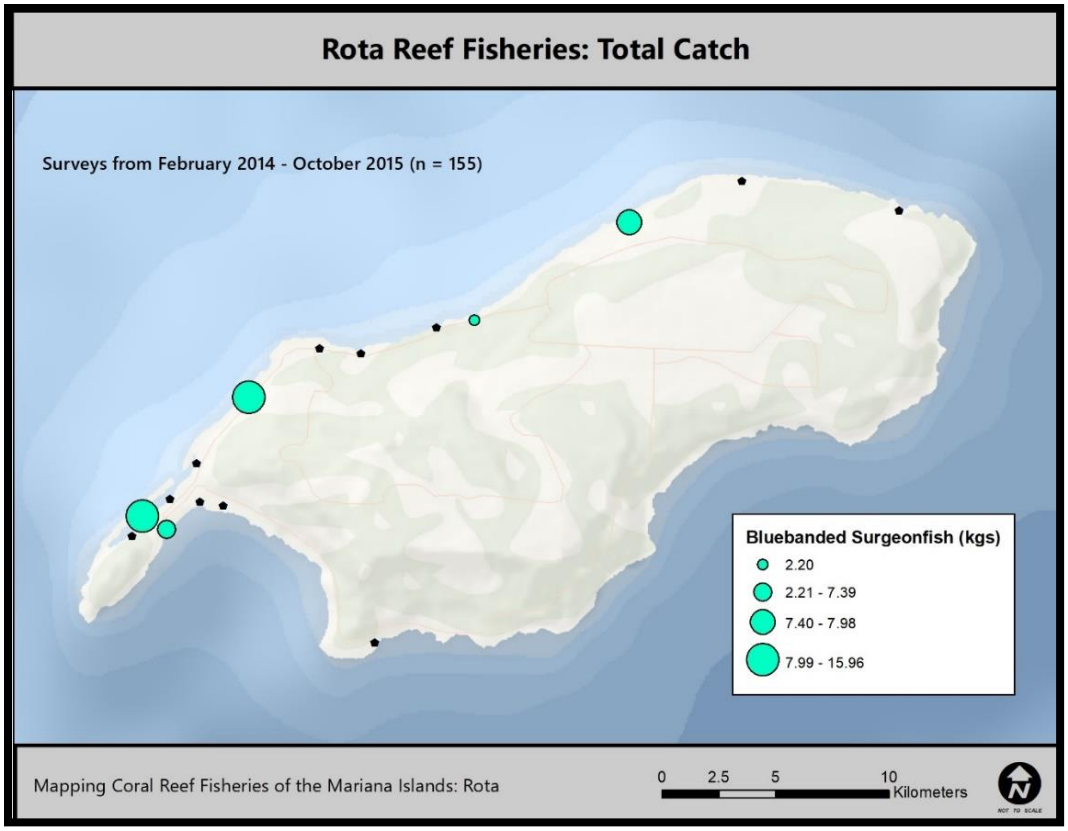

Figure A-14: Rota total shore-based catch: bluebanded surgeonfish (kg).

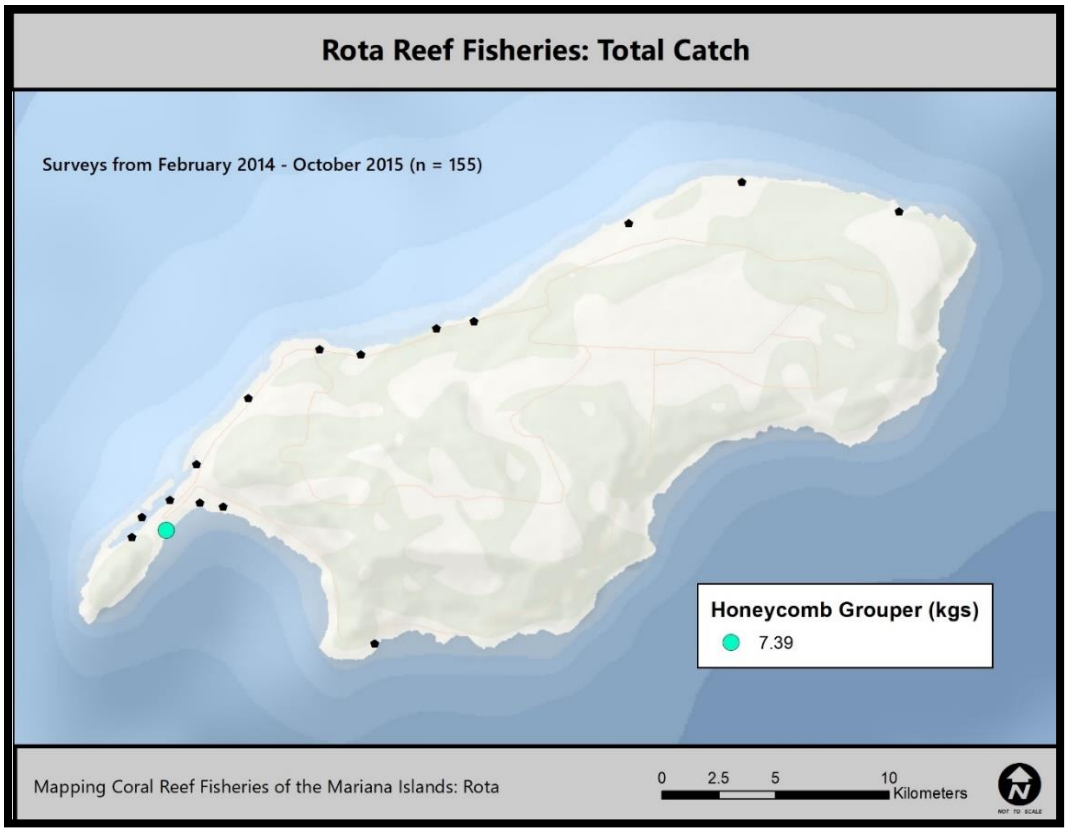

Figure A-15: Rota total shore-based catch: honeycomb grouper (kg).

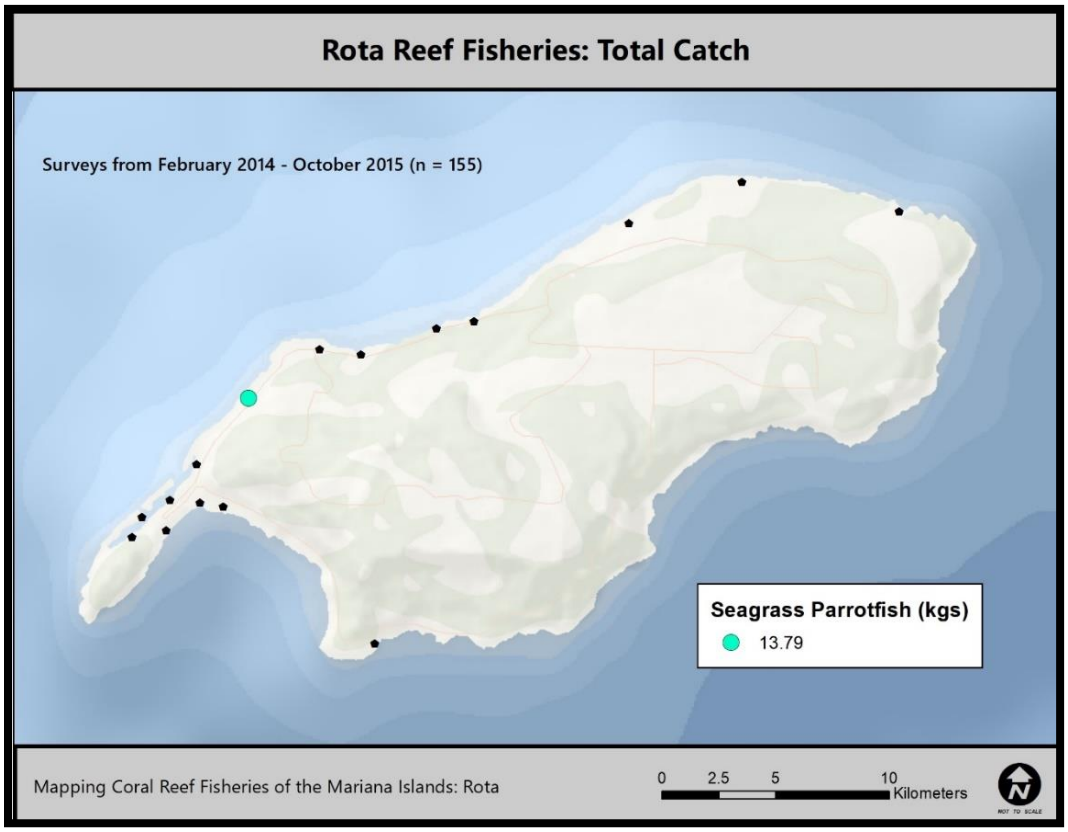

Figure A-16: Rota total shore-based catch: seagrass parrotfish (kg).

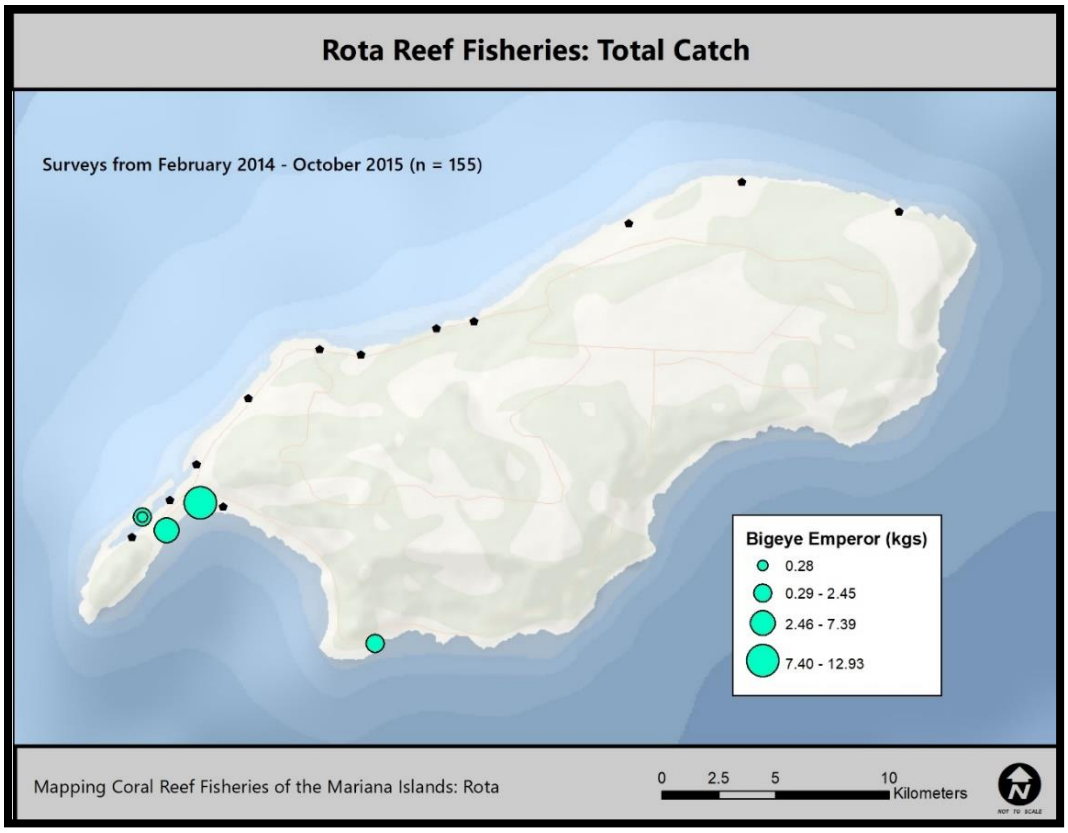

Figure A-17: Rota total shore-based catch: bigeye emperor (kg).

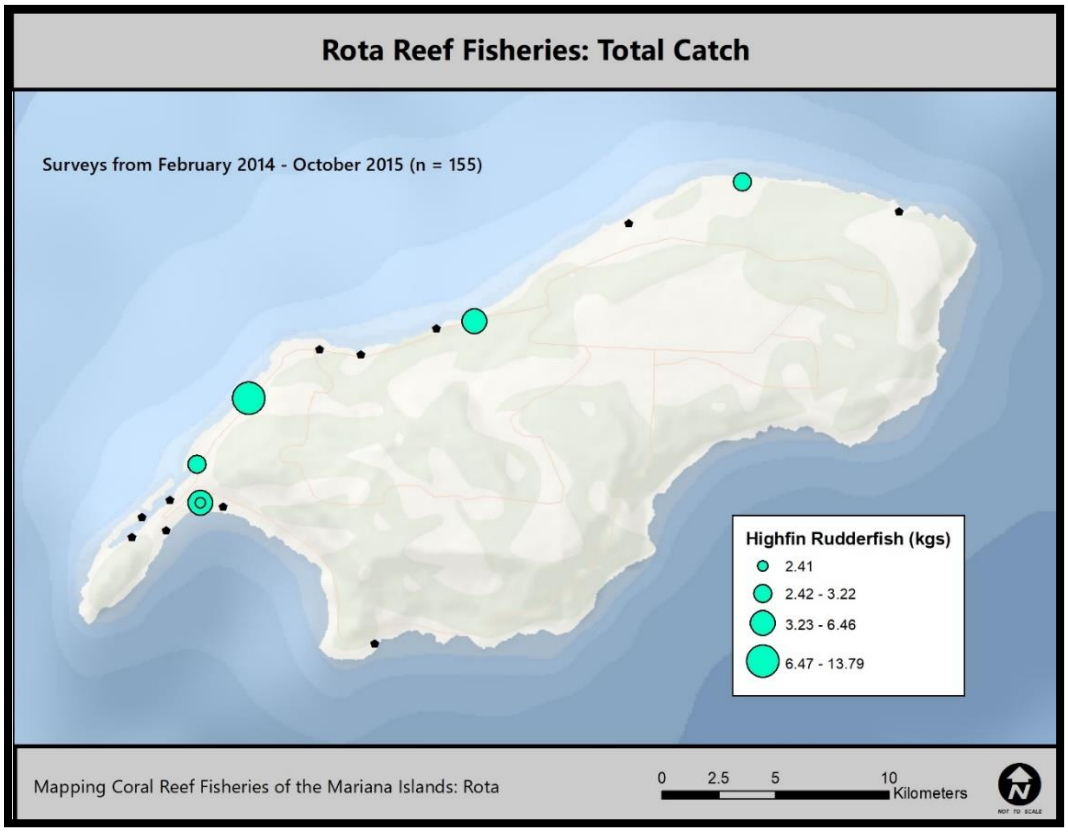

Figure A-18: Rota total shore-based catch: highfin rudderfish (kg).

Appendix B: Selected PGIS Maps for Saipan, Tinian, and Rota

The maps on the following pages represent a sample of the final map results from the PGIS study. A total of 43 maps were produced covering six different “fields”, or categories of information: access type, frequency, gear-method, shift, species, and issues. The full catalogue of maps, including higher resolution versions of the 14 found on the following pages, can be found in the *CNMI Reef Fisheries Map Atlas* that accompanies this report.

Table of Maps

Saipan selected PGIS maps

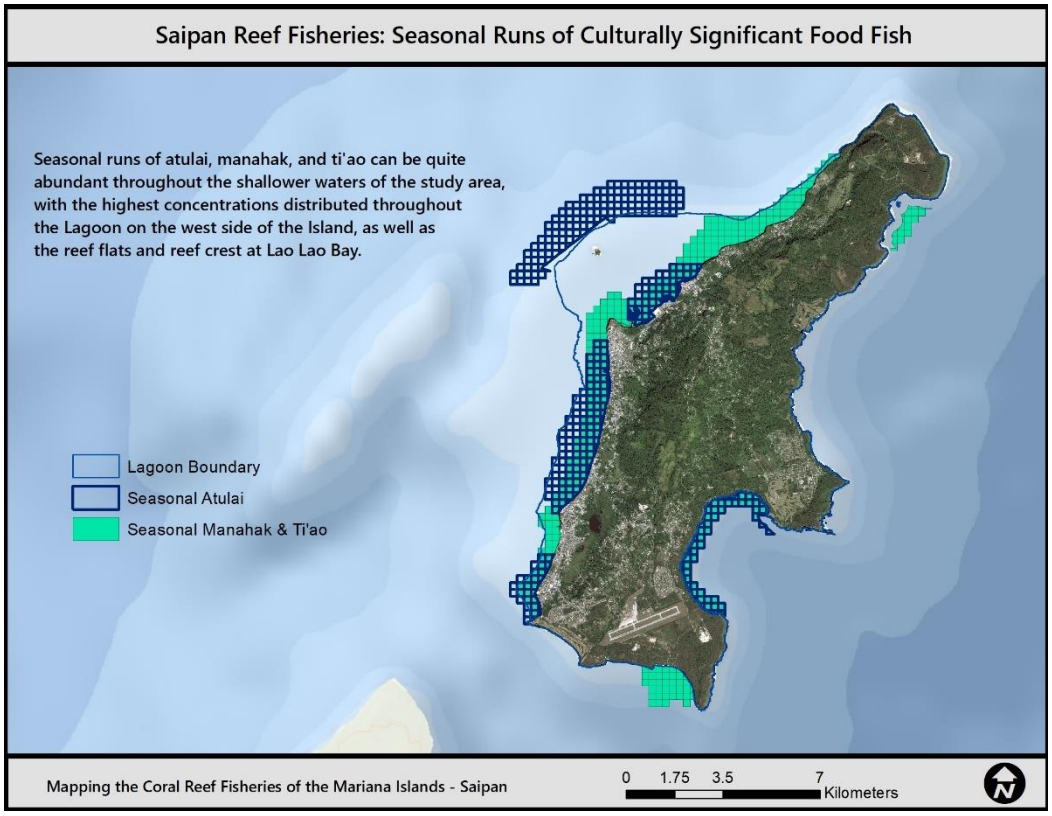

Figure B-1: Saipan seasonal runs of culturally significant food fish (atulai, manahak, ti'ao).

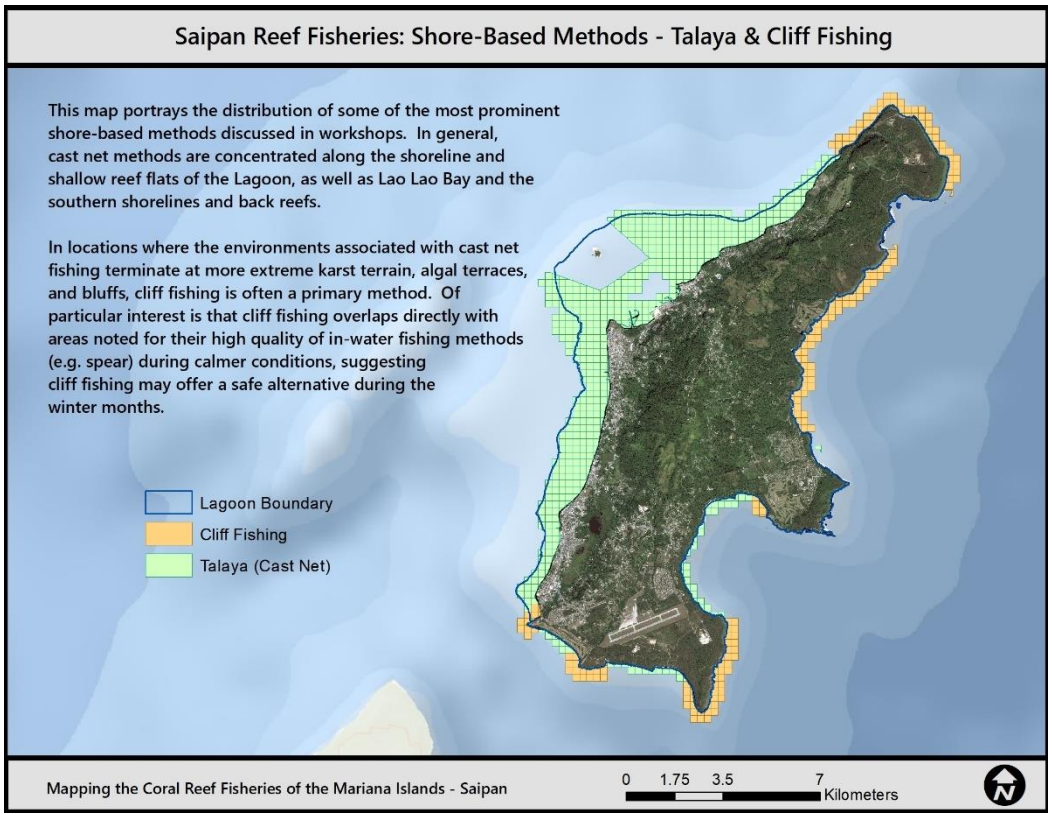

Figure B-2: Saipan distribution of talaya (cast net) and cliff fishing.

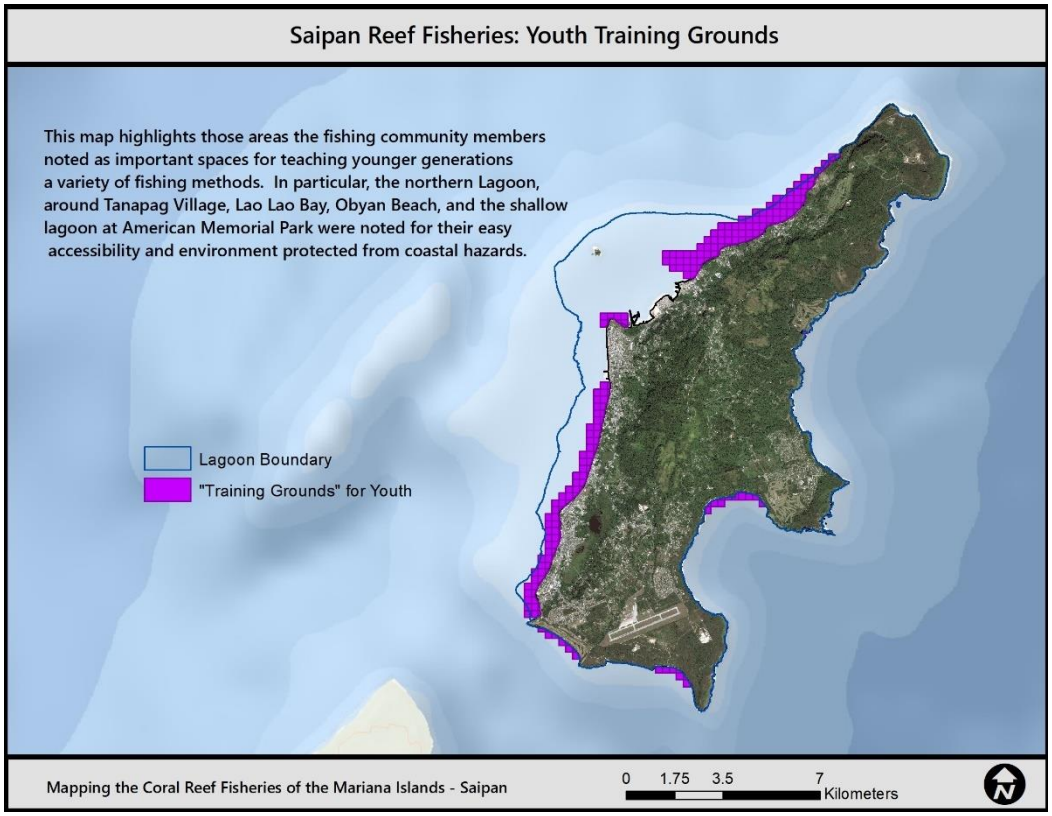

Figure B-3: Saipan "training grounds", used to teach younger generations different fishing methods.

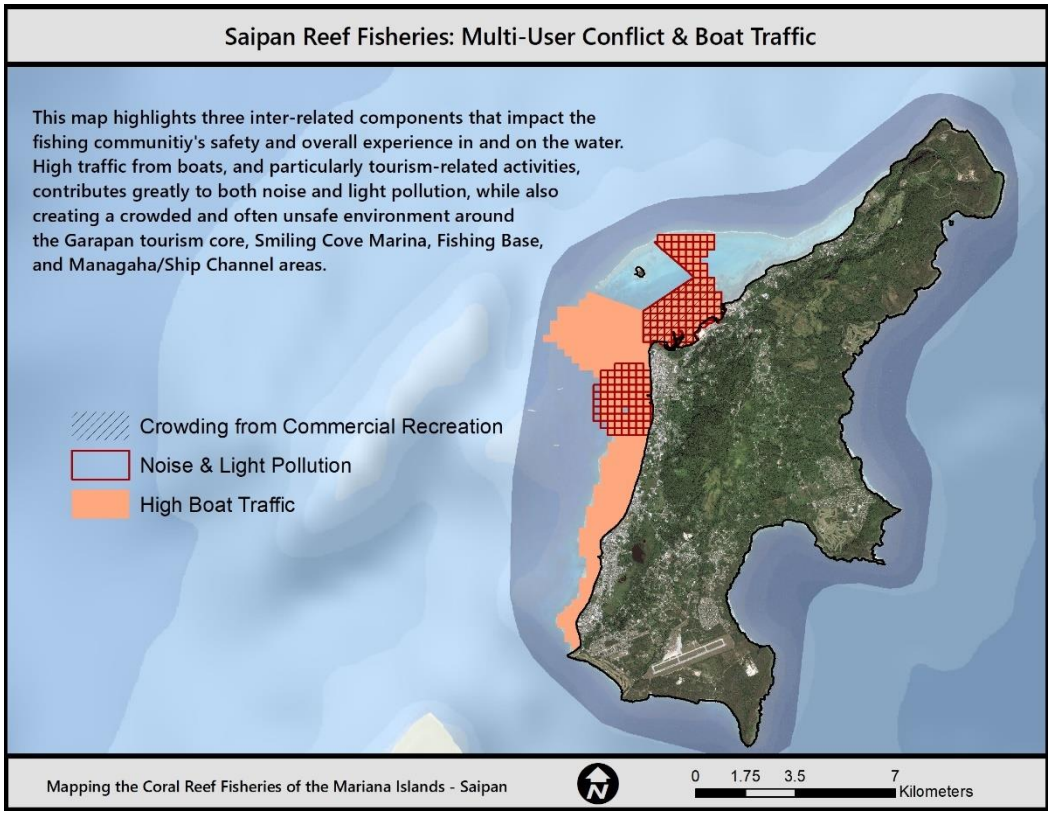

Figure B-4: Saipan conflict areas due to multi-user crowding and noise & light pollution.

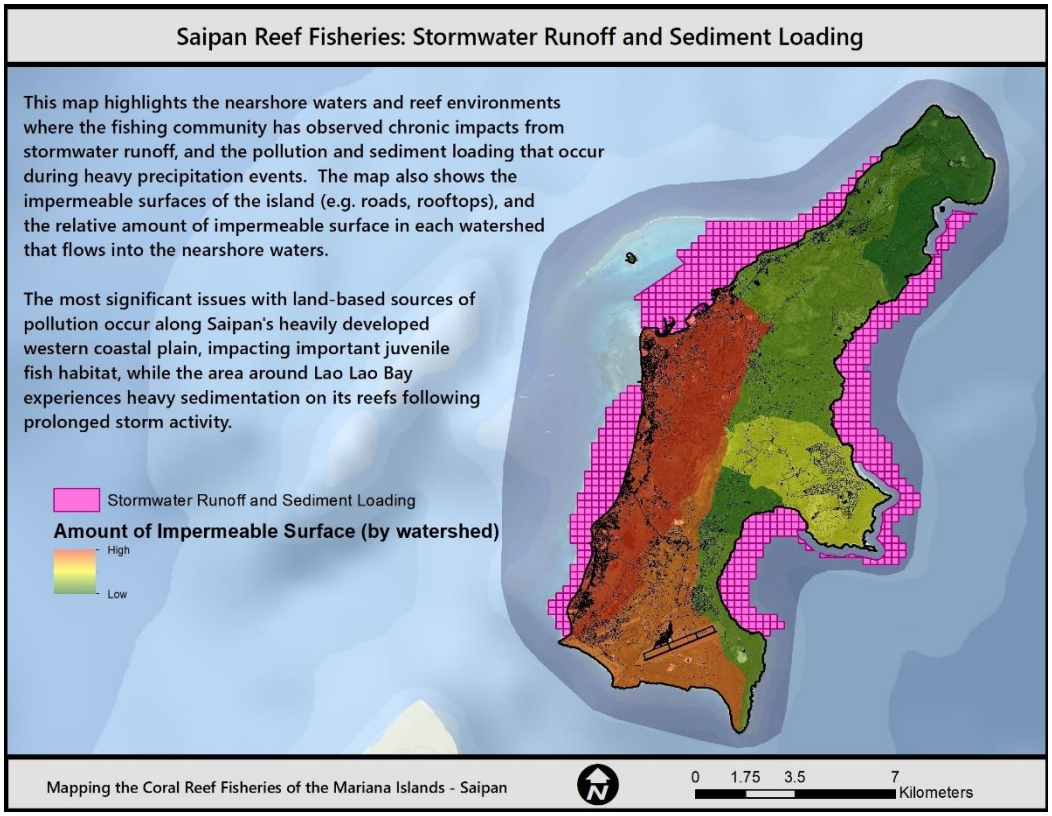

Figure B-5: Saipan issues with stormwater runoff as compared to amount of upland impermeable surface.

Tinian selected PGIS maps

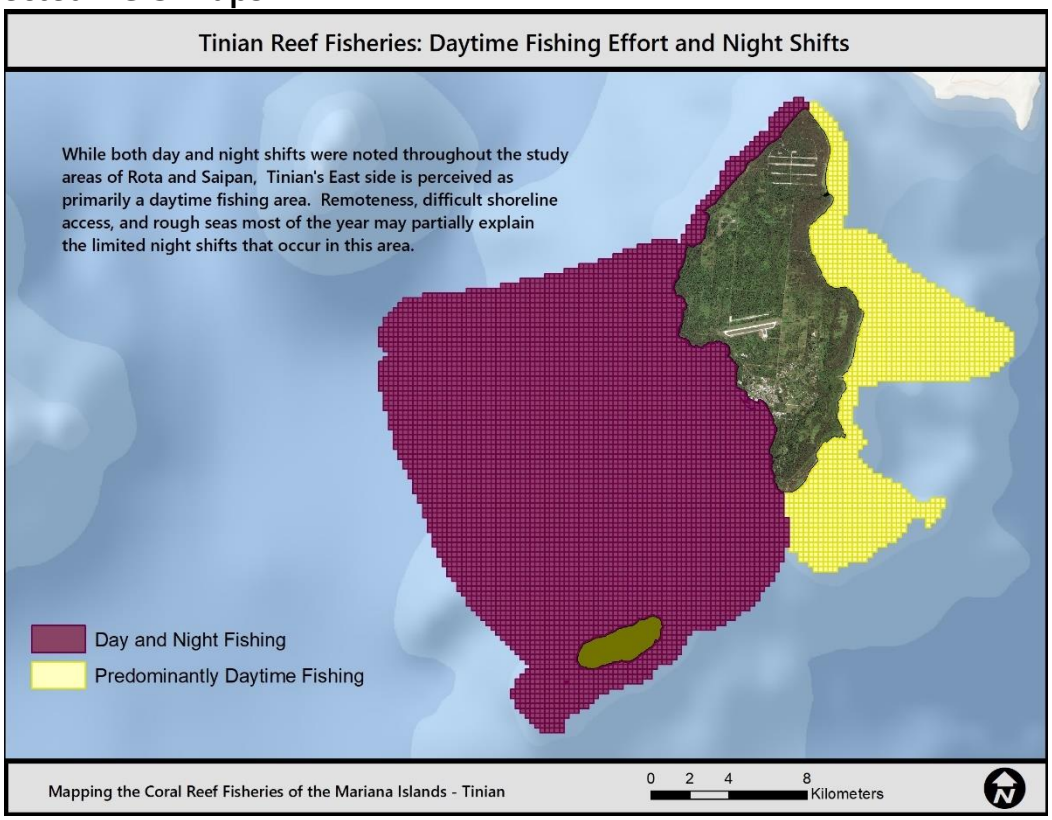

Figure B-6: Tinian day and night fishing versus predominantly daytime fishing.

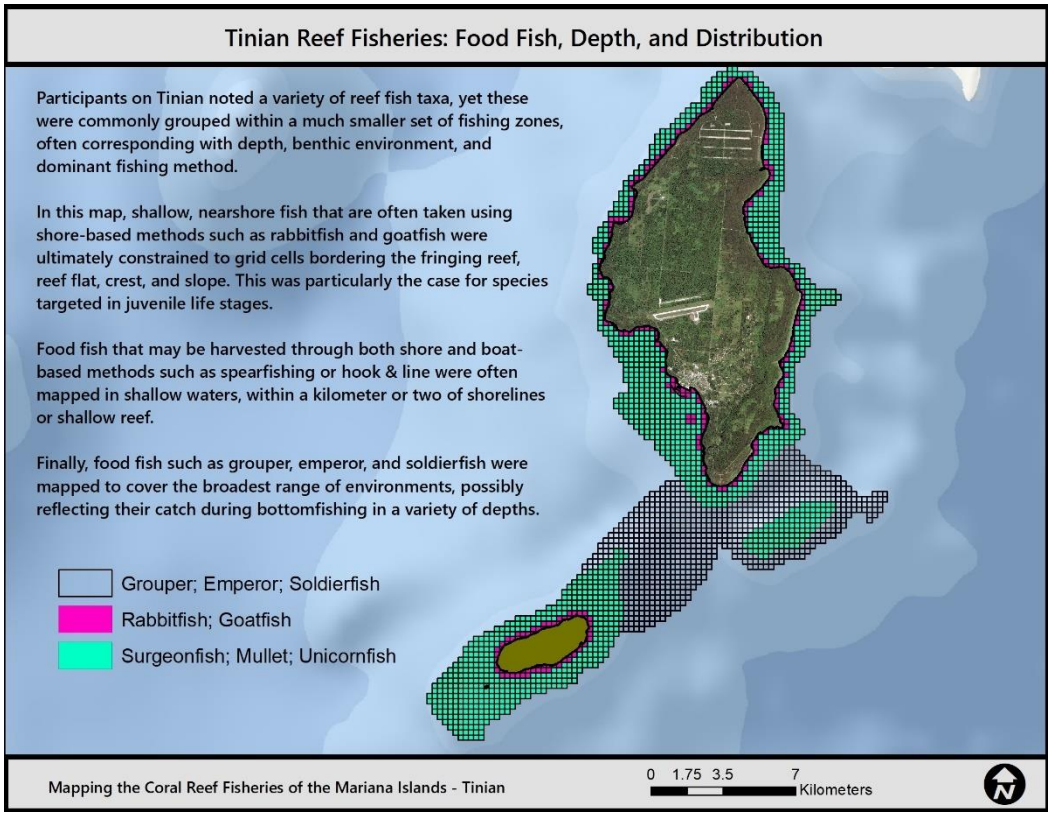

Figure B-7: Tinian food fish distribution by depth and distance from shore.

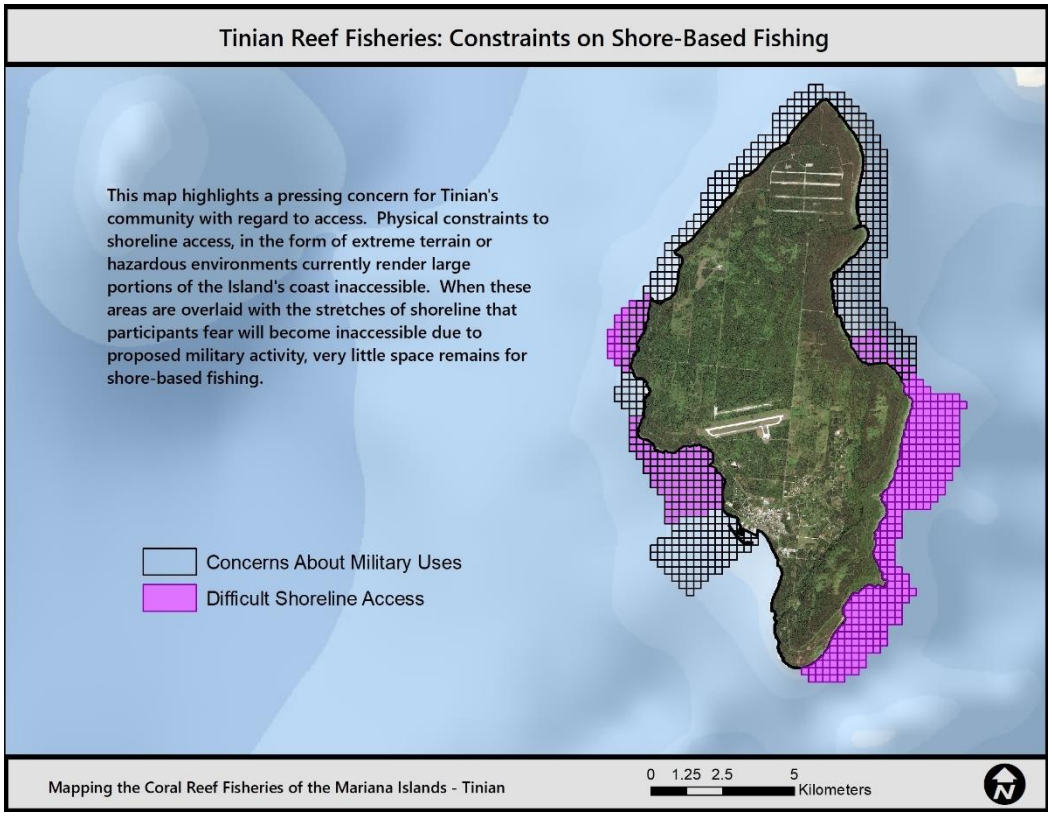

Figure B-8: Tinian issues with difficult shoreline access as compared to potential military closures.

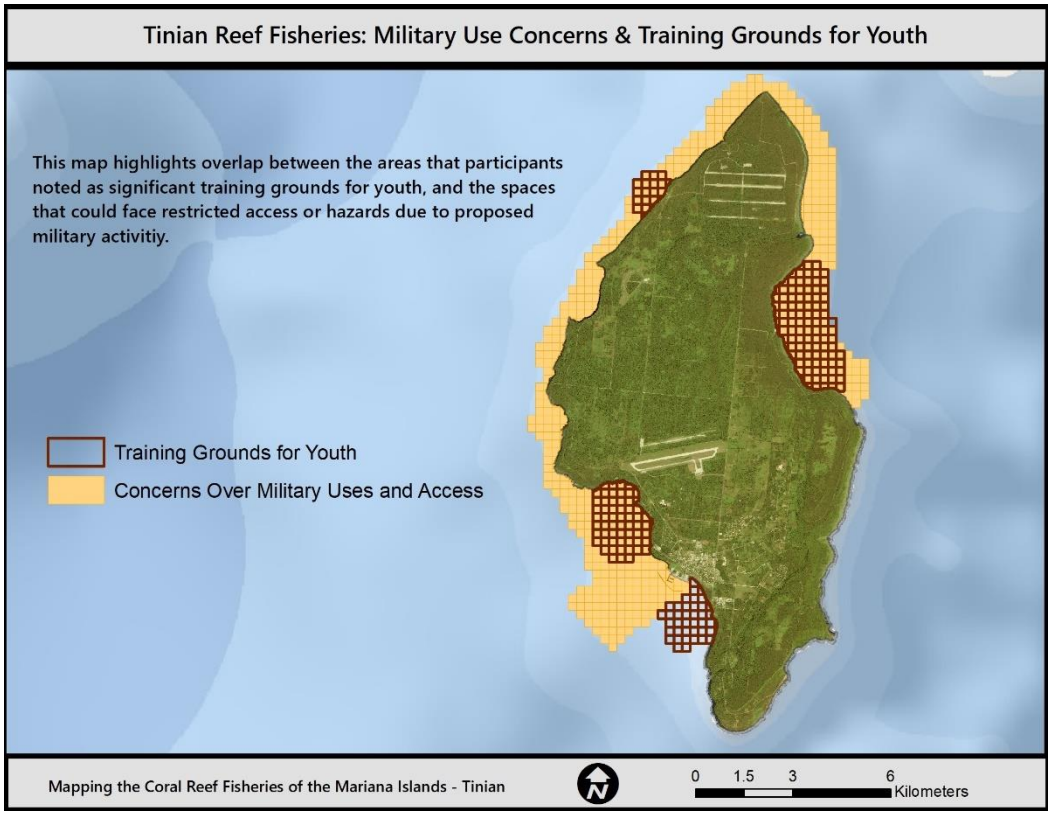

Figure B-9: Tinian "training grounds" for younger generations as compared to potential military closures.

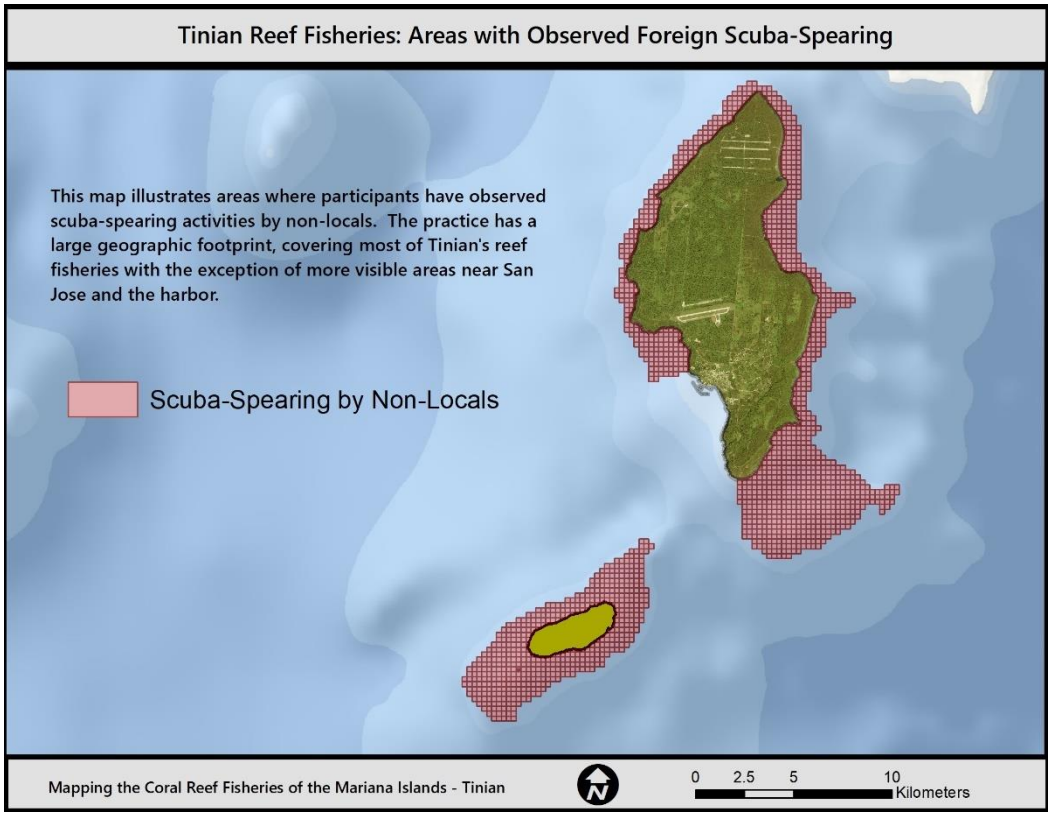

Figure B-10: Tinian areas with observed illegal SCUBA-spearfishing by non-locals.

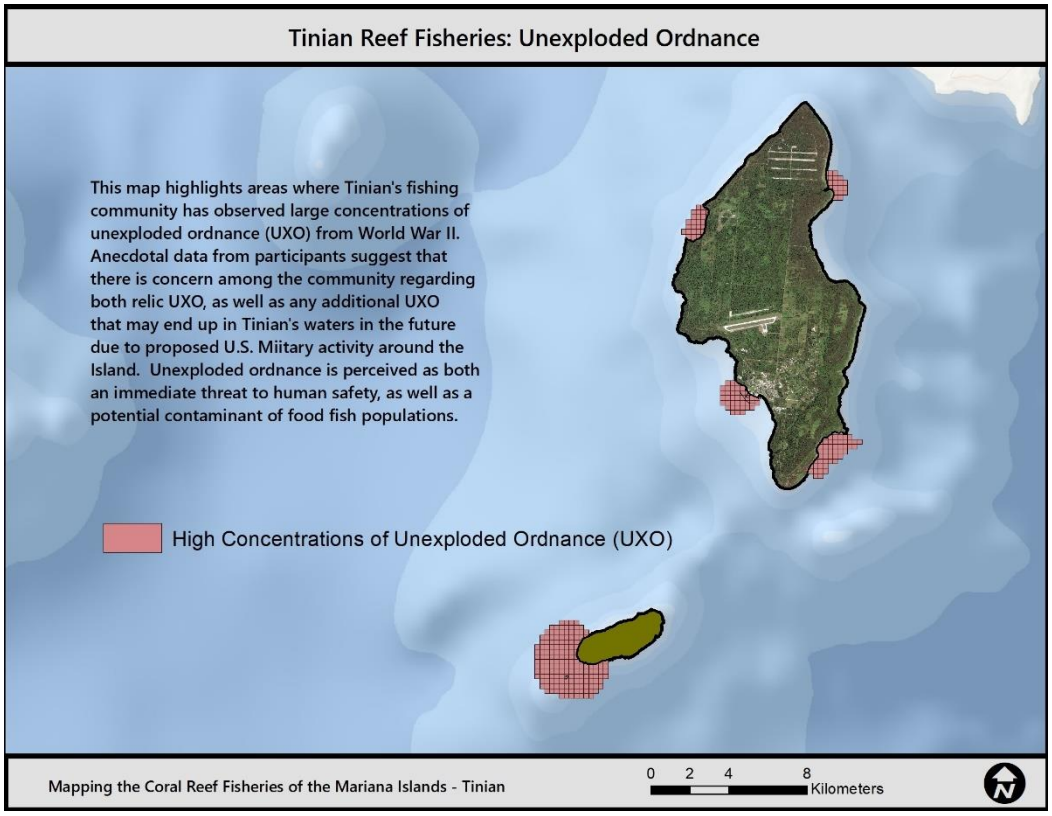

Figure B-11: Tinian fishing community observations of high concentrations of underwater unexploded ordnance (UXO).

Rota selected PGIS maps

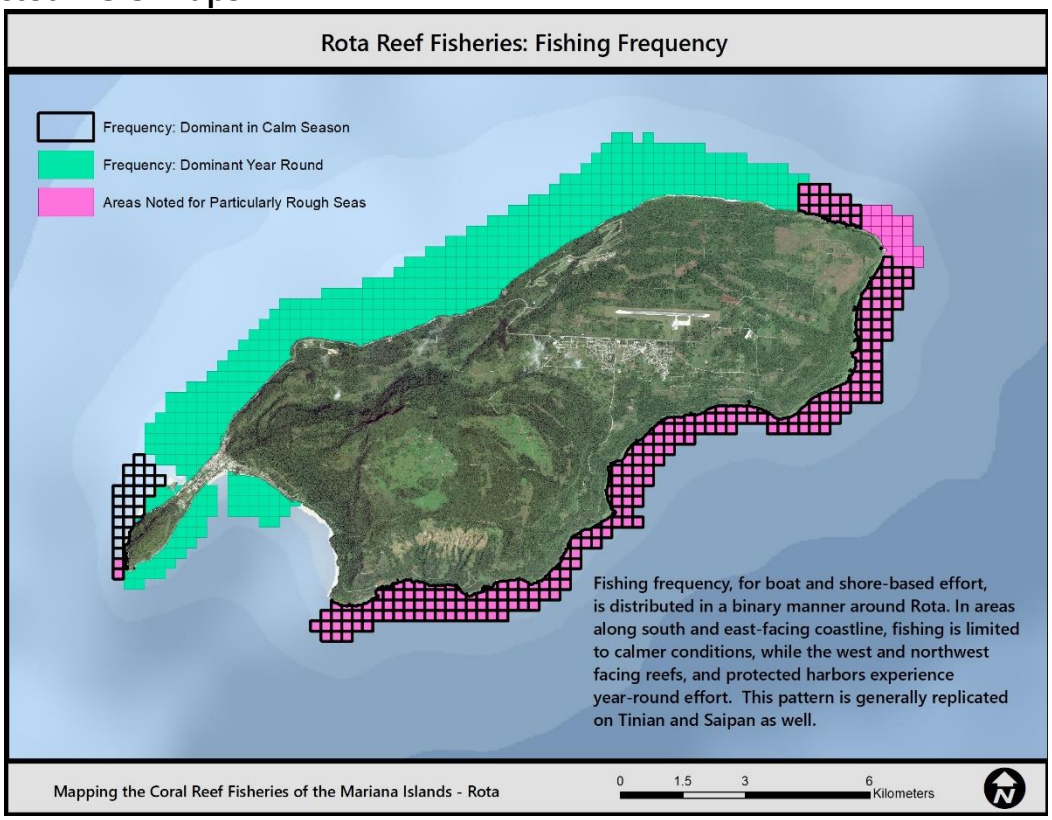

Figure B-12: Rota year-round versus calm-season fishing frequency.

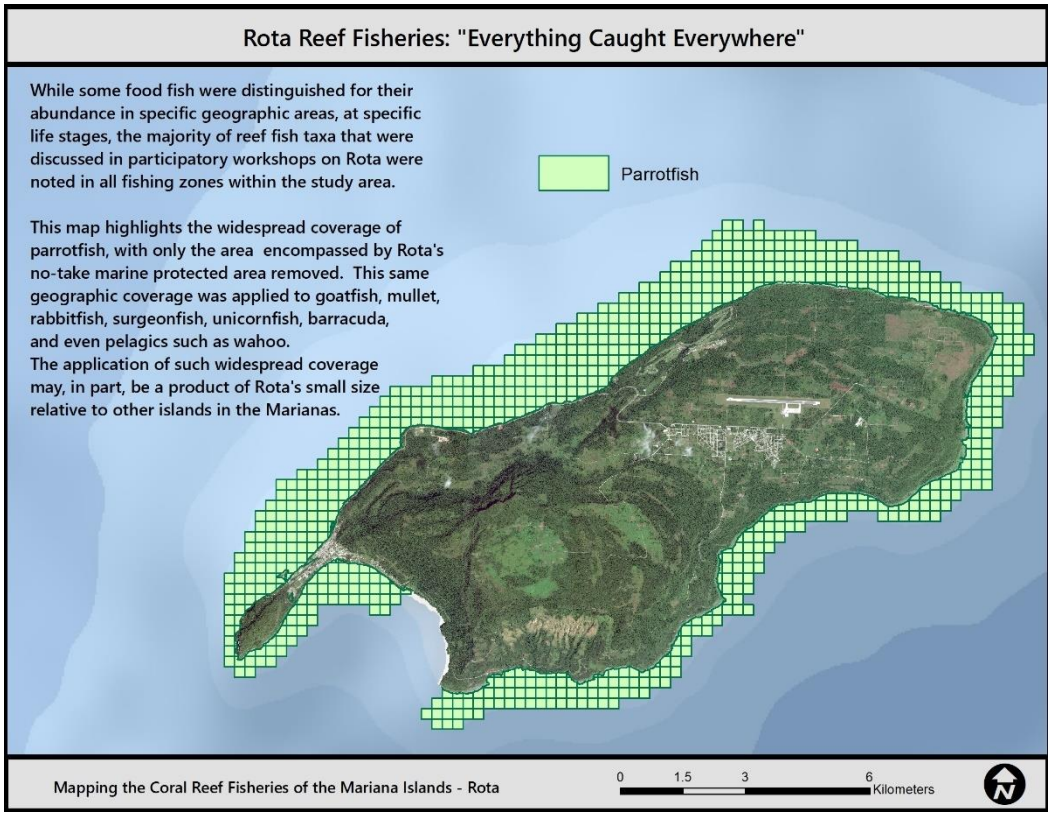

Figure B-13: "Everything Caught Everywhere" - Rota species-specific fishing effort for parrotfish and most reef species.

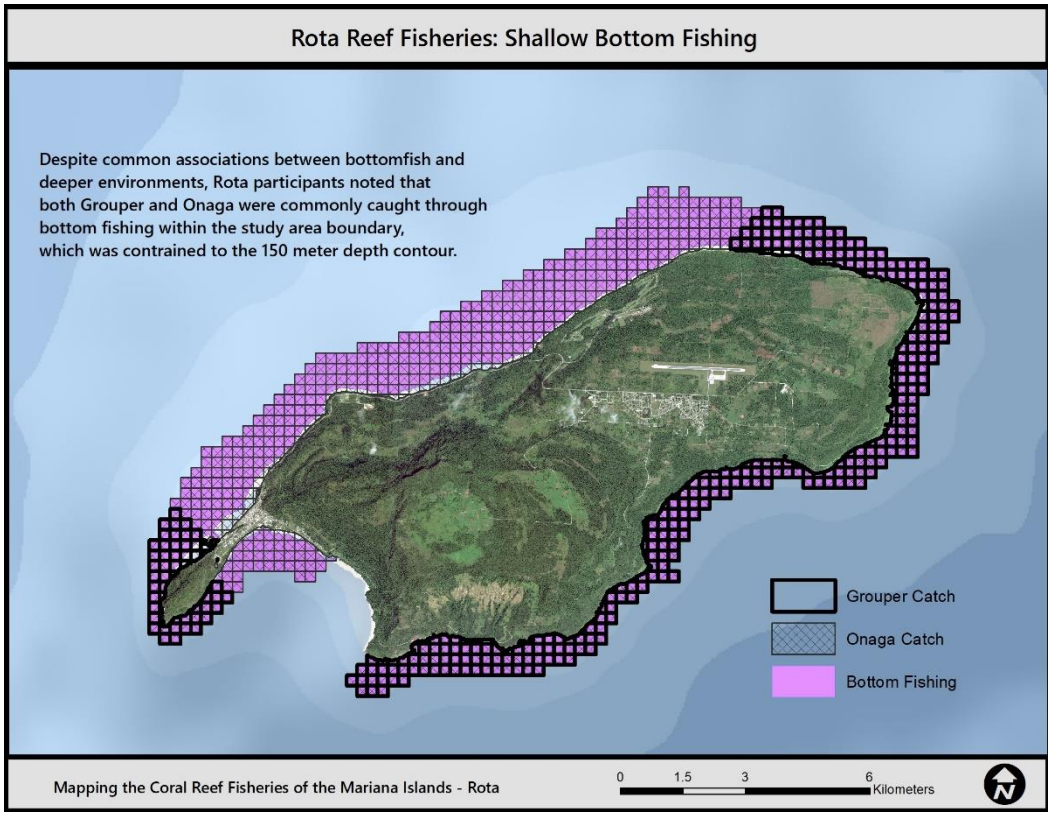

Figure B-14: Rota shallow-bottom fishing, specific to grouper and onaga.

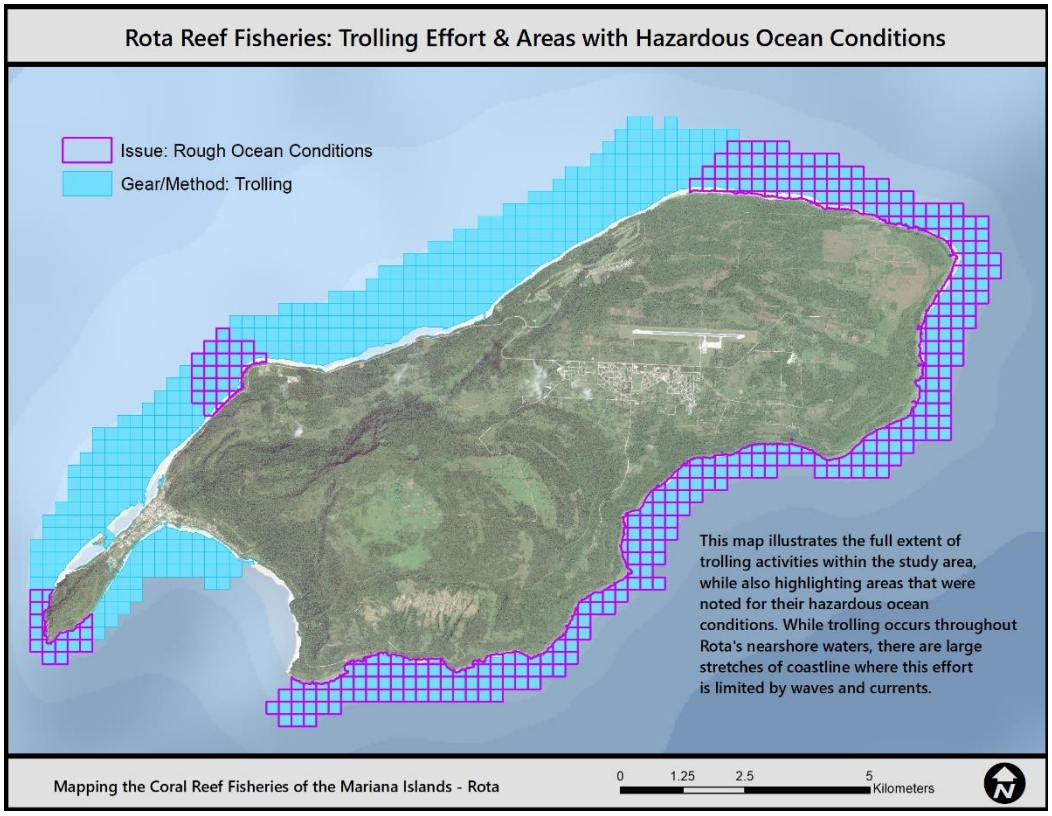

Figure B-15: Rota trolling effort as compared to areas with hazardous ocean conditions.

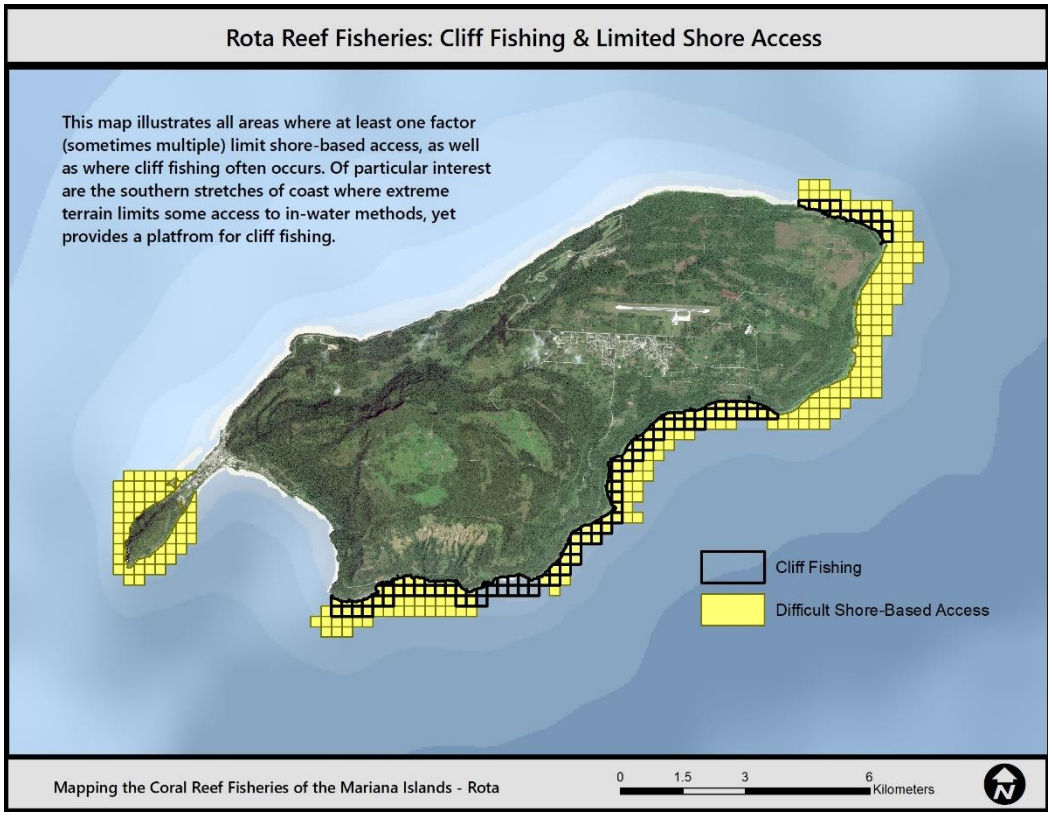

Figure B-16: Rota cliff fishing as compared to areas with difficult shore-based access.