2016

# Mapping the Coral Reef Fisheries of the Mariana Islands

## AN ATLAS OF GUAM'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 Guam'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. The study and its associated products are intended to supplement existing fisheries data from the island of Guam with a range of geographic datasets that were derived from the experiences of Guam's fishing community. Using multiple participatory mapping techniques, this project resulted in a variety of spatial data that tells a geographically explicit story. The following pages describe this process and its outcomes.**

## Use Limitations

**The results presented in this report and the accompanying *Guam Reef Fisheries Atlas* are intended to provide a general portrait of fisheries 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 Guam's fishing community.**

## Credit

**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 Guam Fishermen's Cooperative Association and other members of the Guam fishing community. 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 information to this project, including the Guam Division of Aquatic and Wildlife Resources, 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 2016 Guam's fishing community and aquatic resource stewards were engaged in a participatory mapping project to both identify and fill knowledge gaps pertaining to Guam's coral reef fisheries. 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 from 1982 through 2014 and other relevant fisheries information were joined in a geographic information system in order to identify the spatial coverage of fisheries data, and delineate areas that might have potential knowledge gaps. Members of the fishing community and Fishermen's Co-op, local liaisons to the Western Pacific Regional Fishery Management Council, 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 as a way of geo-referencing local knowledge.**

***Data processing and GPS data collection:* Data collected from an initial participatory mapping workshop was edited and processed to match existing geographic boundaries of nearshore fisheries data, and attribution for that data was developed in a manner that would be compatible with existing analytical tools. In addition, GPS units were distributed to six citizen science volunteers in order to document boat-based fishing effort over a three month period from June through September.**

***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

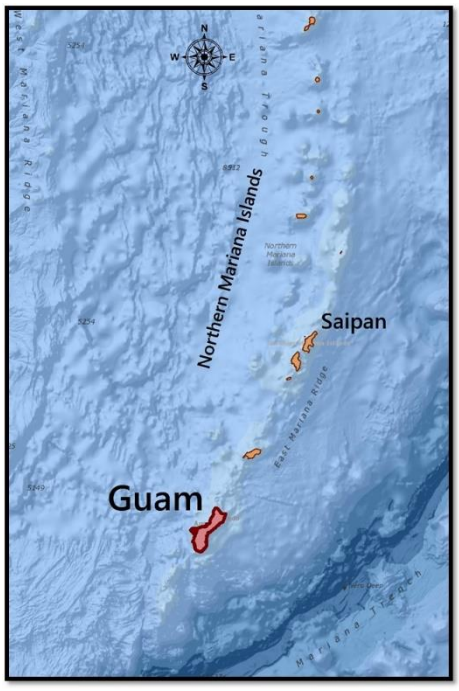
## Purpose and Intent

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 Guam's coral reef fisheries and fishing effort.

Based directly upon the robust, experience-based knowledge that Guam'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 Guam'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.

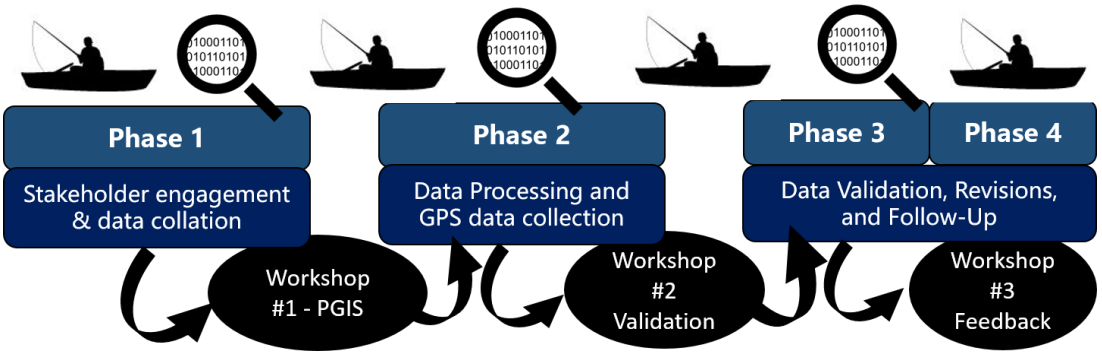
1: Context Map of the Mariana Islands




## Project Approach and Methodology

At its core this project was a participatory mapping initiative that assumed structured discussions about Guam'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.




2: Diagram of Project Sequence

The first phase of this work centered on stakeholder engagement and review of existing reef fisheries data in order to better understand Guam's nearshore and inshore fishing effort, and how the community has been involved in the past. Creel data from 1982 through 2014 was provided by NOAA's Pacific Islands Fisheries Science Center at the same time that spatial data related to creel survey zones throughout Guam were procured from the author of a marine megafauna study of Guam (Martin, S.L. et. al, 2015). These two datasets were linked within a geographic information system (GIS) in order 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.

At this same time creel data collectors, members of the fishing community and Fishermen's Co-op, and 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 community, along with invitations to an initial participatory mapping workshop 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 during opportunistic creel surveys around the island, as well as among various Mayor's offices.

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 late June through late 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 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

Prior to designing any sort of participatory mapping protocol or data collection scheme, it was crucial that the project consider existing reef fisheries data within a geographic context. This was accomplished primarily by linking the boundaries of creel survey zones with survey records pertaining to both participation and species. Both sets of data (surveys and zone boundaries) were procured in the initial stage of the project through the Pacific Islands Fisheries Science Center (via the Western Pacific Fisheries Information Network), and through researchers that had recently developed spatial data pertaining to Guam's survey zone delineations (see *Martin et. al, 2015*). It should be noted that there are a number of caveats and limitations to Guam's creel data, which were underscored in the initial creel data package. These limitations are highlighted by the following two issues:

- For shore-based data, the entirety of Guam's shoreline cannot be covered as areas that are more difficult to access due to topography or military activity end up being either under-represented, or in some cases not sampled at all.
- The creel survey shifts generally occur between 6:00 am and 6:00 pm, so it would be reasonable to suggest that a significant portion of fishing effort (e.g. night shifts) goes un-surveyed.

Given these potential data gaps, an even stronger case is made for engaging the fishing community in participatory mapping studies. This idea steered the project's initial assessment of creel data toward identifying where those geographic gaps were.

### Integrating Creel Data with GIS

Creel data spanning the timeframe from 1982-2014 was joined to polygon features corresponding to 92 creel survey zones, plus a 300 meter seaward buffer from Guam's reef line (see *Martin et. al, 2015*), and was then imported into a geodatabase.

Query tables were built to establish a 'One to Many' relationship between the 92 shore-based creel zones and the creel data tables for shore based participation and species summaries.

Manual digitization of boat access points was necessary to create data with an ID field that would correspond with fields in the boat-based creel participation and species summaries. Digitization was based off of "coastal features" point data, published by the Guam Bureau of Statistics and Plans. Additional query tables were then built to establish a 'One to Many' relationship between boat-based access (survey) points and boat-based creel data summaries.

The datasets described above were examined within GIS, with a particular focus on geographic representation and spatial gaps between effort summary records from 1982-2014. In addition, all records for ten individual species that were recently identified as priorities for Guam fisheries

management (*Pacific Islands Fisheries Science Center, 2014*) were assessed for geographic distribution of their shore-based catch. A separate document detailing processing steps and field name mapping for creel spatial data was packaged with the creel geodatabase and provided to the Western Pacific Regional Fisheries Management Council.

**3: Creel Data Fields**

| Shore-Based Fields from Creel Table | Boat-Based Fields from Creel Table |
|---|---|
| Record ID | Record ID |
| Year | Year |
| Location/Creel Zone Code | Location/Boat Access Code |
| Location/Creel Zone Name | Location/Boat Access Name |
| Shift | Method Code |
| Method Code | Method Name |
| Method Name | Number of Interviews |
| Number of Interviews | Species Code |
| Species Code | Species Name |
| Species Common Name | Interview Kilograms |
| Kilograms in Interviews | |
| Gear Hours in Interviews | |

## Linkage to Benthic Data

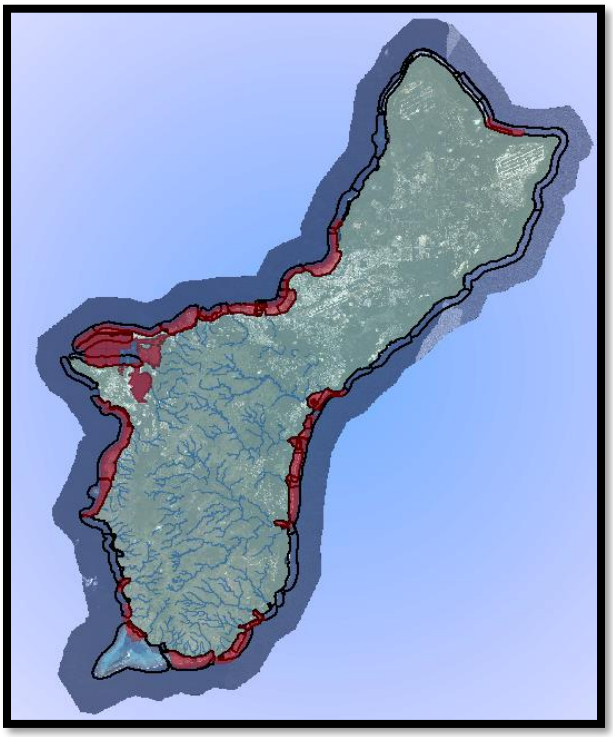
Detailed benthic cover data (see *D. Burdick, 2005-2007* in *Spatial Data References*) were brought into GIS, and a geometric union was performed to join benthic habitat features to the 92 creel zones. The

intent for this dataset was to enable summarization of benthic habitats associated with various creel survey areas and their related species data. The feasibility of establishing useful associations between benthic data and survey data was considerably limited due to the size of each zone. Most of the polygons contained the vast majority of benthic structure and cover values, therefore a more precise delineation of species catch area is necessary to understand these associations. The participatory mapping data resulting from this project may provide an alternative set of boundaries for analyzing benthic composition in relation to particular fish species or families.

## Spatial Assessment

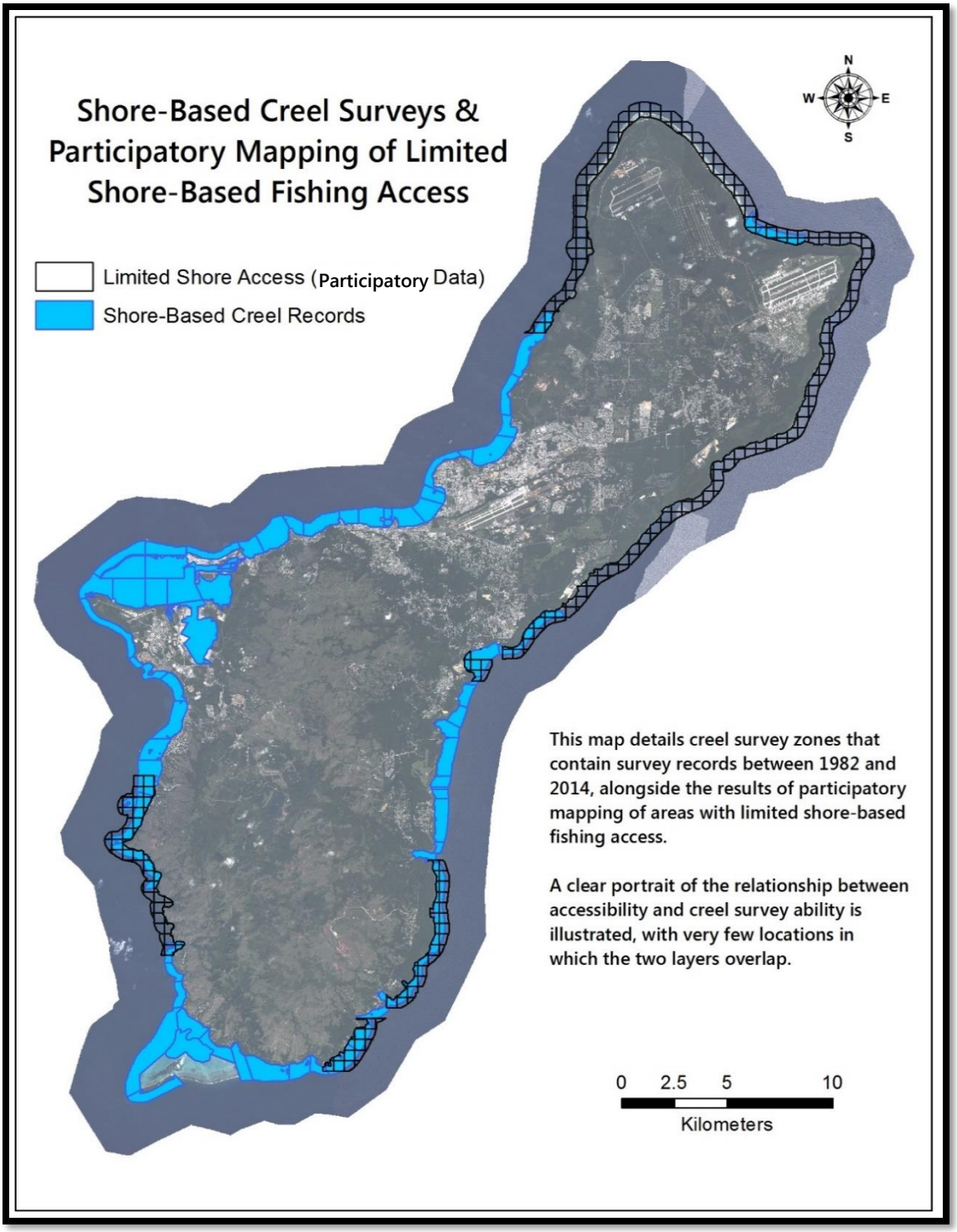
Shore-Based participation records were examined to better understand the subset of 92 survey zones in which data had been collected and procured. This was performed with respect to both overall effort, as well as species-specific data. Geographic gaps among shore-based data were later compared with the initial delineations of fishing areas that participants in the mapping workshops identified. This assisted in understanding where participatory mapping results would potentially fill some areas that were missing surveys.

Shore-based creel interviews were limited to areas that generally offer public access, manageable topography, and non-hazardous conditions. This map illustrates the extent of most shore-based creel surveys (in red), with general fishing areas identified by participatory mapping outlined in black. Significant data gaps exist for fishing effort on east and north sides of the island. These areas were also noted for their limited shore-based access, remoteness, and potentially hazardous ocean conditions. Considering these limitations, gaps are to be expected. This project made an initial effort to fill these holes, but these limitations should be held in consideration for future data collection efforts.



**4: Creel survey zones and participatory map zones**

A more detailed map of creel survey extents and results of participatory mapping is presented on the following page, illustrating the areas that the fishing community felt had limited shore-based fishing access.




**5: Shore-based creel surveys and limitations to shore access**

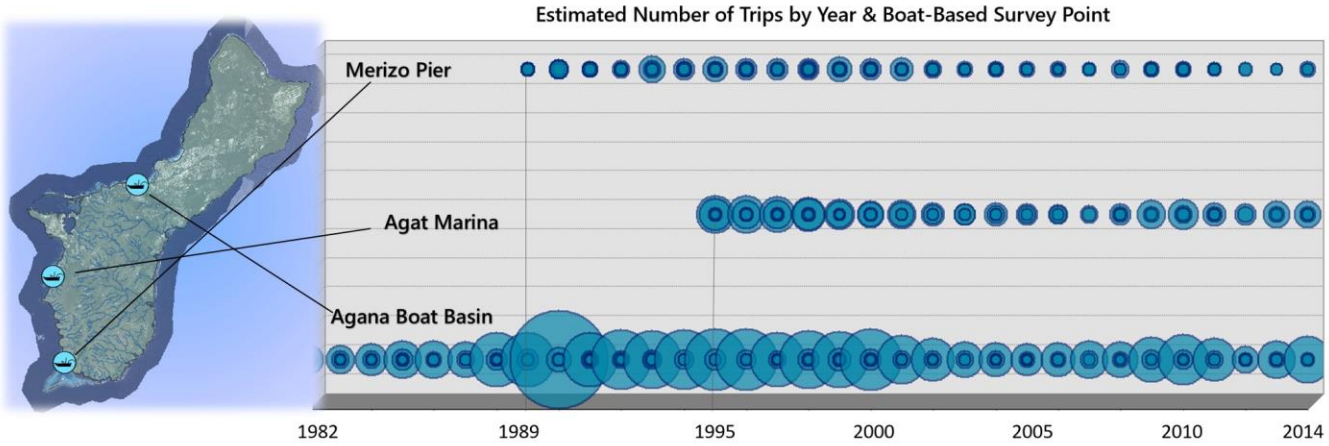
**Boat-based data is limited in geographic analytical capacity due to its spatial reference being constrained to just a few points, but records were examined to identify if boat-based effort yielded any trends over time between different launches.**

## Discussion

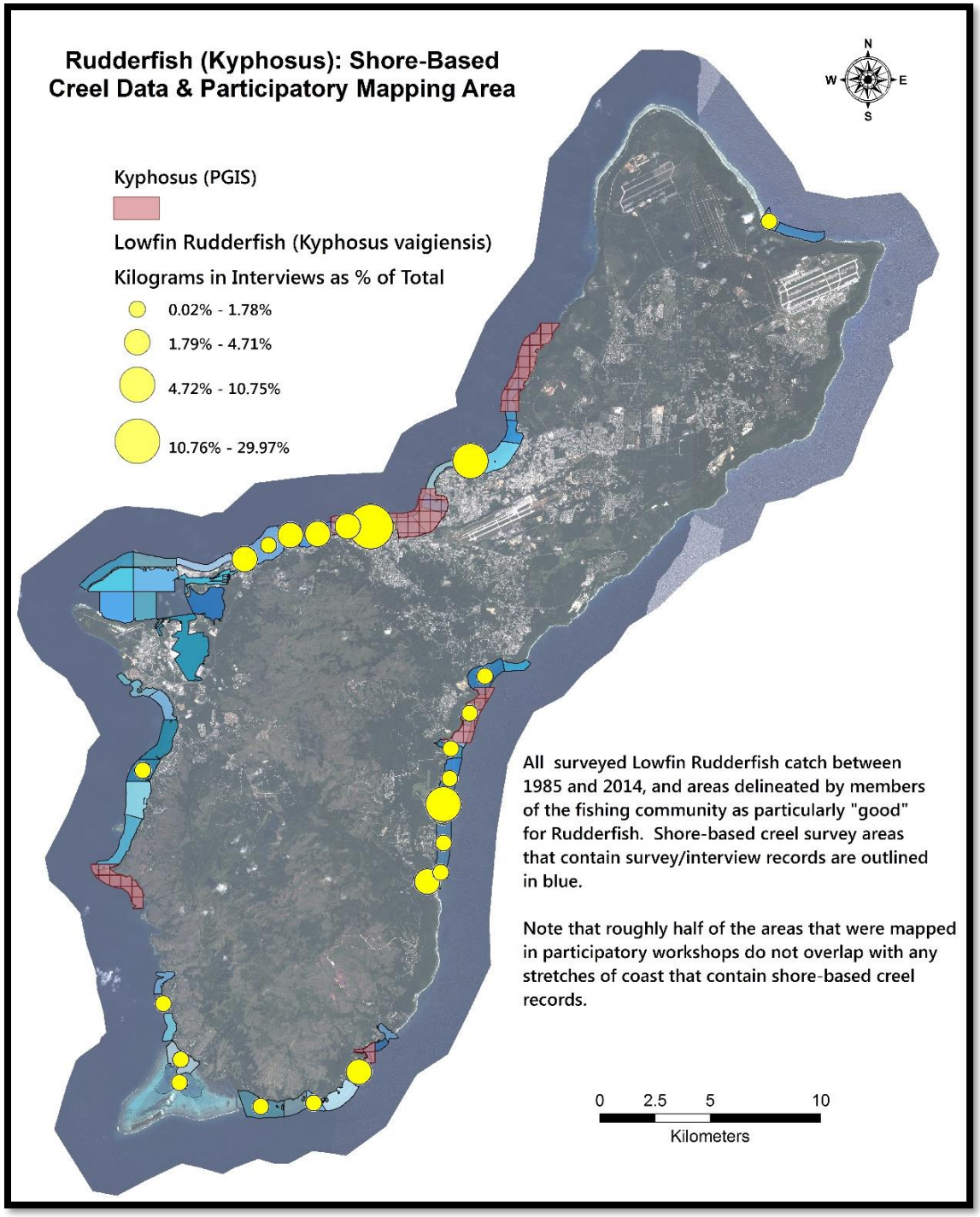
Significant spatial gaps exist between shore-based survey zones that contain data records. Large stretches of coastline with multiple survey zones have no records, while the majority of interview records are concentrated among a subset of polygons. Interestingly, these same sections of coast without creel records align closely with the largest polygons drawn by participants in mapping workshops. In the latter areas, limited access and low effort were noted by participants, and perhaps the largest generalizations about specific fishing grounds were made due to the wide coverage. This geographic alignment between absence of creel records and large participatory mapping features strongly supports the notion that access and frequency of fishing effort are potentially major factors that play into the ability to capture full geographic representation among fishing effort via field interview.

Even greater gaps are evident among species-specific data, wherein records exist for priority species in an even smaller subset of the 92 survey zones. An example of a comparison of shore-based species data pertaining to Lowfin Rudderfish (Kyphosus vaigiensis) to participatory mapping data is provided on the following page. Maps illustrating the geographic distribution of species-specific shore-based creel records are also provided in the following pages.

Concentrations of boat-based survey records at Guam's three main access points has remained fairly consistent over time, likely due to the capacity of launching areas and associated volume of trips at each point (see figure below).



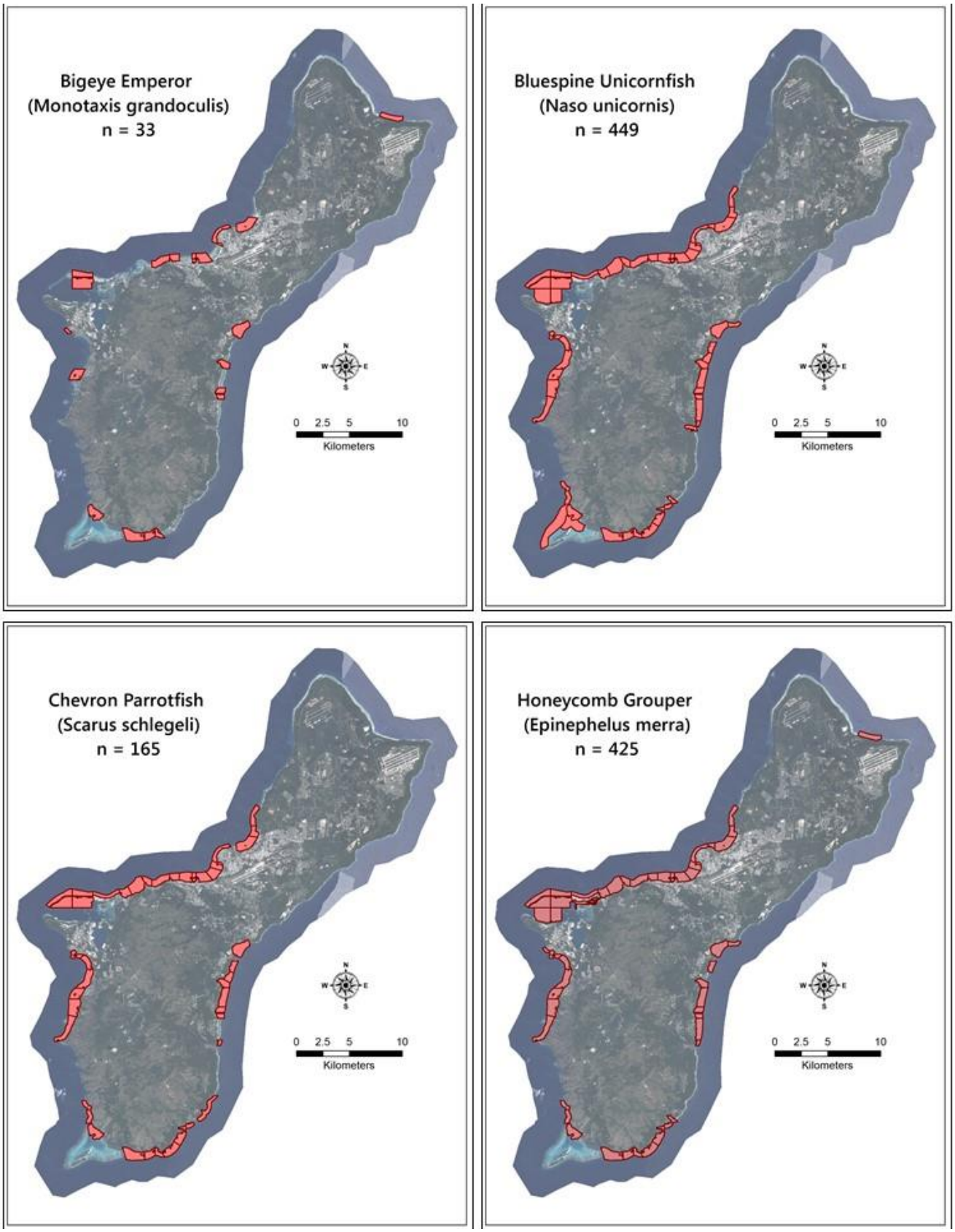

Later comparisons of this data with GPS field data from phase two of this project are consistent with this result, with boat-based launching hot-spots derived from GPS data aligning with the relative amount of interviews and survey data at those points. One potential means of mapping this data in future study would be to generate convex hulls (polygons) around boat-based GPS data points, and join survey data records from those points to the GPS data boundaries. This was not feasible in this project due to limited GPS data collection time and issues with confidentiality.

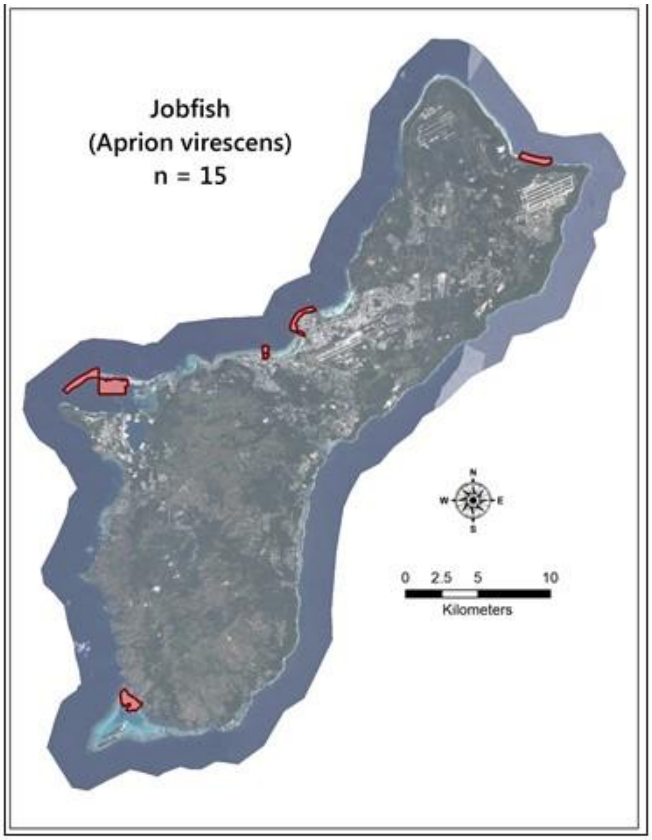


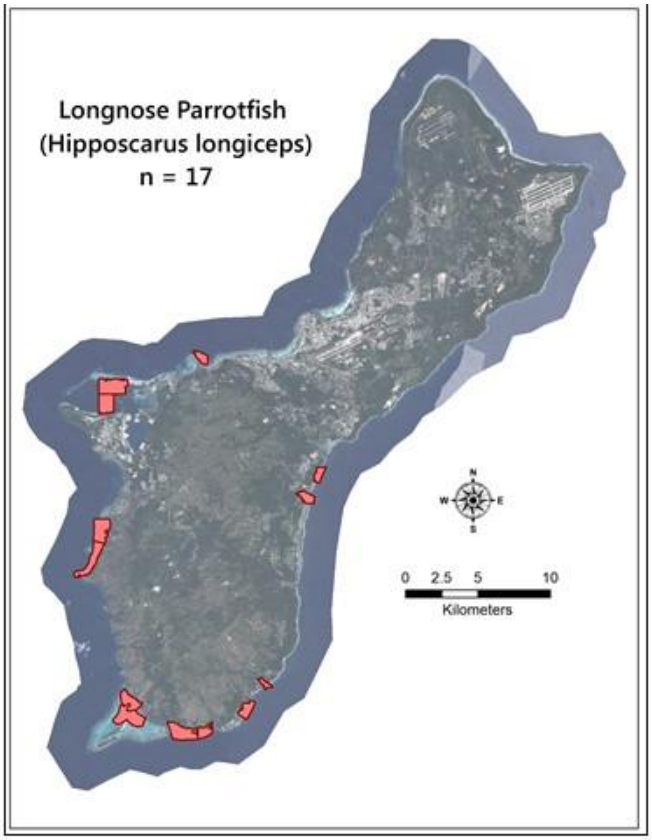

6: Creel records and participatory map of Rudderfish

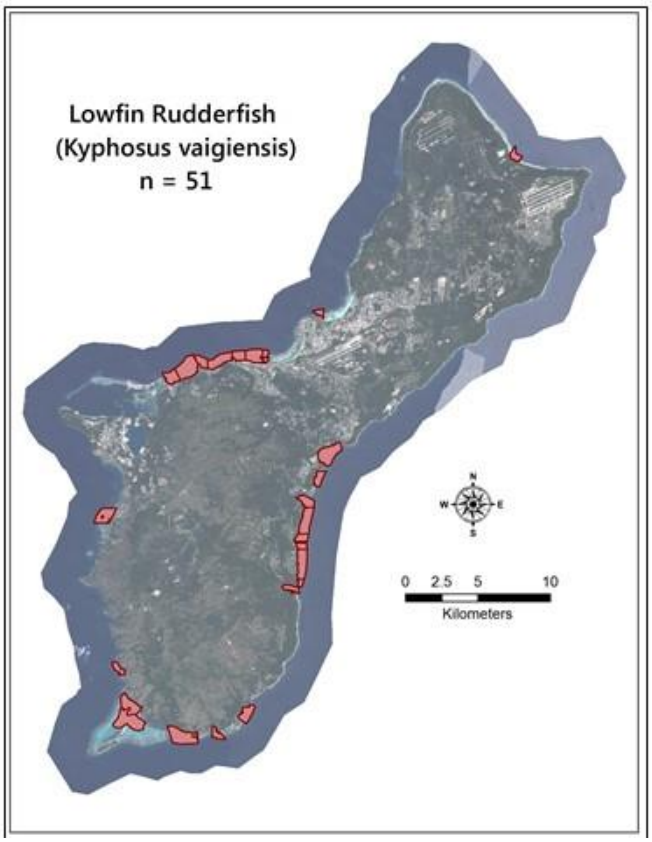
**The following pages contain maps illustrating the geographic distribution of creel survey zones that contain shore-based summary records for the ten species that have been prioritized for fisheries managers on Guam.**

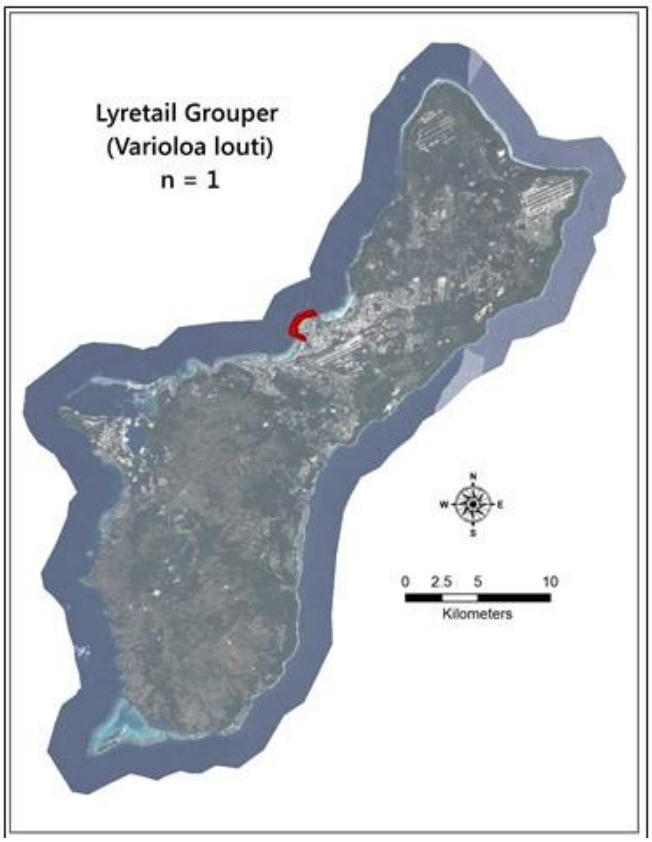
**7: Geographic distribution of creel records for priority species**

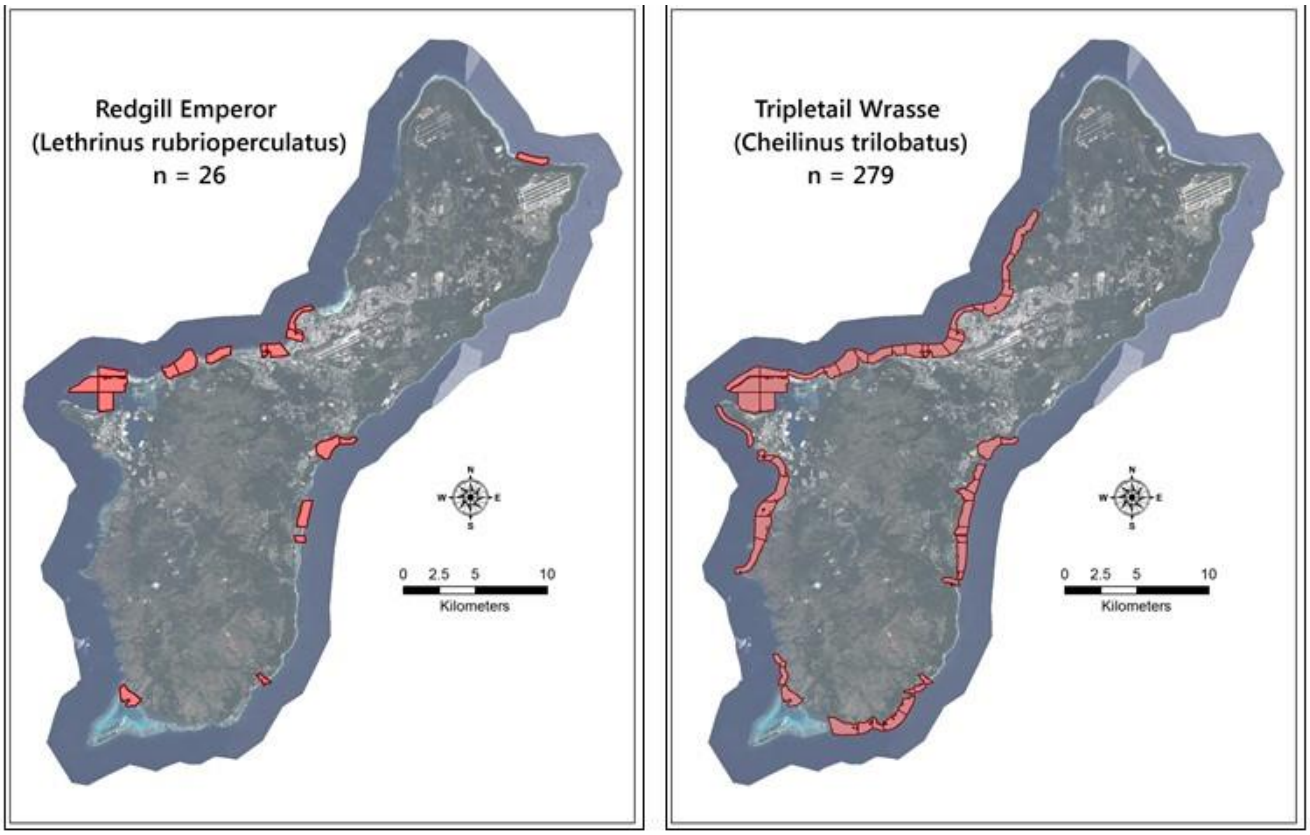



Jobfish
(Aprion virescens)
n = 15
0 2.5 5 10
Kilometers


Longnose Parrotfish
(Hipposcarus longiceps)
n = 17
0 2.5 5 10
Kilometers


Lowfin Rudderfish
(Kyphosus vaigiensis)
n = 51
0 2.5 5 10
Kilometers


Lyretail Grouper
(Varioloa louti)
n = 1
0 2.5 5 10
Kilometers




**From 1982 through 2014 there have been somewhat limited records for many shore-based species, with the exception of the more accessible zones adjacent to Merizo, Pago Bay, Agat, Agana, and Tumon. In addition, over half of the priority species had less than one-hundred records in a 30 year period, further demonstrating the need for data supplementation with a qualitative inquiry into geographic distribution of species and effort. The following section of the report outlines the design and process of that inquiry.**

## Participatory Mapping

A Participatory Mapping Workshop was held on Saturday, June 11th, 2016 at the Guam Hilton Resort. Given the potential merits of various participatory mapping techniques (NOAA Office for Coastal Management, 2015), the workshop was designed to include both printed mapping (hard copies) and a facilitated participatory GIS (PGIS) exercise using digital whiteboard technology (E-Beam). This allowed for both indirect (paper maps) and direct (digital whiteboard) translation of fishermen input and contributions related to fishing effort into spatial data. Forty-two unique fishing areas were mapped in the PGIS exercise, and data related to fishing frequency, type, access, species, habitat, and issues of concern were captured for each of these areas. Detailed notes were taken during this process to supplement and help validate the live capture of attribute information during the facilitation and mapping process.

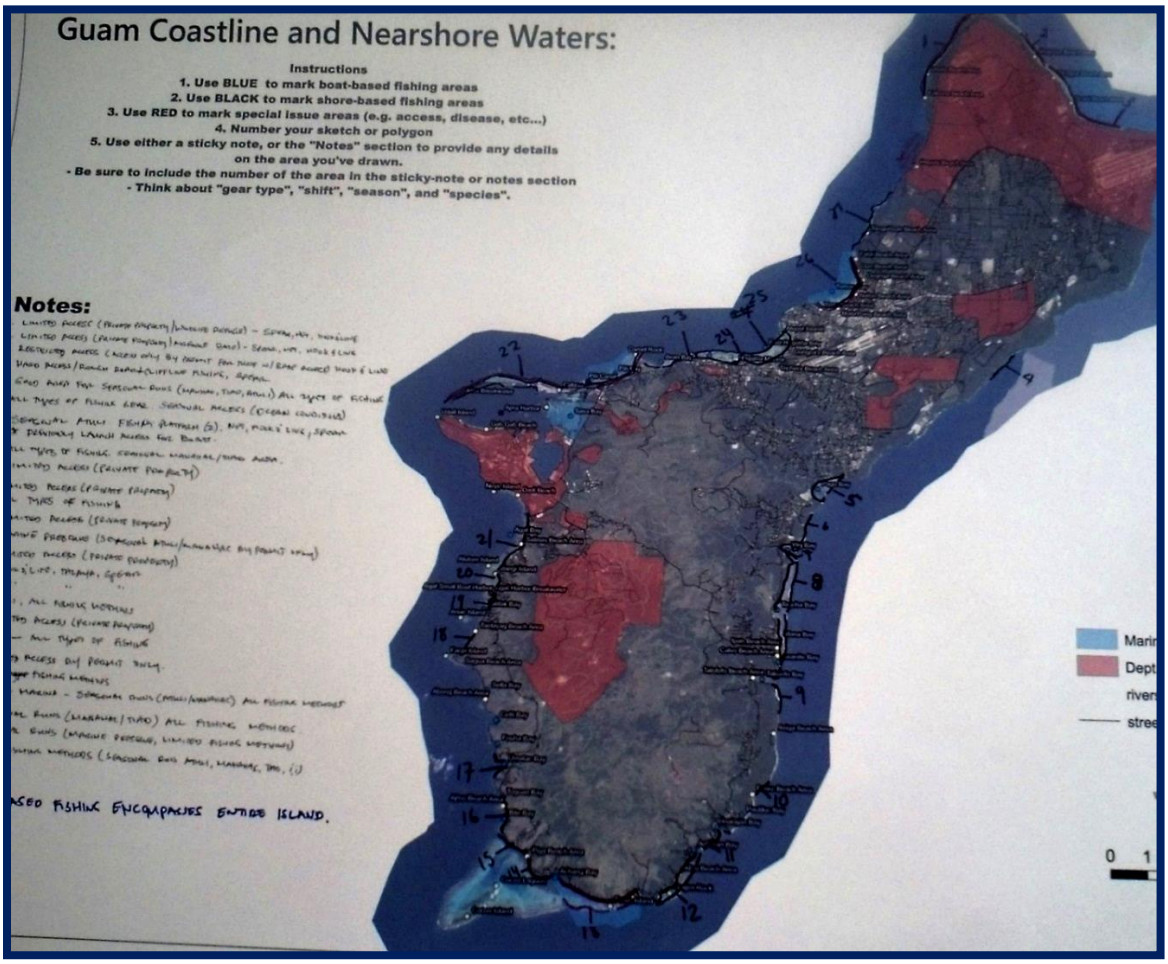
The hands-on mapping component of the workshop involved the use of four printed base-maps, allowing for the geo-referencing of forty-five additional unique features and fishing areas. Similar attribution for these areas was captured in a "notes" section on the printed base maps.

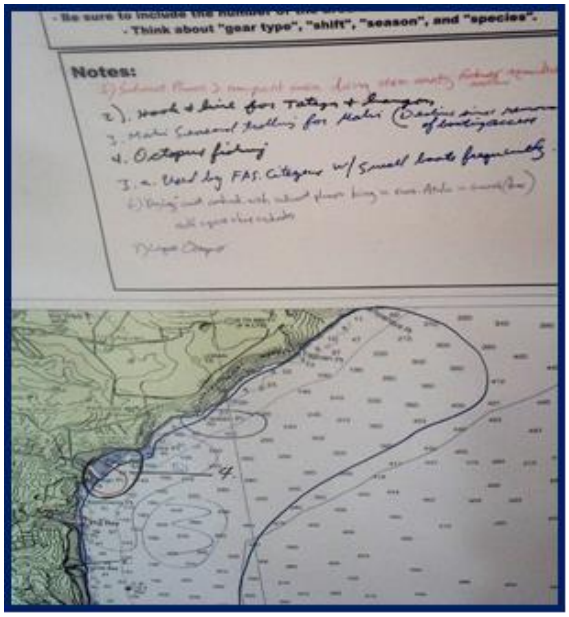
### Printed Mapping, Digital Data Capture, & GIS

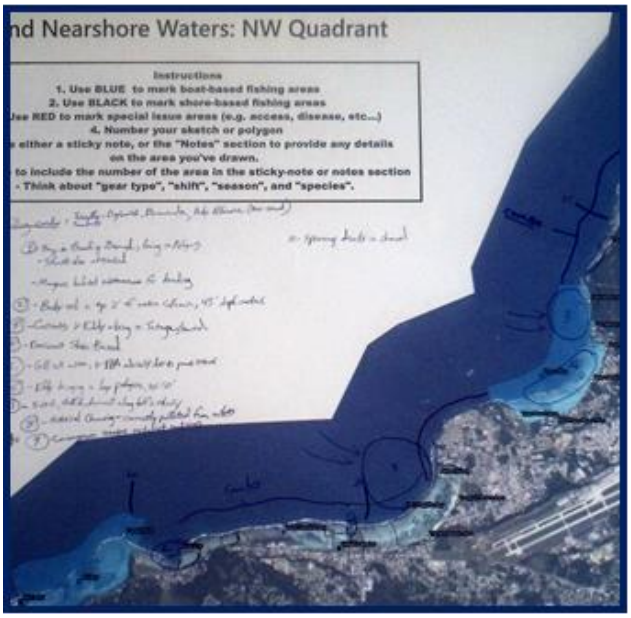
Workshop exercises attempted to mesh a semi-structured discussion around fishing effort and concerns with real-time spatial data capture. Two facilitators were responsible for (1) leading discussion and assisting participants in sketching fishing areas on an interactive digital map, and (2) editing the 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 87 distinct features, some of these were redundant in terms of duplication between digital and paper mapping, and in other cases there simply wasn't enough information recorded for the feature. Of the 45 features drawn on the printed base maps, 30 of these contained sufficient information concerning gear type, frequency, targeted species, and fishing environment to be included in the PGIS geodatabase. Additional features referenced "special issue" areas, with a focus on limitations to access/property boundaries and the sources of land-based pollution. These themes were added as values within a separate "issues" field in the feature attribution. Spatial data resulting from geo-referenced discussions of these themes may also find application in future, relevant projects (e.g. Access Mapping).

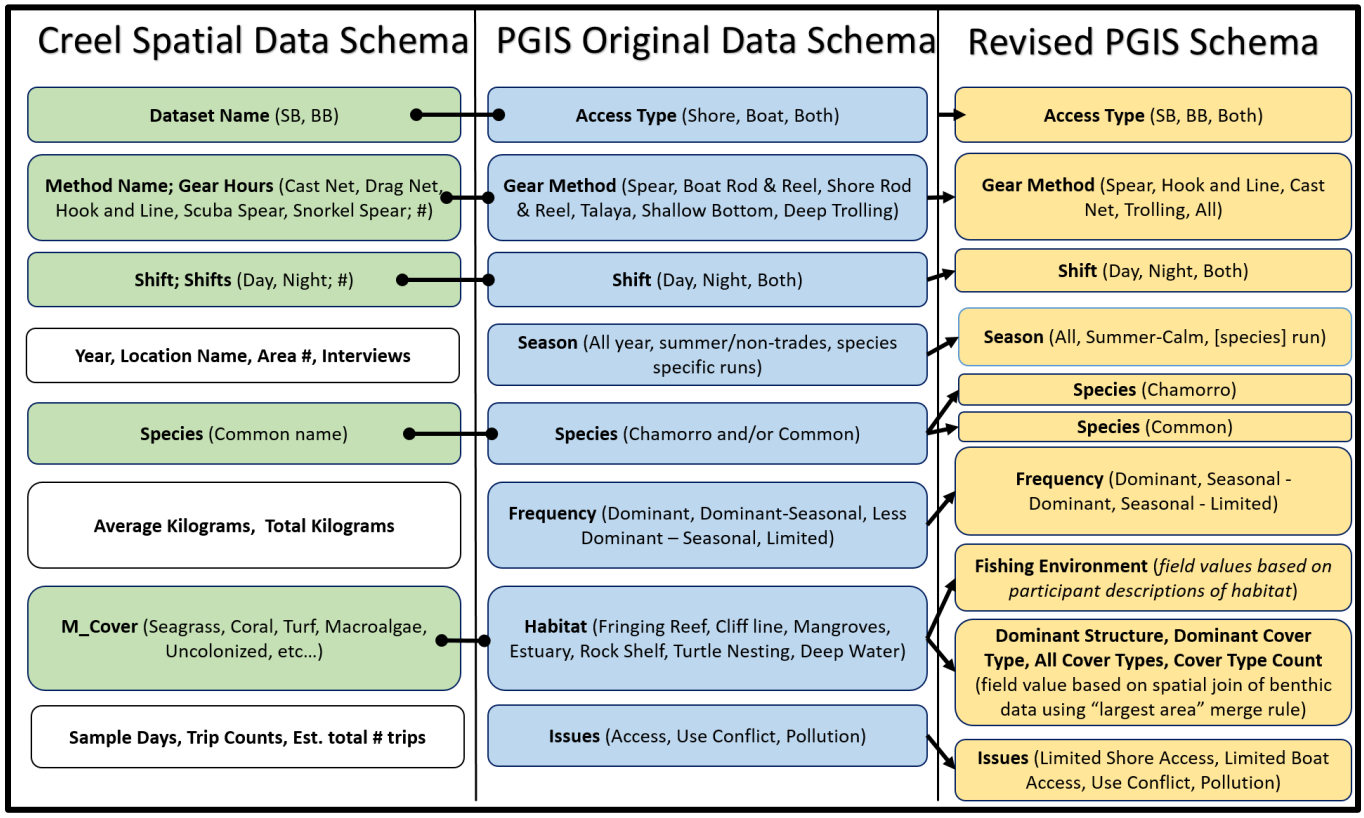
**8: Photos of print-based participatory mapping**



The spatial data fields that were developed for real-time data capture during the PGIS exercise 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. The general schematic for this matching is illustrated below:




9: Diagram of relationship between creel and PGIS data

E-Beam results and attribution were edited to reflect workshop notes and new fields were added to include targeted species in both common English and Chamorro, multiple benthic characteristics, and a distinction between the *frequency* of fishing effort and the *seasonality* of that effort.

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 Pago Bay, so the print map polygon for that feature would derive benthic characteristics and fishing effort attributes from the PGIS feature for Pago Bay.

Both print and PGIS features were edited and "cleaned" to be consistent with high resolution shoreline data and a 500 meter seaward buffer from the reef line. For the latter boundary, a 200 meter seaward extension from the creel survey zones (which only included a 300 meter buffer from the reef line) was applied. This additional extension was intended to reflect participant input on bottom fishing and trolling along shelves and reef slopes that might extend past the creel zones' 300 meter buffer. Some gaps in depth contours that were derived from bathymetry data deterred using those contours as an outer extent or clipping feature.

The cleaned results of both PGIS and print-based mapping served as the basis and foundation for final project output and spatial data. Polygons and associated attribution were used to generate maps showing various levels of fishing effort, environments, and seasonal catch in preparation for the Data Validation and Feedback workshops.

## Results and Discussion

The final spatial data resulting from the participatory mapping exercises matches the following fields and domains. References to "fishnets" within this table refer to a type of map grid that was used to process the final project data and display it in a consistent format. This is discussed and illustrated in greater detail in the *Data Validation* section of this report:

| Guam Reef Fisheries Mapping - Participatory GIS Data | | |
|---|---|---|
| **Field** | **Description** | **Domain (Range & Coded)** |
| Island | The island(s) comprising the project's area of interest. For this project the only area of interest was Guam; however, future study may include the Northern Mariana Islands, so this distinction may be relevant at a later date. | 'Guam' (in 2017 may be 'Guam' or 'CNMI') |
| 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 Net', 'Spear', 'Bottom Fishing' (boat-based), 'Hook and Line' (Shore-Based), 'Trolling', 'All'. |

| | | |
|---|---|---|
| Shift | Whether fishing effort is occurring primarily during daylight hours or at night. This category proved to be homogenous throughout Guam's shoreline and coastal waters, as participants noted that both fishing shifts occur in most areas. | 'Day', 'Night', 'Both' |
| Environ | 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. | 'Bay', 'Lagoon', 'Channel', 'Reef Flat', 'Deep Water', 'Narrow Fringing Reef', 'Cliffline', 'Seagrass', 'Estuarine', 'Mangrove', 'Shelf', 'Breakwater' |
| Species_Common* | 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"). The range of species was supplemented by any additional fish mentioned in the category of 'Species_Chamorro'. | Bigeye Scad', 'Bigeye Emperor', 'Blackspot Emperor', 'Bluespine Unicorn Fish', 'Orangespine Unicorn Fish', 'Parrotfish', 'Goatfish', 'Rabbitfish', 'Jobfish', 'Trevally', 'Barracuda', 'Rudderfish', 'Jack', 'Mangrove Crab', 'Spiny Lobster', 'Slipper Lobster', 'Octopus', 'Snappers', 'Dogtooth Tuna', 'Albacore Tuna', 'Longface Emperor', 'Milkfish', 'Oriental Sweetlips', 'Clam', 'Spider Conch' |
| Species_Chamorro* | The Chamorro 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. The range of species in this category was supplemented by any additional fish mentioned in the category of 'Species_Common', but often focused on culturally significant juvenile populations of particular species (e.g. tia'o). | Atulai', 'Mafute', 'Hagon', 'Manahak', 'Laggua', 'Palakse', 'Mamulan', 'Panglao', 'Guili', 'Tataga', 'Tia'o', 'I'e'', 'Tagafi', 'Bangus', 'Alu', 'Uku', 'Botague', 'Gamson', 'Hamala', 'Mahongang', 'Lililok', 'Aliling', 'Tarakitu' |
| 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 could be the focal points of additional research. | Land-Based Pollution', 'Marine Toxics', 'Limited Boat Access', 'Limited Shore Access', 'Use Conflict', 'Shark Predation', 'Regulated Effort' |
| Seasons* | Instances in which fishing effort may focus or increase during certain times of the year based on ocean conditions, lunar cycle, or other factors that influence seasonal runs of particular species. | Summer-Calm', 'Bigeye Scad Seasonal', 'Goatfish Seasonal', 'Rabbitfish Seasonal', 'Jack Seasonal', 'Mahi Seasonal' |

| | | |
|---|---|---|
| Dom_Structure | The benthic habitat structure occupying the largest percentage of a fishing area polygon (delineated by PGIS participants). Benthic data from 2005 (NOAA Biogeography Branch data + ground truthing by D. Burdick) clipped to and 'unioned' with PGIS polygons. *'Unknown' value for Dom_Structure generally corresponded with deeper water (e.g. beyond 100 ft. depth contour) | 'Coral Reef and Hardbottom', 'Unconsolidated Sediment', 'Unknown'* |
| Dom_Cover | The benthic habitat cover type occupying the largest percentage of a fishing area polygon (delineated by PGIS participants). Benthic data from 2005 (NOAA Biogeography Branch data + ground truthing by D. Burdick) clipped to and 'unioned' with PGIS polygons. *'Unknown' value for Dom_Cover generally corresponded with deeper water (e.g. beyond 100 ft. depth contour) | 'Coral 10%-<50%', 'Macroalgae 10%-<50%', 'Macroalgae 50%-<90%', 'Turf', 'Turf 50%-<90%', 'Uncolonized 90%-100%', 'Unknown'* |
| All_Cover | All benthic habitat cover types present within a fishing area polygon (delineated by PGIS participants). Benthic data from 2005 (NOAA Biogeography Branch data + ground truthing by D. Burdick) clipped to and 'unioned' with PGIS polygons. | 'Coral', 'Algae', 'Macroalgae', 'Coraline Algae', 'Seagrass', 'Emergent Vegetation', 'Turf', 'Uncolonized', 'Unclassified', 'Unknown' |
| Join Count | The number (count) of benthic cover types (from All_Cover field) present in a fishing area polygon. This count is intended to serve as a very broad proxy for habitat diversity within certain features, after normalizing by feature 'area'. | 0' - '8' |
| Area_SqM | The area in square meters of the participatory mapping feature that was originally drawn in a PGIS workshop and then constrained to the mapping envelope (shoreline to 500 meters seaward of reefline). The fishnet data retained this field and its values so that data users may have a quantitative description of how large the generalizations about specific fishing areas are. | '46454.170403' - '13192174.591785' |
| Area_SqKm | The area in square meters of the participatory mapping feature that was originally drawn in a PGIS workshop and then constrained to the mapping envelope (shoreline to 500 meters seaward of reefline). The fishnet data retained this field and its values so that data users may have a quantitative description of how large the generalizations about specific fishing areas are. | '0.046454' - '13.192175' |
| *Notation: * Category or theme highlighted in Guam Reef Fishery Atlas* | | |

**Certain fields within the table above are noted for their inclusion in the thematic maps from the *Guam Reef Fishery Atlas* that accompanies this report. Because the values within those fields are largely derived from coding of semi-structured 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 property ownership and seasonal ocean conditions, those areas could see more of a balance between "shore" and "boat". Therefore there was some overlap and potential conflict as to the values for "Access Type" in the initial stages of data collection. In the resulting 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. |
| 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 Guam's eastern and northern shoreline, it was noted that under calm ocean conditions an area might experience far more fishing effort than it would under more hazardous, 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 initially quite fuzzy. Participants first suggested that just about all methods are employed in all accessible areas throughout the island. 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 area was known as being especially "good" for certain methods. This distinction is highly subjective, but was deemed appropriate as a means of facilitating a richer discussion about various types of effort and their distribution around the island. 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 an absence of other methods. |

| | |
|---|---|
| **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 shoreline, bays, or coastal features, participants were asked to point out areas that might yield particularly abundant and high-quality catches of specific species, or areas where certain fish are targeted. The focus on the species level was rapidly broadened to include participant input on fish 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 might fall within a polygon that was also noted as part of a stretch of high quality trolling for Mahi, or simply "pelagics". This feature or polygon would then appear on maps for both "seasonal Manahak catch" and "Pelagic Species Catch". 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. The mixed classifications of fish within the PGIS features do, however, seem less structured than Guam's other fisheries data, which often breaks down field data or surveys into more precise groupings. Analyses that can be conducted using the latter datasets cannot be applied to this project's geospatial products.** |
| **Seasonality** | **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. Most notable among these distinctions was the differentiation among catches of culturally important species during early life stages. Many fishing locations were noted for their significance as areas that have traditionally been important for juvenile Rabbitfish and Goatfish, as well as populations of Bigeye Scad. In addition, some areas were identified for hosting abundant runs of Mahi or jacks during certain times of the year.**<br><br>**In discussing this topic, participants also made substantial comments relating the ability to access some of these areas to the seasonal presence of hazardous ocean conditions. As a result, this field of data contains values pertaining to the seasonal catch of certain species, as well as a value designating certain areas as seasonably accessible based on ocean conditions. For example, Atulai could be caught in seasonal abundance in a certain location, but only if seas were not prohibitively rough. This dependent relationship illustrates a major consideration for the appropriate use of project data. The viewing or use of any single layer of data, such as "seasonal Tia'o areas", will not paint a complete portrait of the potential catch of Tia'o in that area unless it is assessed in combination with a data layer for shoreline accessibility.** |
| **Issues** | **The categorization of "issues of concern" was an effort to include some of the most prominent topics of discussion during mapping workshops. The prominence of these topics was not originally anticipated to arise within the semi-structured PGIS exercises, so this information was appended after initial workshop data was processed. The primary caveat with layers pertaining to issues such as "Land-Based Sources of Pollution" 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.**<br><br>**Areas that participants pinpointed for excessive sedimentation and turbidity following extreme precipitation events have a direct relationship to issues with changes in adjacent** |

| | |
|---|---|
| | **landcover, development, and terrestrial hydrology. All of these factors arose within discussions about these issues, yet an analysis of contributing factors to these issues is far beyond the scope of this study. Therefore the map layers for "Issues" have a greater level of context-stripping than the other categories of information. That being said, a qualitative inquiry such as the semi-structured workshop discussions is best served by due consideration of the themes that arise most often.** |

**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. Guam's fishing community, and particularly those who consistently participated throughout the project process, provided essential feedback on the broadness of these categories 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 a data validation workshop in September 2016
- Data comparisons between GPS field data and PGIS data
- Final adjustments based on feedback from a map-based presentation in early December 2016

While this lineage of quality control does not render the final project output as infallible, it was an important endeavor to better reflect the input of those community members that contributed time and sensitive knowledge to the data.

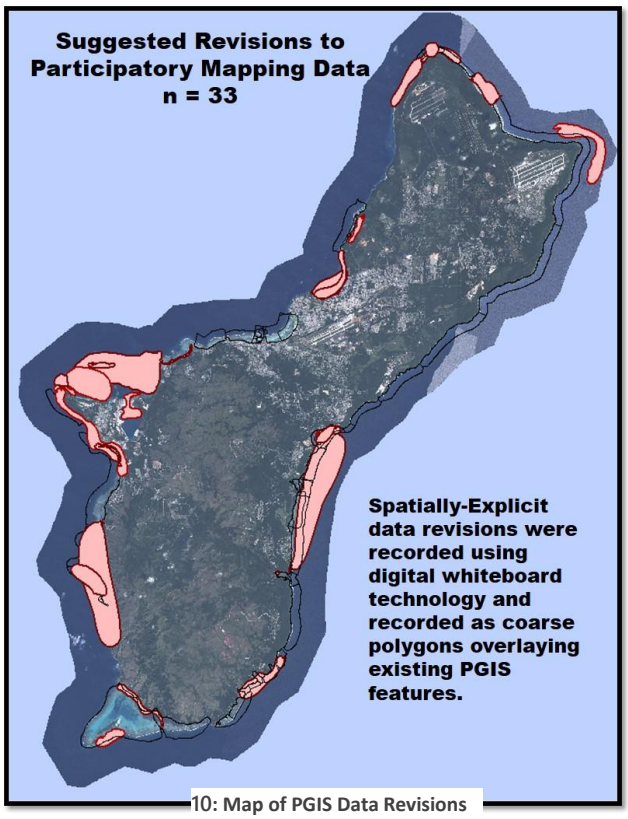
### Validation Workshop Results and Adjustments

A data validation workshop was held on Guam on September 24th 2016, with eight participants returning from June's participatory mapping workshop. Both digital maps (PGIS) and printed base 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 such as accessibility and the influence of seasonal conditions on fishing effort.

Significant discussions focused on data privacy and the limitations of the project, specifically with regard to designating areas as "dominant" or "limited" in terms of effort and access type. The notion of context stripping was brought up, as mapping necessitates generalizations that may not capture the nuances of fishing effort. An acceptable resolution (0.5 km) for final mapping products was decided upon based on the smallest fishing area that was delineated in the initial workshops.

Ultimately thirty-three revisions to PGIS polygon boundaries and associated feature attributes were recorded digitally, and additional annotation and details concerning these revisions were captured on the printed base maps.

In addition to real-time edits to spatial data, and associated note-taking from the workshop, several follow-up interviews were conducted with key members of Guam's fishing community who had participated in both the mapping and validation workshops. The results of individual follow-up discussions are detailed further in later sections of this report.




10: Map of PGIS Data Revisions

## Use of GPS Data

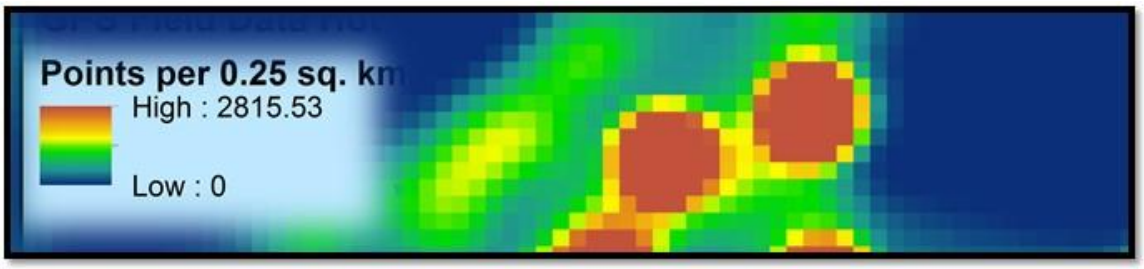
Six citizen scientists from the fishing community volunteered to carry global positioning system (GPS) units with them on their fishing trips (boat and shore-based) from late June through mid-September 2016. Point data was recorded at even intervals during these trips, allowing GPS points and tracks (.GPX) to be processed and analyzed within a GIS environment. Forty-nine track files were recovered from the GPS units, though these files included some redundancy where multiple files were generated for a single trip. Post-processing in GIS revealed 44 distinct fishing trips, largely concentrated on boat-based effort.

Data was integrated into a geodatabase as individual trip files, a comprehensive track dataset, and a series of raster datasets resulting from a density analysis of GPS points for boat, shore, and combined trips. The latter data was intended to provide a means of visual, spatial comparison with results of participatory mapping data. All GPS data is to remain confidential according to agreements with citizen scientists, so only snapshots of these results are discussed in this report.

## Hot Spot Analyses for Boat & Shore Trips

A Kernel density analysis was conducted to assess hot spots of fishing effort between June and September. The analysis consisted of a simple count & density of points (track points at 15 second intervals) within 500 meter raster cells (0.25 sq. km), matching the resolution of final participatory mapping results. This analysis was conducted on data from shore and boat-based trips separately and in combination, as wells on all point data that was located within the participatory mapping grid (described in the following section).

11: Sample of GPS Hot-Spot Grid




Comparisons of field density data with participatory mapping data are accompanied by a range of caveats, mostly associated with the field data sample size and temporal coverage, as well as an overwhelming dominance of boat-based trips in that data. Nevertheless, initial analyses point to some significant overlap between hot-spots derived from field data and participatory mapping results. This is particularly evident in comparisons between hot-spots and fishing areas that participants highlighted as predominantly boat-based fishing during calm ocean conditions in Guam's rainy season (roughly July-November).

**Final Adjustments**

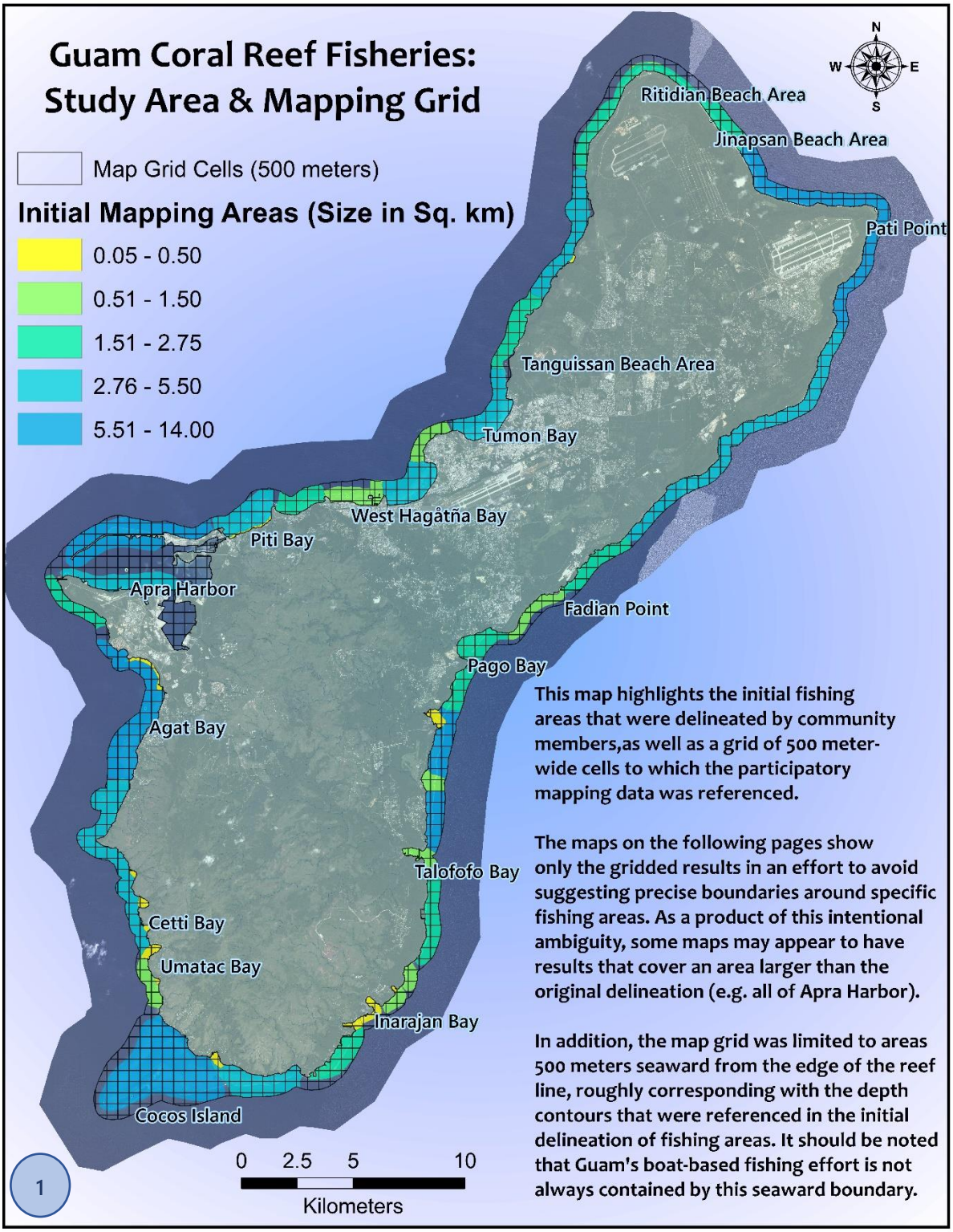
**Following data revisions from the validation workshop and analysis of GPS field data, the participant-based delineations of fishing areas and their attributes were referenced to a mapping grid. This processing step, which dissolved fishing area boundaries into a 500 meter resolution "fishnet"grid, was performed in order to create a broader spatial representation of participant data, and therefore avoid creating final map products that might lead resource users to come to conclusions about fishing areas at a finer grain than is reasonable given the generally broad input.**

**A spatial join was performed, allowing grid cells within the fishnet to inherit the attributes of the PGIS polygons that they intersected. A one-to-many join was specified in order to capture the multiple records from overlapping polygons. Using the various data fields that were joined to the fishnet, individual selections of pieces of the fishnet were exported as individual layers. For example, grid cells that contained attribution suggesting "limited shore-based access" were extracted as an individual "limited shore access" layer.**

**These gridded layers were then presented to community members who suggested some final revisions and edits to the data. In particular, the following input prompted some important changes in the data:**

- **Specific coastal features that impact nearshore water quality parameters (e.g. turbidity) were pinpointed in an effort to add additional areas to the "land-based pollution" layer. These included multiple quarries, spaces where land cover has shifted toward impermeable or erodible cover types, and some additional stream outlets in watersheds along the southeast and southwest shoreline.**
- **Other areas that were associated with concerns about marine toxins or heavy metals were removed from grid. This was due to recommendations to distinguish between areas that have published health advisories or studies of presence of marine pollutants from areas that may have been assigned those values based primarily on speculation. While much of the participatory mapping was flexible in terms of incorporating local knowledge that isn't necessarily published or previously verified, the issues related to safety hazards, particularly toxins, involved additional scrutiny to avoid misrepresentation within final maps.**
- **The distinction between inshore and nearshore fishing efforts is not necessarily clear within the maps. This is primarily due to the deliberate broadening of fishing area delineations and boundaries to a 0.5 kilometer resolution grid. This ambiguity was intentional for the purposes of avoiding the communication of fishermen's' knowledge at fine scales. However, with respect to some items, especially the mapping of trolling areas or features that might have high quality**

pelagic fishing, adjustments were made to separate those layers according to depth contours and benthic environments.




12: Map of "fishnet" grid of participatory data

## Mapping Results Summary

Twenty-eight maps were produced and included as an appendix within this report, and as a separate atlas. These maps are intended to illustrate basic results pertaining to the different categories and fields of data that were collected, along with a couple examples of how different layers of data can be combined to communicate a more telling portrait of Guam's coral reef fisheries. It is important to note that the spatial information (i.e. GIS data) that was produced in this project can be of greater value to managers than the static maps, as it allows for manipulation and analysis of various layers to inspect any specific management inquiries that may arise in the future.

Narratives pertaining to each of the 28 maps in the report appendix and accompanying atlas are embedded as text within those figures, while descriptions of terminology used in the spatial data attribution are discussed in the "Participatory Mapping" section of this report. Here a broader discussion pertaining to the overall themes within the maps is provided. Map numbers refer to the corresponding graphic within the Atlas. This section begins with "Maps 2-3". Map 1 within the Atlas series has been shown and described on the previous page of this report.

Fishing Frequency and Basic Limitations to Effort (Maps 2-3)

Fishing frequency, or the regularity with which a certain spot is fished, is largely dictated by factors that influence shore-based access and relative safety. Frequency was suggested to be far higher on the west side of Guam, with the exception of certain stretches of shoreline between Agat and Umatac. The inshore areas of bays, lagoons, and reef-flats on Guam's east side also experience fairly frequent effort, but some of the finer scale details pertaining to this effort were not captured within the map grid. Mapping participants also distinguished areas that are fished on a frequent basis provided with relatively placid seas. Map 3 also introduces the regulatory structure around Guam's nearshore areas as a possible explanation for limited fishing frequency. This is particularly true of areas where only specific gear types or methods are permitted, thus narrowing the scope of effort and potentially the timing based on seasonal abundance of certain species.

Type of Access to Fishing Areas (Maps 4-5)

The geographic distribution of access via shore and/or boat is a complex topic that was the source of slight confusion in the initial mapping exercises. On most stretches of shoreline there are areas where both boat and shore-based fishing occurs. The maps related to access were an attempt to tease out which type of access was *most common* in particular areas. Areas accessed primarily via boat directly correspond with those spaces that participants delineated as having "limited shore access", thus providing some slight validation. Areas that were predominantly accessed via shore were more difficult to identify as most areas can be accessed via a boat provided with the right ocean conditions. Spaces on Map 5 that are designated as "accessed predominantly from shore" were often delineated in smaller polygons within bays, or along stretches of reef flats. The maps may

suggest a larger area of shore-access based on the methods used to assign access values to the grid cells, especially at the north end of the island around Ritidian and Jinapsan, where shore access may be constrained by rough conditions off of the reef line. It is also interesting to note the absence of any access classification around Pati Point. In this case the area of boat-based fishing, which is restricted by depth contour, was primarily outside of the reserve and the mapping grid.

Gear Type and Method (Maps 6-9)

An overriding consideration during the mapping exercises was that most fishing methods (and types of fish caught) are found in accessible locations throughout Guam's coastal areas. This idea led to lower confidence in the mapped areas for particular fishing methods because participants were asked to identify only those areas where a particular method was employed with great regularity and effectiveness. While this assisted in delineating some focal points for gear or methods that may be culturally significant (e.g. Talaya), it is the combination of these layers that is perhaps most telling. In short, the maps related to this theme, when combined, suggest that the entire area encompassing Guam's nearshore and coral reef areas has significance for at least some method of fishing.

Seasonality (Maps 10-16)

Seasonal preferences, based on species presence or ocean conditions, were a common topic of discussion during mapping workshops and follow-up activities. Materials that have been produced with input from the fishing community such as Guam's Lunar Calendar (Western Pacific Regional Fishery Management Council, 2016) indicate that seasonality is an indispensable component of understanding and communicating about Guam's coral reef fisheries, and therefore was a priority in spatial data development. Within maps 10-16 in the accompanying atlas there are seasonal fishing grounds highlighted for species that were mentioned for their cultural significance, and an additional layer reinforcing the role that ocean conditions play in fishing effort. The latter is an important, albeit broad proxy for "safety", which was suggested as a priority topic for future mapping efforts. Areas for seasonal Atulai, I'e', Manahak, and Tia'o tended to coalesce around locations with abundant shoreline access, partially reflecting preferred gear types and methods for those fish. It is also interesting to note the overlap between important seasonal fishing grounds and some of the areas that were later pinpointed for their issues with land-cover related pollution.

Fish Families and Priority Species (Maps 17-21)

As with the maps related to geographic distribution of gear and method, the spatial data concerning catch of various species was blanketed by the concept that "everything is caught everywhere". While maps 17-20 attempt to illustrate fishing areas that have particularly high abundance of certain families or species, Map 21 combines these layers to illustrate how significant catches of species that are targeted or highly valued by the community envelop the entire island. Some generalizations about large stretches of shoreline and regulated areas are involved in this map, and these are

inherited from the generalizations made in the individual family and species maps. Regardless, this map series may serve a useful tool in filling gaps about particular fish families or species in areas where creel or field data might not exist.

Issues Related to Access, Pollution, and Crowding (Maps 22-28)

The final set of maps within the Atlas address issues that were consistently discussed during the participatory process. The frequency with which concerns about various types of pollution, development, crowding, and access were voiced led to some extended focus on these topics. Despite assigning values related to these concerns within the project spatial data, the range of factors contributing to each concern are far beyond the scope of this project. For example, land-based sources of pollution (later referred to as "land cover issues") was noted in both broad swaths of the coast, as well as adjacent to specific features. This translates into contributing factors from both point and non-point source pollution, and would necessitate an in-depth spatial analysis of watershed dynamics and land-cover, as well as field-based sampling to fully address. Likewise, the initial attempt to outline areas with potential crowding or multi-use conflicts would be best served by field-based sampling and partnering with entities involved in marine spatial planning or tourism activities.

While these maps don't necessarily achieve a great deal of depth in further delineating such issues, they could certainly be applied in efforts to prioritize geographic areas for further study or management initiatives. In addition, project data may also assist in demonstrating the relationship between fishery characteristics or areas of significance and broader resource management plans. Maps 27 and 28 are very basic examples of this, highlighting a simple spatial overlap between areas of culturally significant catch and topics that are often addressed outside of fisheries management. Visualizing this intersection of data could be key in ensuring that aspects of Guam's fishing community are effectively communicated and subsequently integrated into other planning and management strategies.

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In reviewing the figures referenced in the preceding pages, it would be reasonable to suggest that a more detailed investigation into certain issues that impact Guam's reef fisheries is necessary. The final section of this report partially elaborates on those threads; however, one of the most important bins of information that is simply not conveyed in project output or data is the less-tangible nuances that influence the geographic distribution of fishing effort, particularly at the individual level.

In early November 2016, several members of Guam's fishing community were provided with semi-structured interview guidance and reference maps and asked to discuss the personal and cultural factors that guide preferences in fishing locations. The purpose of these follow-ups was to gather insight on the less-tangible elements of geographic fishing patterns, which cannot necessarily be

mapped. This information is critical in telling a more complete story of the significance of reef fisheries, and ultimately avoiding the context-stripping that can accompany the translation of discussions to data. Three primary instances of this need for nuance are provided here:

• Familiarity: Fishermen tend to revisit locations that they are familiar with. Familiarity in this context includes the locations where they grew up fishing or had significant learning experiences, locations close to a particular village or "home", and access points that individuals ascribe a significant level of ease or comfort to. Familiarity is conceived on a person-by-person basis, and therefore would require an unacceptable amount of generalization to portray spatially. However, understanding the opportunities and constraints to cultivating a sense of familiarity, such as access to traditional fishing grounds, may be critical for appropriate management decisions.

• Familial Species Preference: Fishermen tend to visit certain locations based upon the species and life stage they are targeting. When the intention of a catch is to share with family or close friends, particular geographic areas may serve as focal points for the preferred catch of those friends or family. Given the wide variety of individuals and groups that engage in fishing activities, mapping fishery preferences based on associations between different people and different species would prove extremely tedious, but would likely provide a more accurate portrayal of a major driver of fishing effort.

• 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. While this concept would appear to have obvious geographic relationships that accompany it, the prospect of developing any sort of index for accessibility becomes far more complex when fishermen perceptions are included. The more tangible factors on Guam that influence perceived accessibility include property configurations and tenure, seasonal ocean conditions, and topography, but despite having available spatial data for these factors, the notions of "safe parking" or personal relationships to private property owners make this issue exponentially more difficult to represent on a map.

These concepts are discussed here simply to acknowledge that the output from this project cannot achieve a perfect representation of reef fishery issues. What it can do; however, is spur conversation in a manner that directs future research and engagement toward more comprehensive understandings of Guam's reef fishery dynamics. The following section addresses some of the more practical directions future efforts might take.

## Next Steps & Recommendations

The participatory mapping workshops and follow-up discussions also served as an opportunity for members of the Guam fishing community to air and discuss topics of concern that were outside of the scope of this project. Building off of this project to investigate some of these topics in greater detail could be mutually beneficial to both the Guam fishing community and resource managers.

Perhaps most prominent among these threads of inquiry are the "issues" highlighted during project workshops that have affected the changing environment and fishing opportunities on Guam. Many of the fishermen who participated in this project were eager to take advantage of a venue in which their concerns and knowledge could be shared, and it is unfortunate that much of the qualitative discussion involved in this project will not be included in this report.

An important aspect of that discussion is its grounding in temporal narrative, and subsequently its potential to be constructed as a map-based chronology. In discussing individual map features and the boundaries of different fishing areas, participants offered rich accounts of how effort has changed over time. Expansion of participatory mapping data to include a time-based dimension within the data schema could reveal a more robust story than relying solely on snapshots of the present or historical creel data. Some examples of events and significant, temporally explicit issues brought up throughout the duration of the project include:

- Many of the fishing sites that were highlighted in this project as "primary" or critical fishing sites for seasonal species are also located in areas that are under heavy pressure from tourism development, sedimentation from land use changes, or military expansion, and have been for some time.
- Fishing access has been affected and restricted unintentionally by new infrastructure, development projects, or other seemingly unrelated changes in property ownership and regulations.
- Changes in population number and dynamics have affected the fishing "culture" of Guam. Several demographic variables relate to stories of cultural shifts, and these two sources of information (quantitative demographic data and narrative-based information) could be meshed to better investigate this topic.
- Many workshop participants highlighted new limitations on fishing access as possible causes for the recent increase in fishing-related deaths on Guam. Discussions about “safety” and “hazards” were at the forefront of conversation when participants were mapping aspects of accessibility on Guam’s east and north sides, and further inquiry into shifts in hazards over time, as well as management solutions to these hazards is certainly warranted.

Given the potential for expansion of mapping efforts to encompass other aspects of Guam’s reef fisheries, it is the researchers' recommendation for future study to pursue additional mixed-methods inquiry into the history of Guam’s reef fishing and the events that have shaped the fishing community. The construction of an in-depth timeline of significant events that is linked temporally and spatially to scientific fisheries data and local narrative would provide for an extremely useful expansion of the work that has been conducted for this project.

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## Spatial Data Sources

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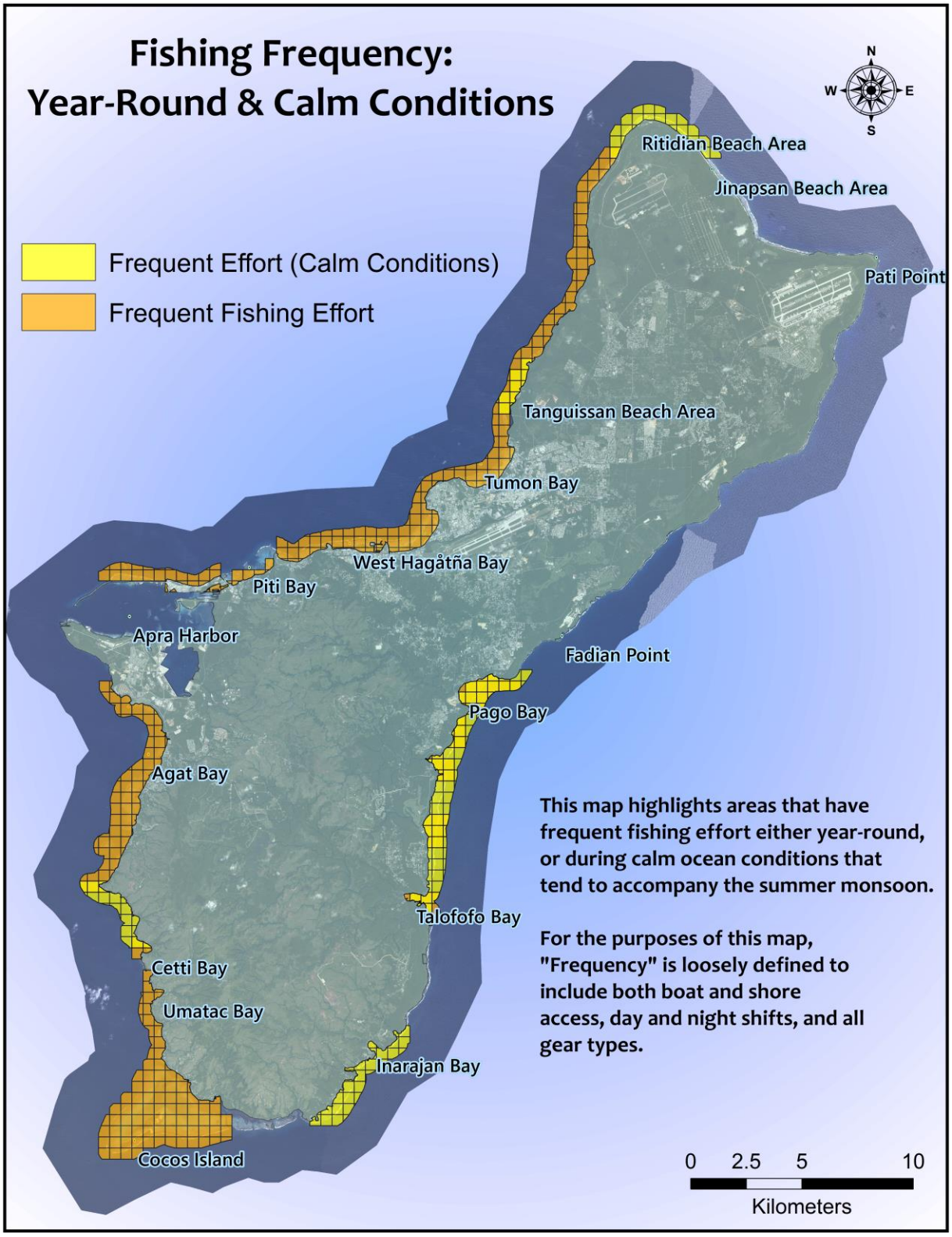
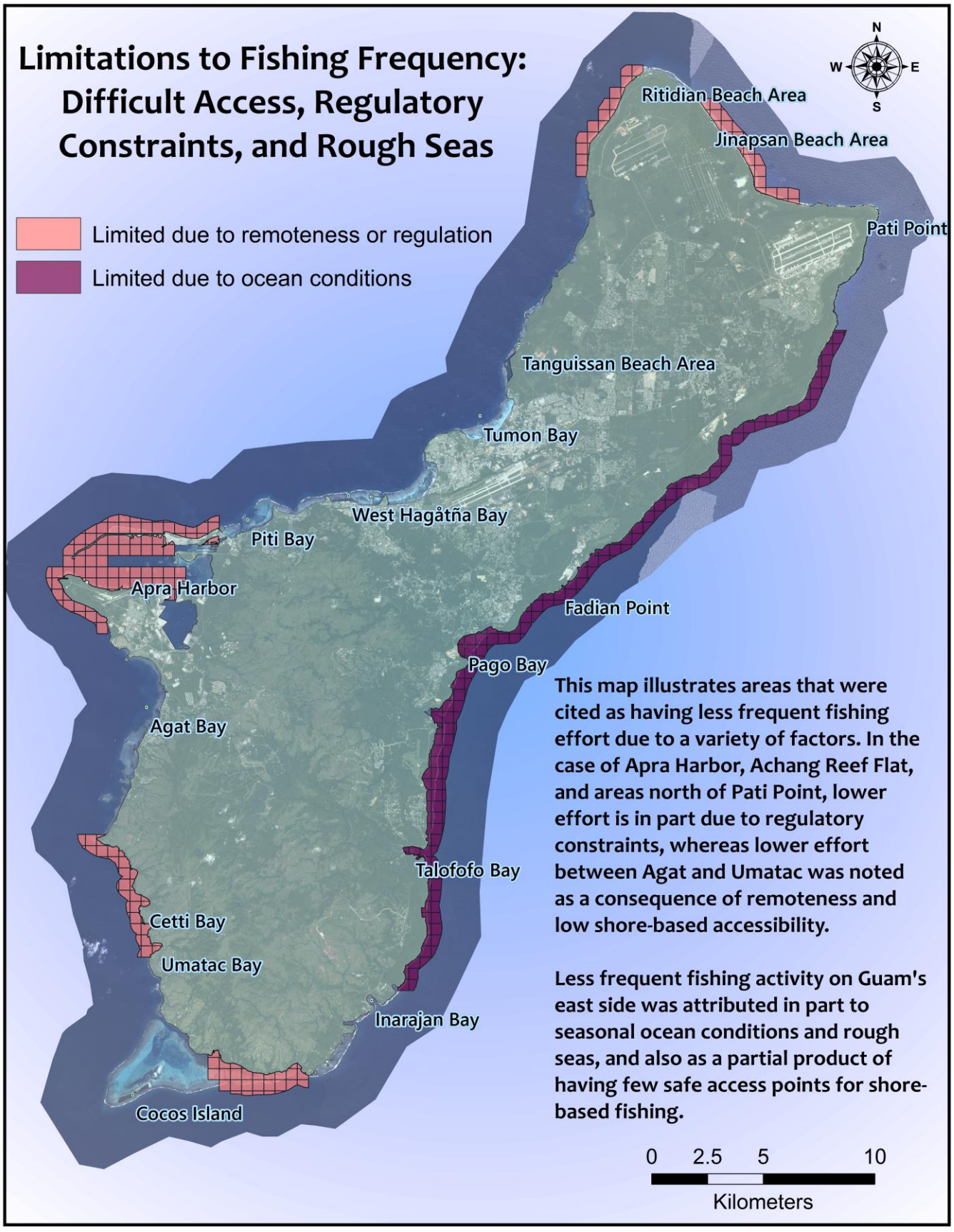
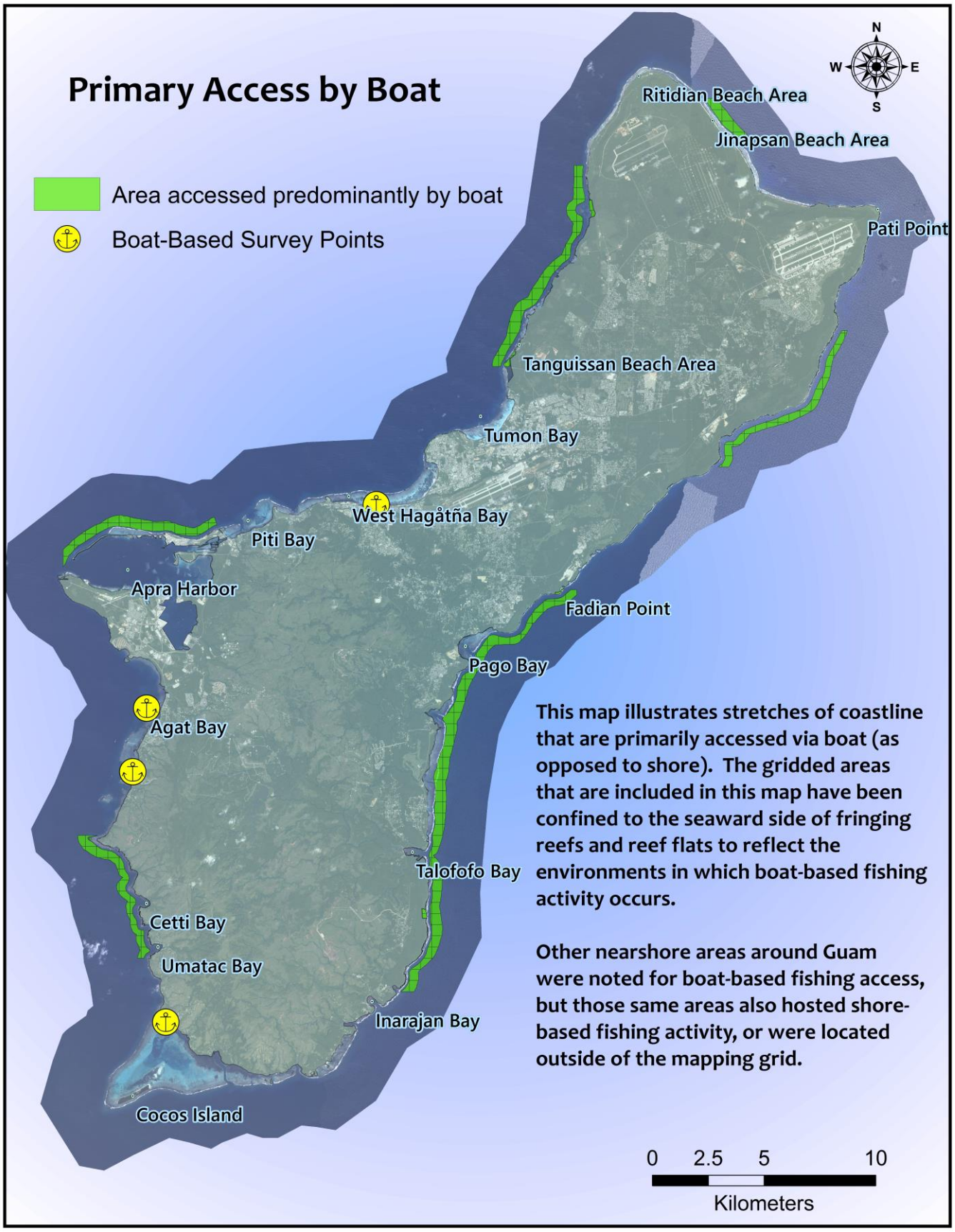
# Appendix

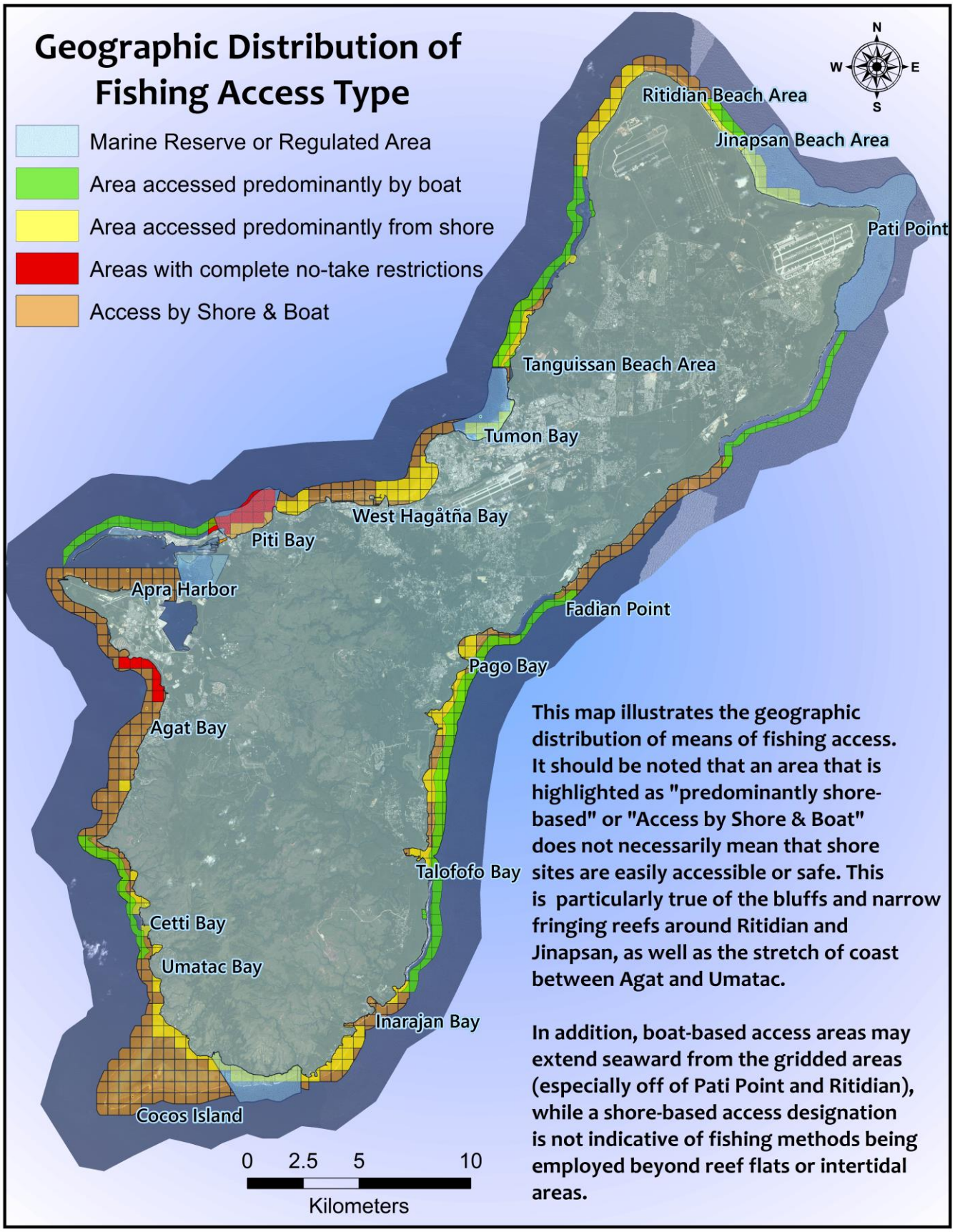
## Appendix A: Participatory Mapping Results

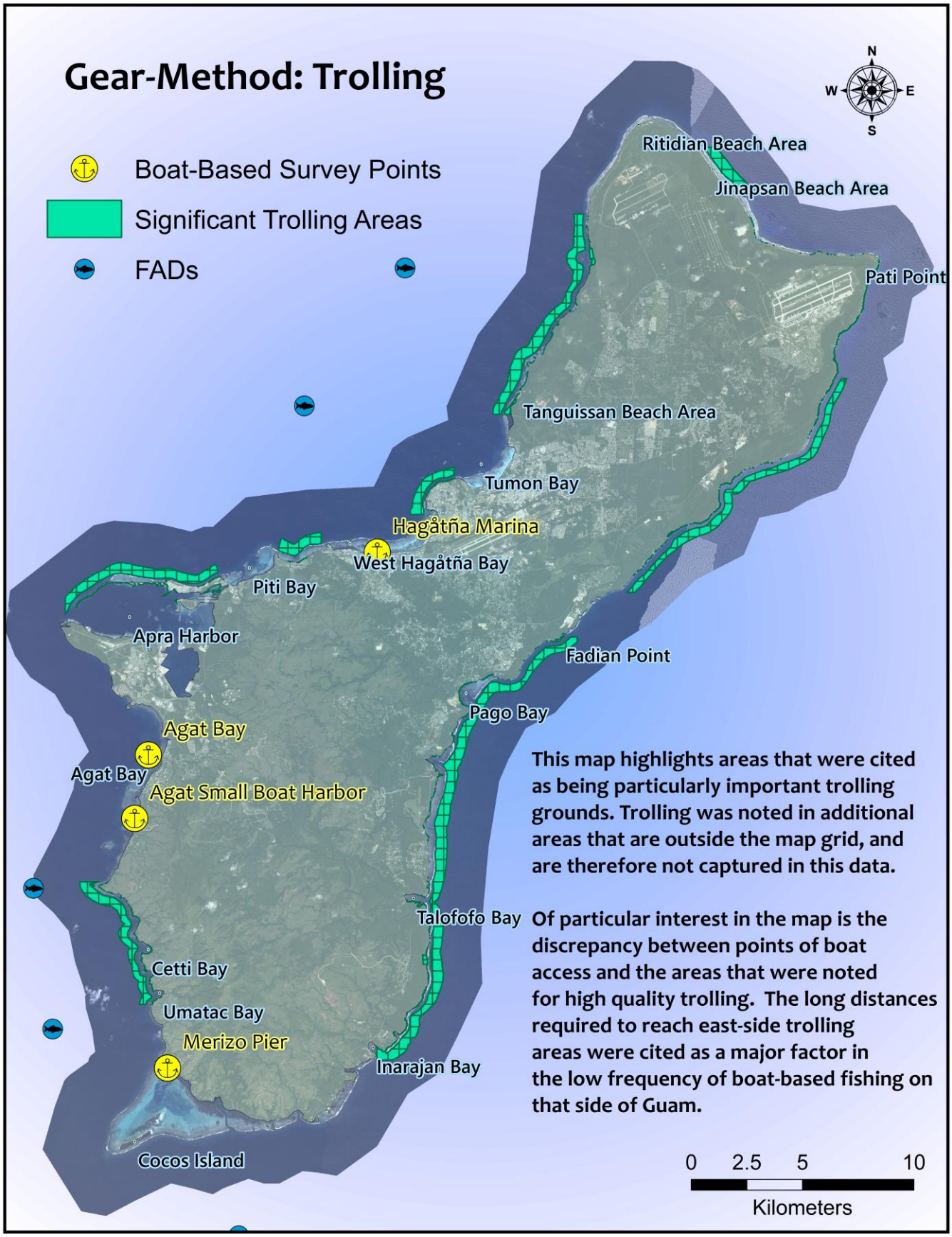
2

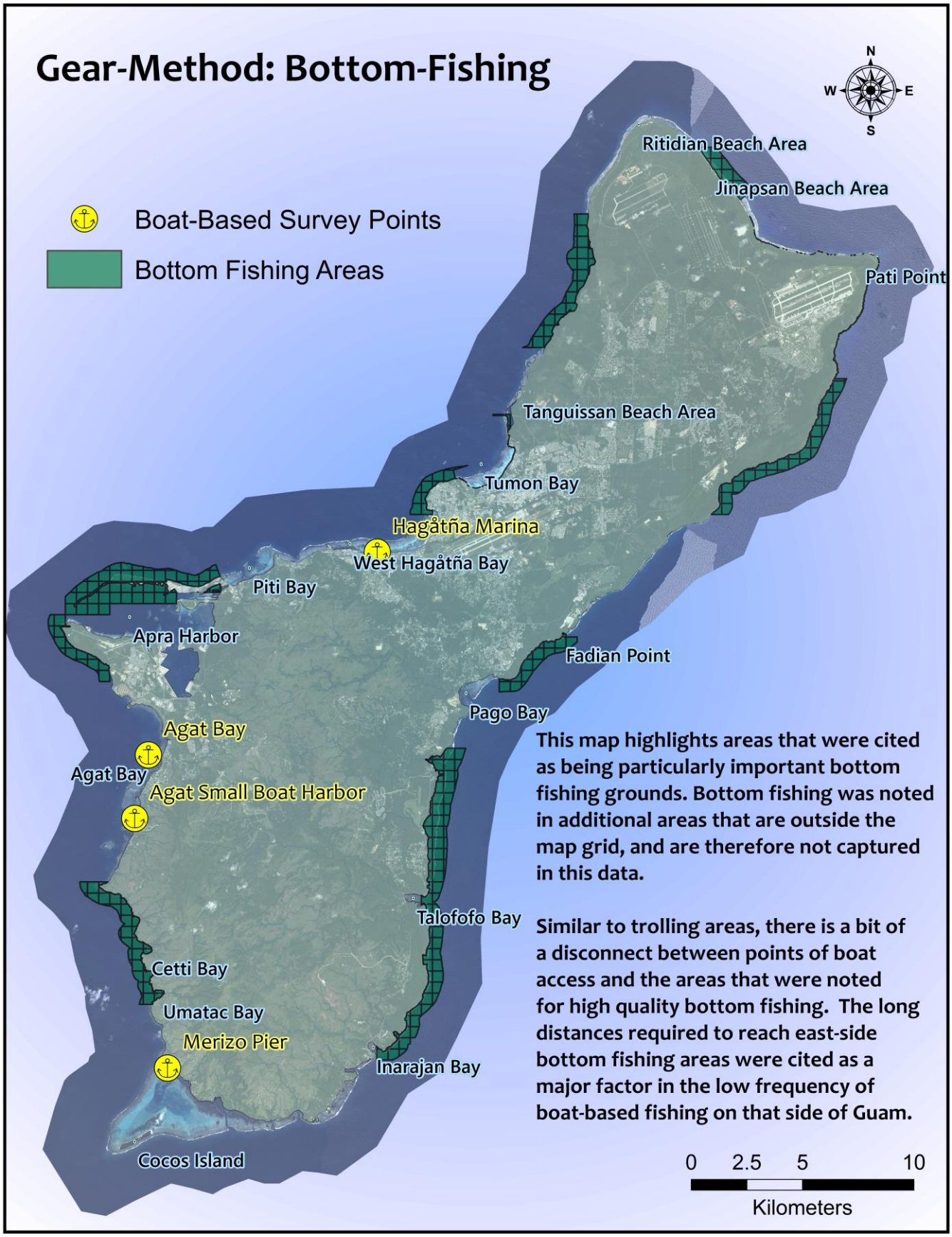


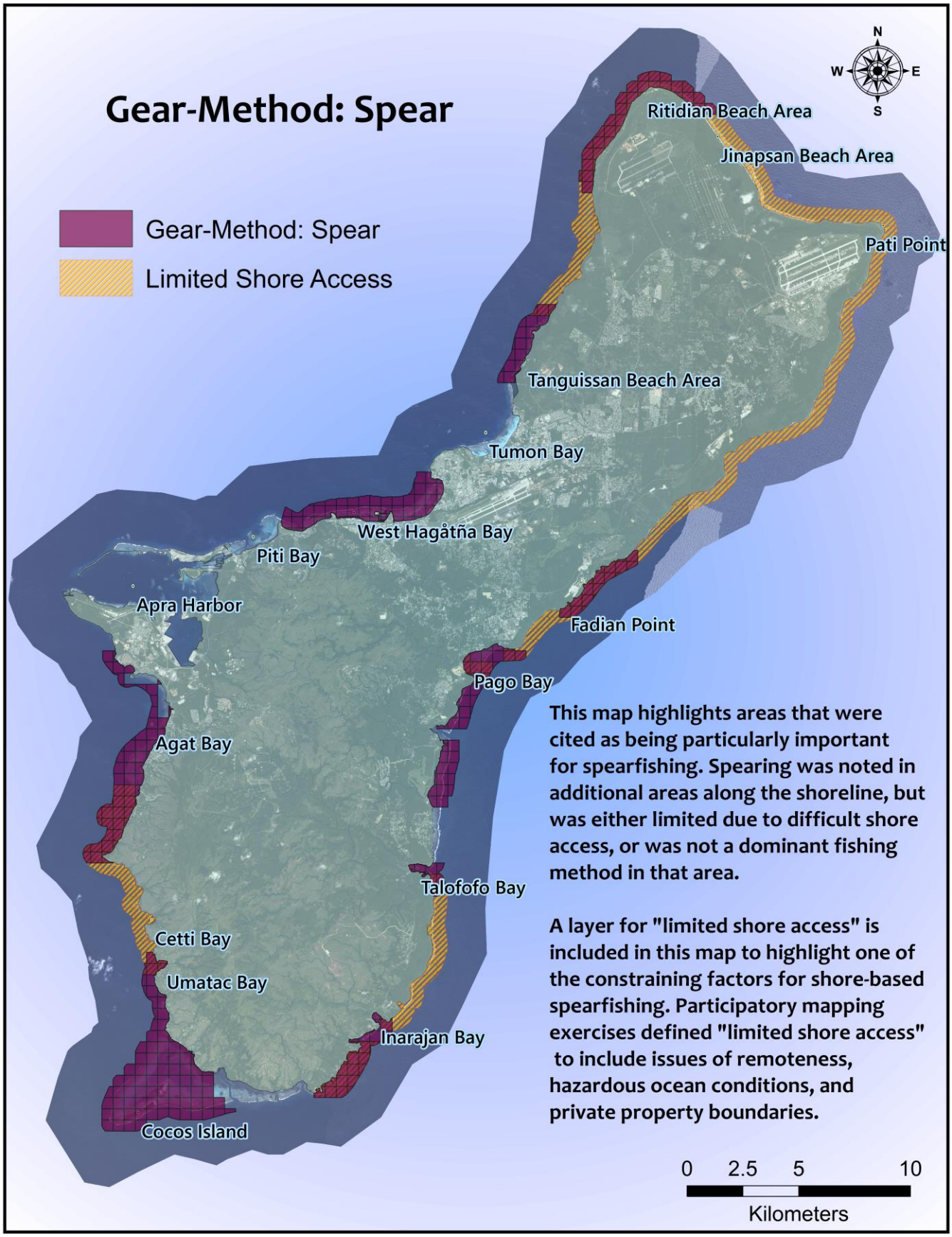

Limitations to Fishing Frequency: Difficult Access, Regulatory Constraints, and Rough Seas
Limited due to remoteness or regulation
Limited due to ocean conditions
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map illustrates areas that were cited as having less frequent fishing effort due to a variety of factors. In the case of Apra Harbor, Achang Reef Flat, and areas north of Pati Point, lower effort is in part due to regulatory constraints, whereas lower effort between Agat and Umatac was noted as a consequence of remoteness and low shore-based accessibility.
Less frequent fishing activity on Guam's east side was attributed in part to seasonal ocean conditions and rough seas, and also as a partial product of having few safe access points for shore-based fishing.
0 2.5 5 10
Kilometers

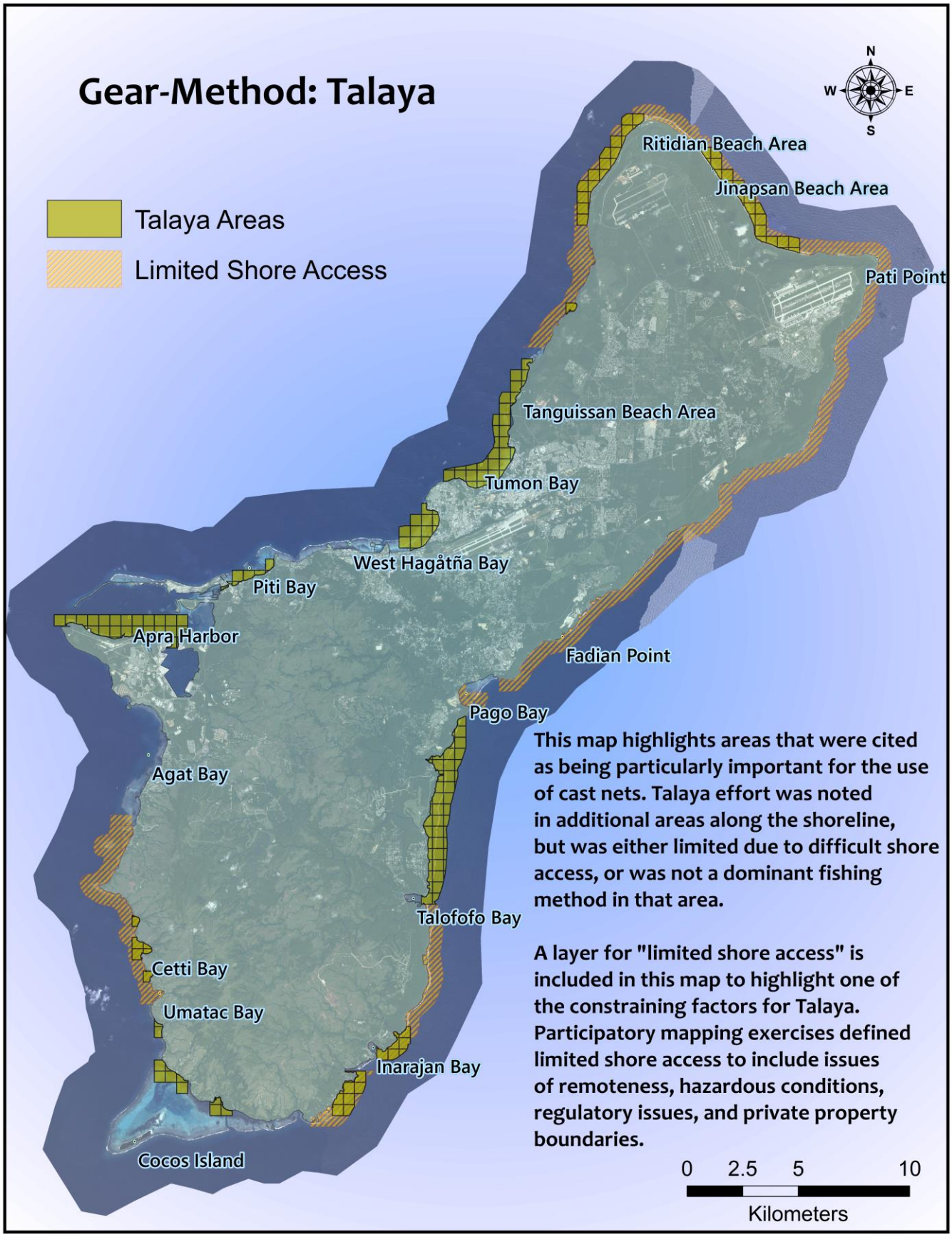

Primary Access by Boat
Area accessed predominantly by boat
Boat-Based Survey Points
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map illustrates stretches of coastline that are primarily accessed via boat (as opposed to shore). The gridded areas that are included in this map have been confined to the seaward side of fringing reefs and reef flats to reflect the environments in which boat-based fishing activity occurs.
Other nearshore areas around Guam were noted for boat-based fishing access, but those same areas also hosted shore-based fishing activity, or were located outside of the mapping grid.
0 2.5 5 10
Kilometers

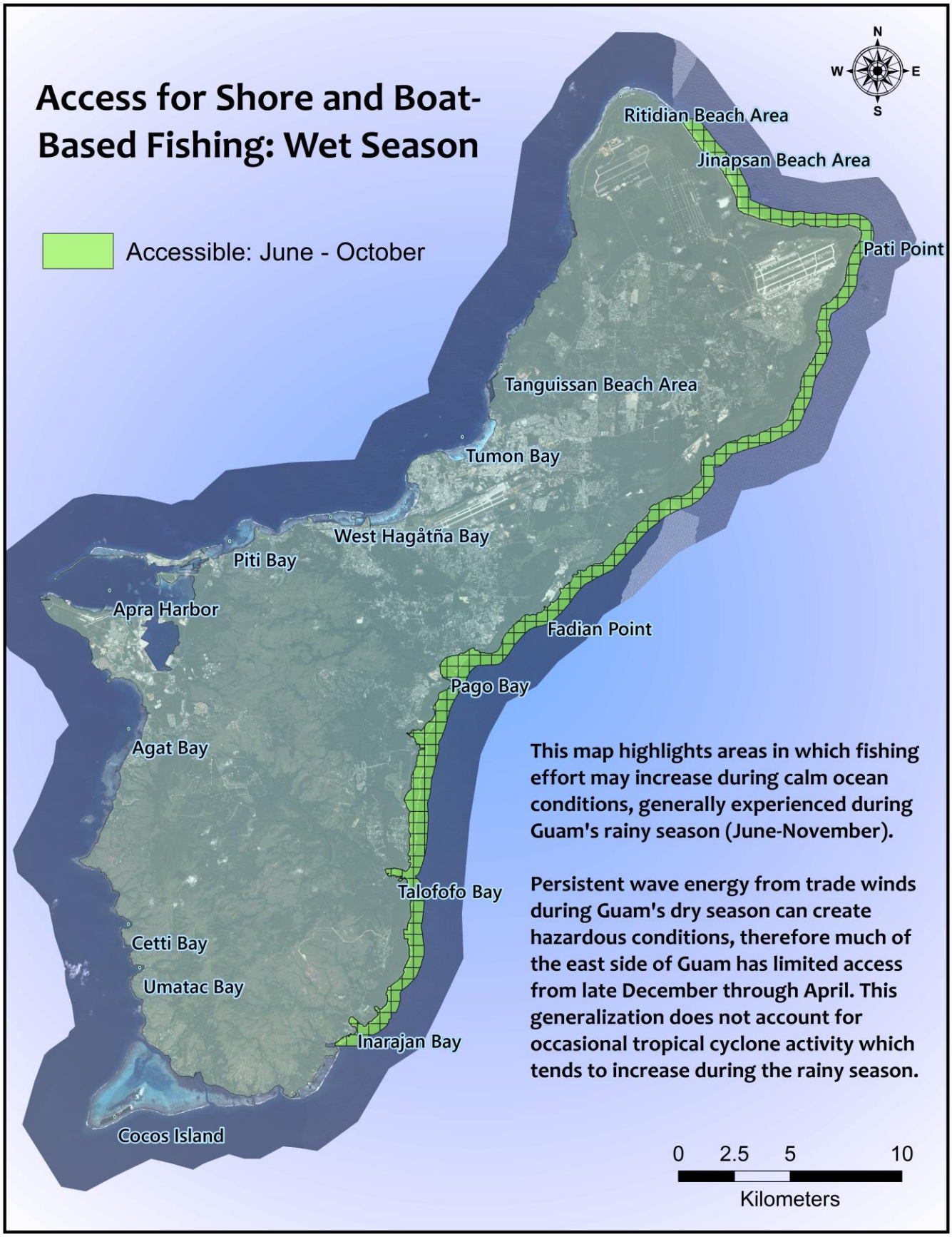

Geographic Distribution of Fishing Access Type
Marine Reserve or Regulated Area
Area accessed predominantly by boat
Area accessed predominantly from shore
Areas with complete no-take restrictions
Access by Shore & Boat
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
0 2.5 5 10
Kilometers
This map illustrates the geographic distribution of means of fishing access. It should be noted that an area that is highlighted as "predominantly shore-based" or "Access by Shore & Boat" does not necessarily mean that shore sites are easily accessible or safe. This is particularly true of the bluffs and narrow fringing reefs around Ritidian and Jinapsan, as well as the stretch of coast between Agat and Umatac.
In addition, boat-based access areas may extend seaward from the gridded areas (especially off of Pati Point and Ritidian), while a shore-based access designation is not indicative of fishing methods being employed beyond reef flats or intertidal areas.

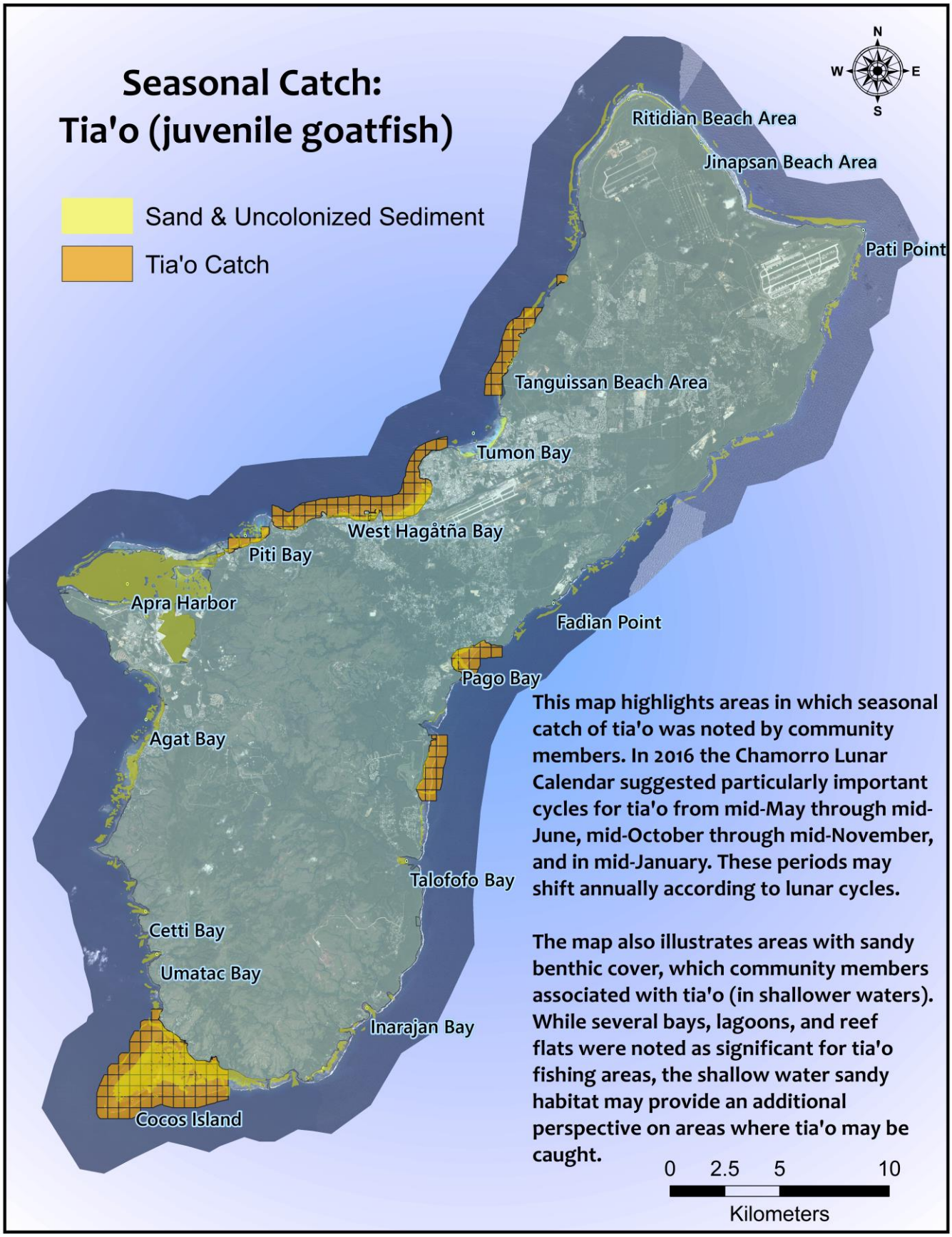

Gear-Method: Trolling
Boat-Based Survey Points
Significant Trolling Areas
FADs
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
Hagåtña Marina
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Agat Bay
Agat Small Boat Harbor
Talofofo Bay
Cetti Bay
Umatac Bay
Merizo Pier
Inarajan Bay
Cocos Island
This map highlights areas that were cited as being particularly important trolling grounds. Trolling was noted in additional areas that are outside the map grid, and are therefore not captured in this data.
Of particular interest in the map is the discrepancy between points of boat access and the areas that were noted for high quality trolling. The long distances required to reach east-side trolling areas were cited as a major factor in the low frequency of boat-based fishing on that side of Guam.
0 2.5 5 10
Kilometers

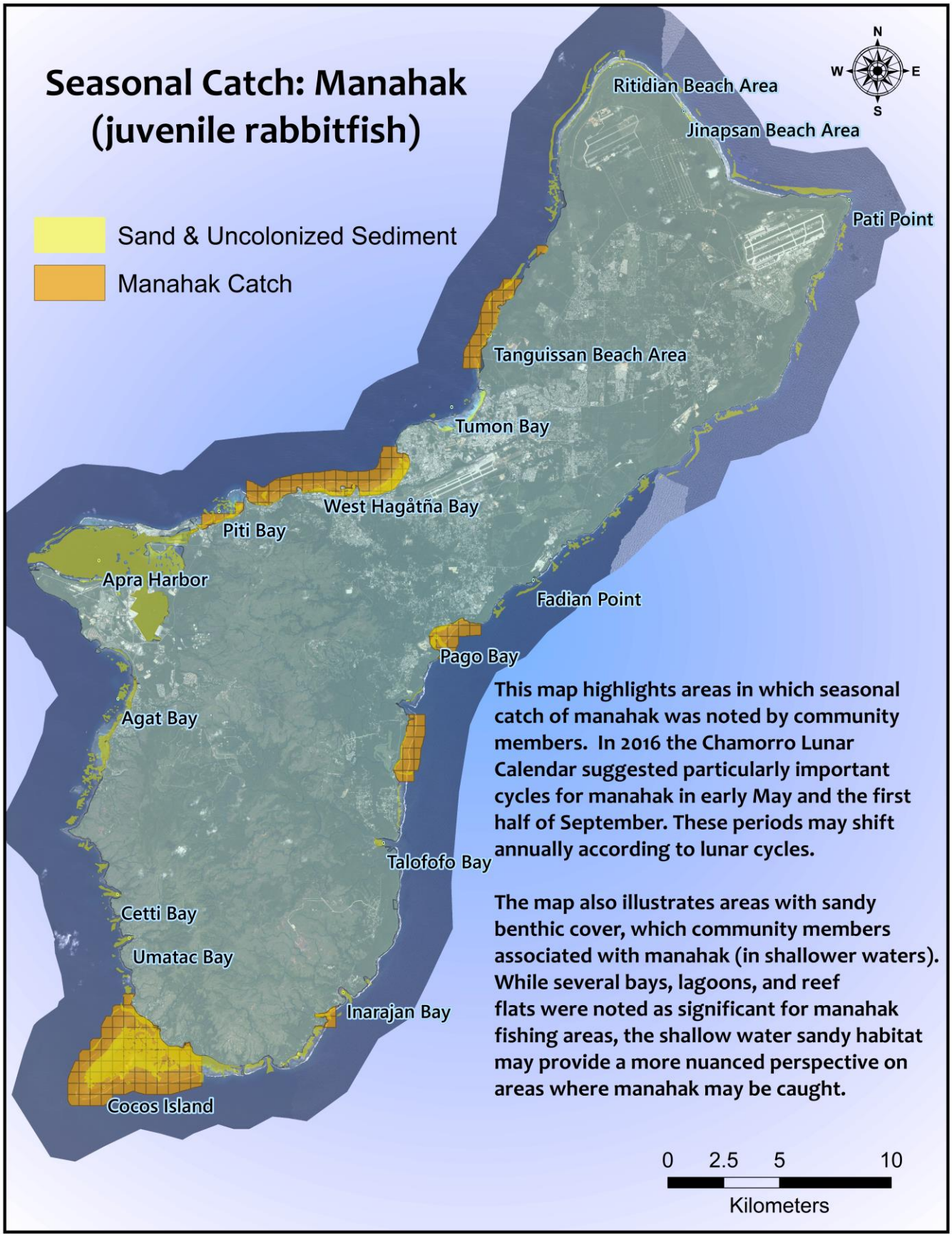

Gear-Method: Bottom-Fishing
N
W
E
S
Boat-Based Survey Points
Bottom Fishing Areas
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
Hagåtña Marina
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Agat Bay
Agat Small Boat Harbor
Talofofo Bay
Cetti Bay
Umatac Bay
Merizo Pier
Inarajan Bay
Cocos Island
This map highlights areas that were cited as being particularly important bottom fishing grounds. Bottom fishing was noted in additional areas that are outside the map grid, and are therefore not captured in this data.
Similar to trolling areas, there is a bit of a disconnect between points of boat access and the areas that were noted for high quality bottom fishing. The long distances required to reach east-side bottom fishing areas were cited as a major factor in the low frequency of boat-based fishing on that side of Guam.
0 2.5 5 10
Kilometers

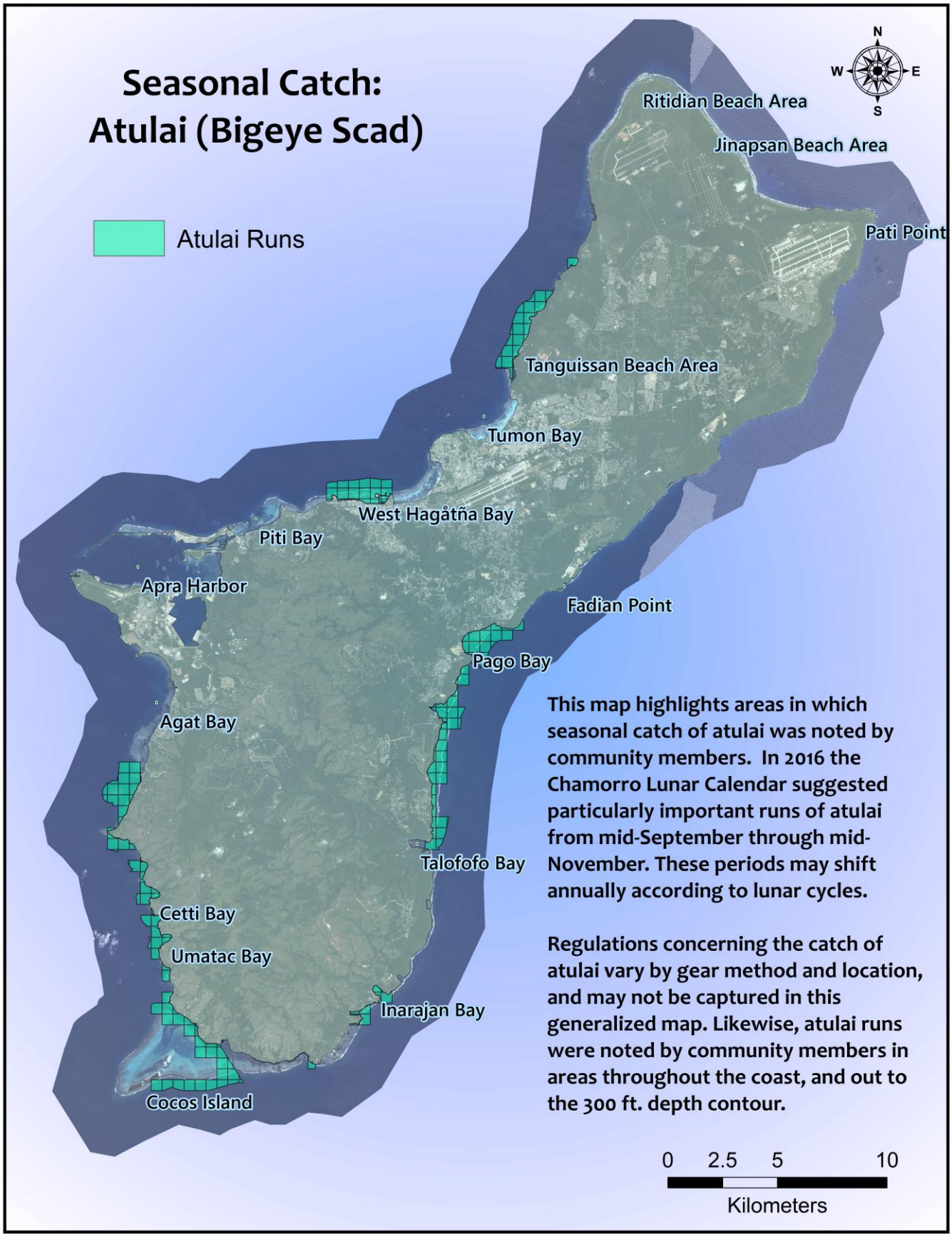

Gear-Method: Spear
Gear-Method: Spear
Limited Shore Access
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas that were cited as being particularly important for spearfishing. Spearing was noted in additional areas along the shoreline, but was either limited due to difficult shore access, or was not a dominant fishing method in that area.
A layer for "limited shore access" is included in this map to highlight one of the constraining factors for shore-based spearfishing. Participatory mapping exercises defined "limited shore access" to include issues of remoteness, hazardous ocean conditions, and private property boundaries.
0 2.5 5 10
Kilometers

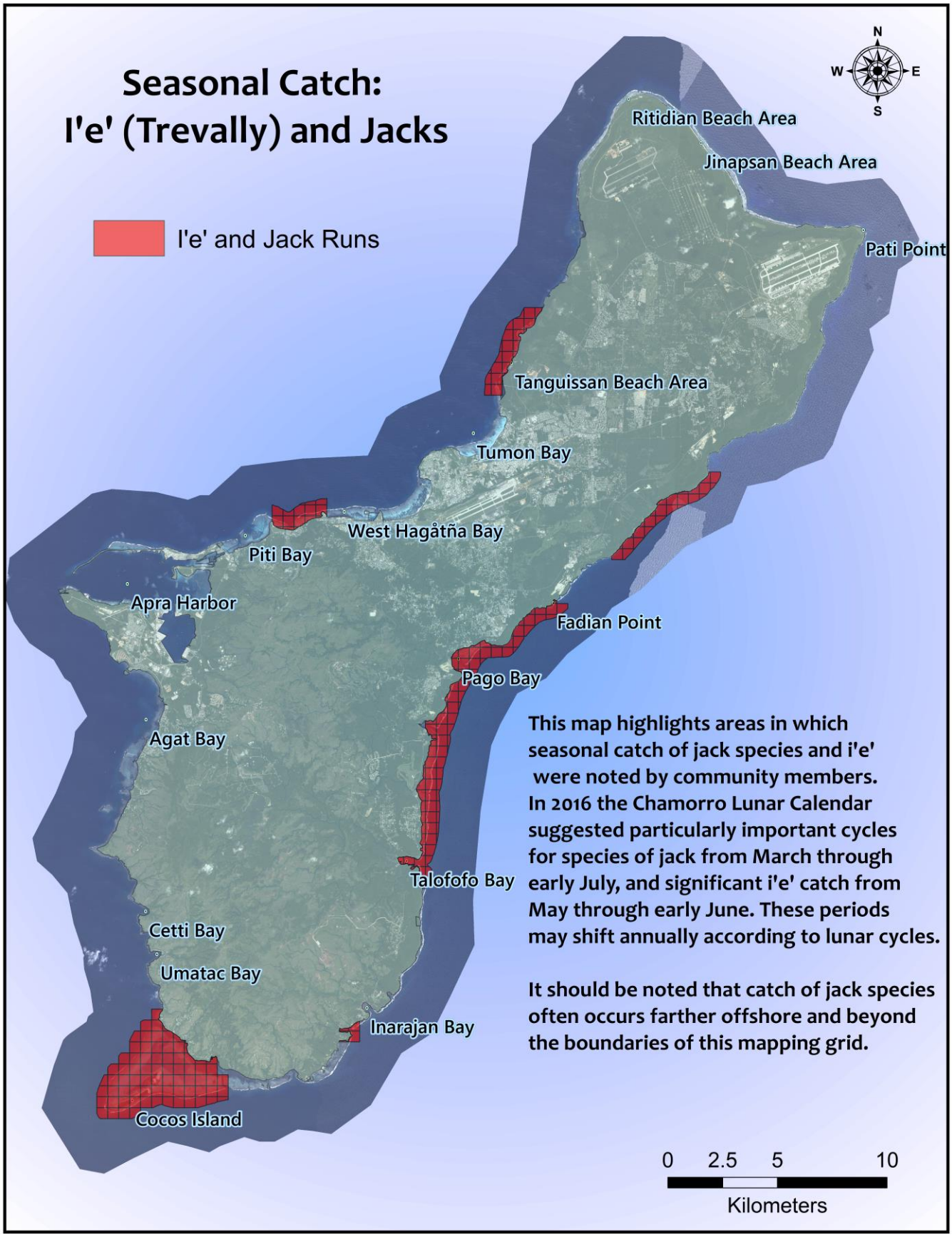

Gear-Method: Talaya
N
W
E
S
Talaya Areas
Limited Shore Access
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas that were cited as being particularly important for the use of cast nets. Talaya effort was noted in additional areas along the shoreline, but was either limited due to difficult shore access, or was not a dominant fishing method in that area.
A layer for "limited shore access" is included in this map to highlight one of the constraining factors for Talaya. Participatory mapping exercises defined limited shore access to include issues of remoteness, hazardous conditions, regulatory issues, and private property boundaries.
0 2.5 5 10
Kilometers

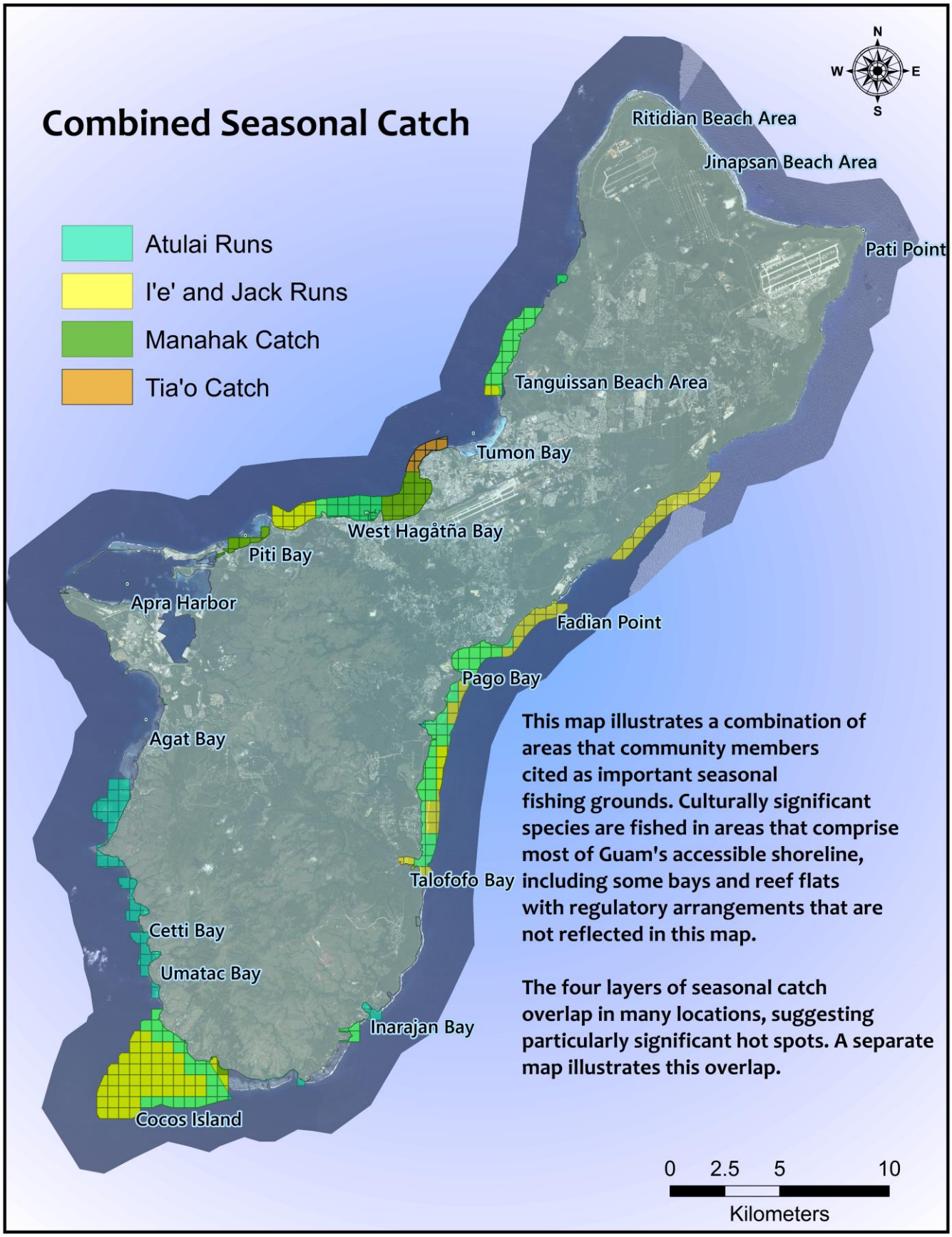

Access for Shore and Boat-Based Fishing: Wet Season
Accessible: June - October
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas in which fishing effort may increase during calm ocean conditions, generally experienced during Guam's rainy season (June-November).
Persistent wave energy from trade winds during Guam's dry season can create hazardous conditions, therefore much of the east side of Guam has limited access from late December through April. This generalization does not account for occasional tropical cyclone activity which tends to increase during the rainy season.
0 2.5 5 10
Kilometers

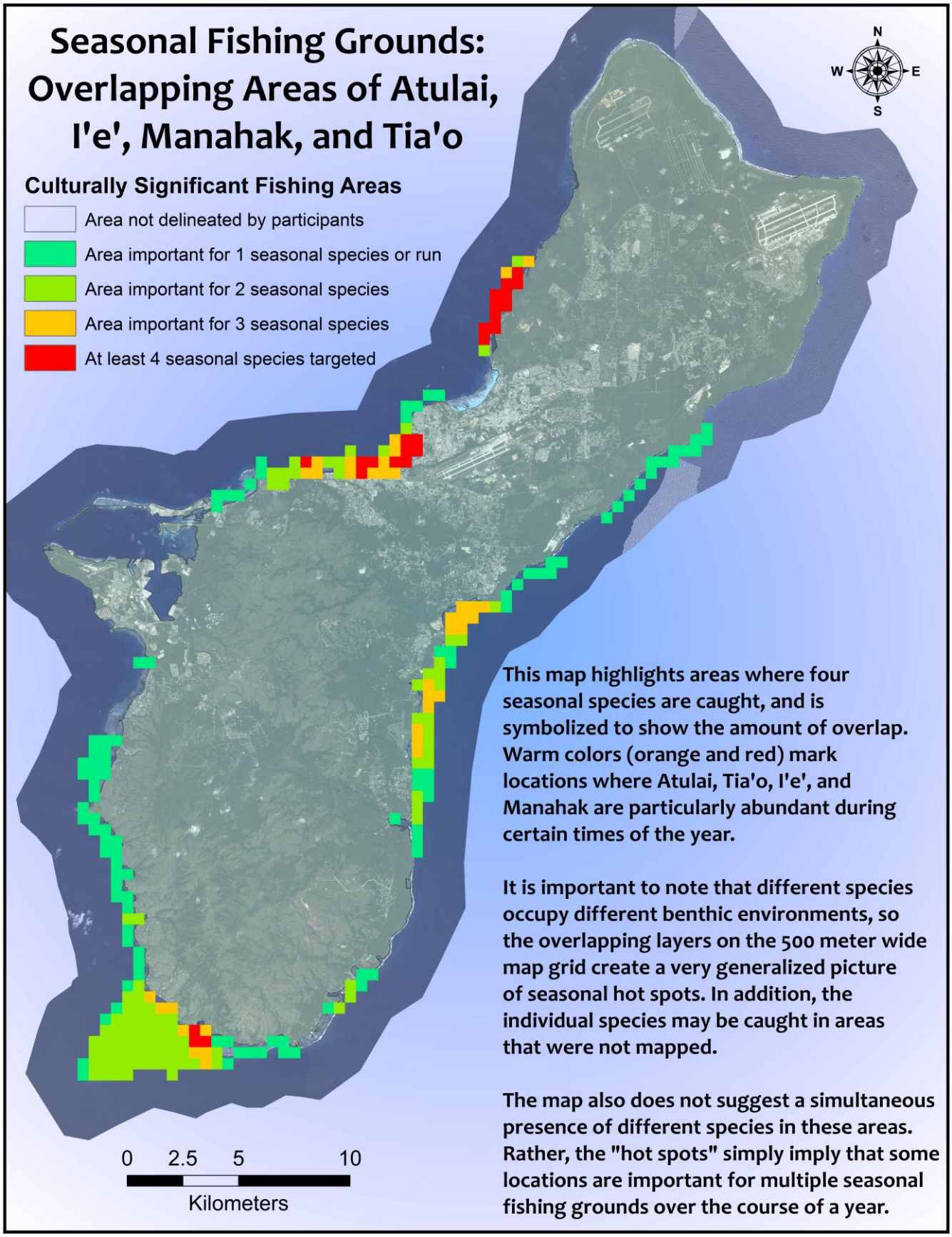

Seasonal Catch:
Tia'o (juvenile goatfish)
Sand & Uncolonized Sediment
Tia'o Catch
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas in which seasonal catch of tia'o was noted by community members. In 2016 the Chamorro Lunar Calendar suggested particularly important cycles for tia'o from mid-May through mid-June, mid-October through mid-November, and in mid-January. These periods may shift annually according to lunar cycles.
The map also illustrates areas with sandy benthic cover, which community members associated with tia'o (in shallower waters). While several bays, lagoons, and reef flats were noted as significant for tia'o fishing areas, the shallow water sandy habitat may provide an additional perspective on areas where tia'o may be caught.
0 2.5 5 10
Kilometers

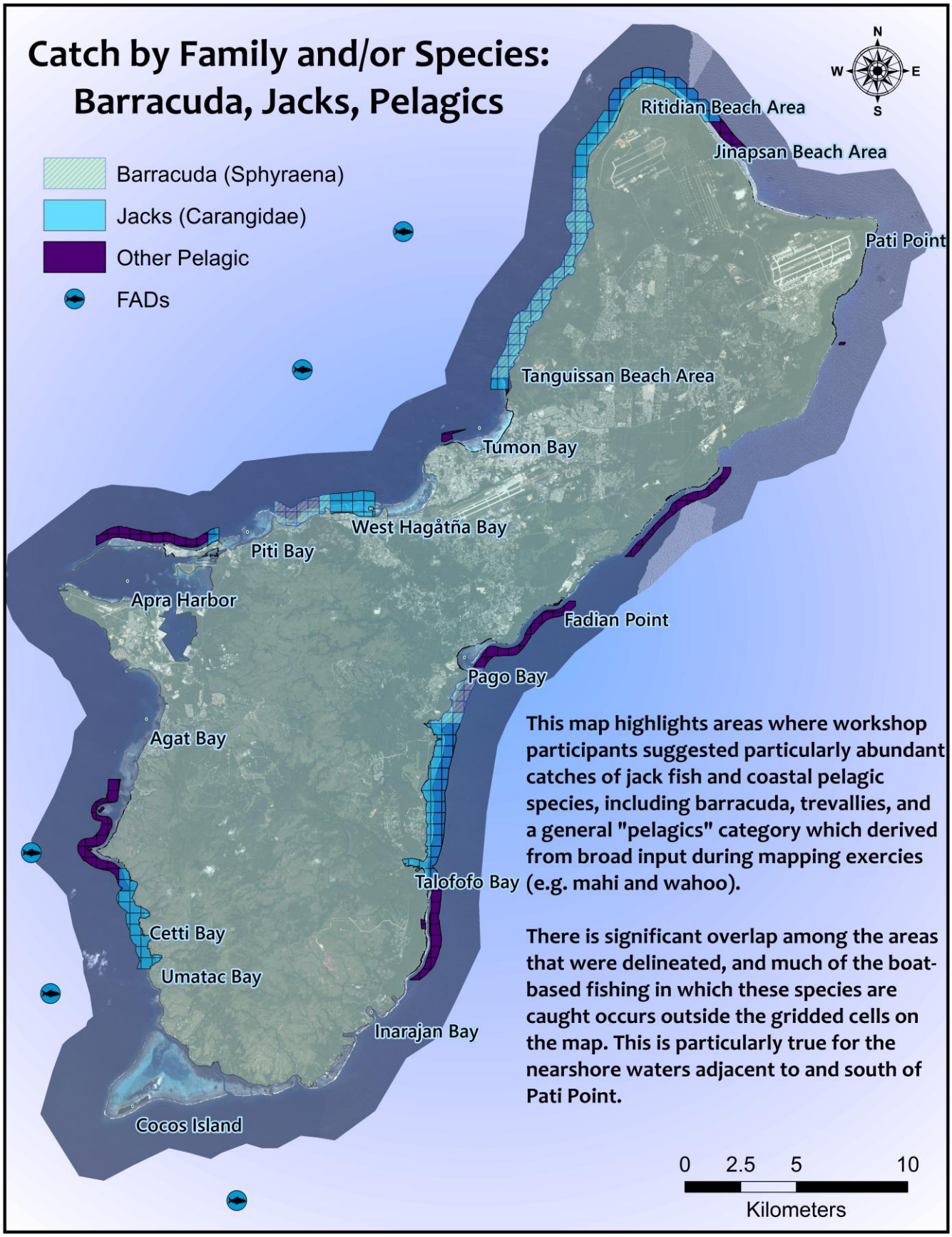

Seasonal Catch: Manahak (juvenile rabbitfish)
Sand & Uncolonized Sediment
Manahak Catch
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas in which seasonal catch of manahak was noted by community members. In 2016 the Chamorro Lunar Calendar suggested particularly important cycles for manahak in early May and the first half of September. These periods may shift annually according to lunar cycles.
The map also illustrates areas with sandy benthic cover, which community members associated with manahak (in shallower waters). While several bays, lagoons, and reef flats were noted as significant for manahak fishing areas, the shallow water sandy habitat may provide a more nuanced perspective on areas where manahak may be caught.
0 2.5 5 10
Kilometers

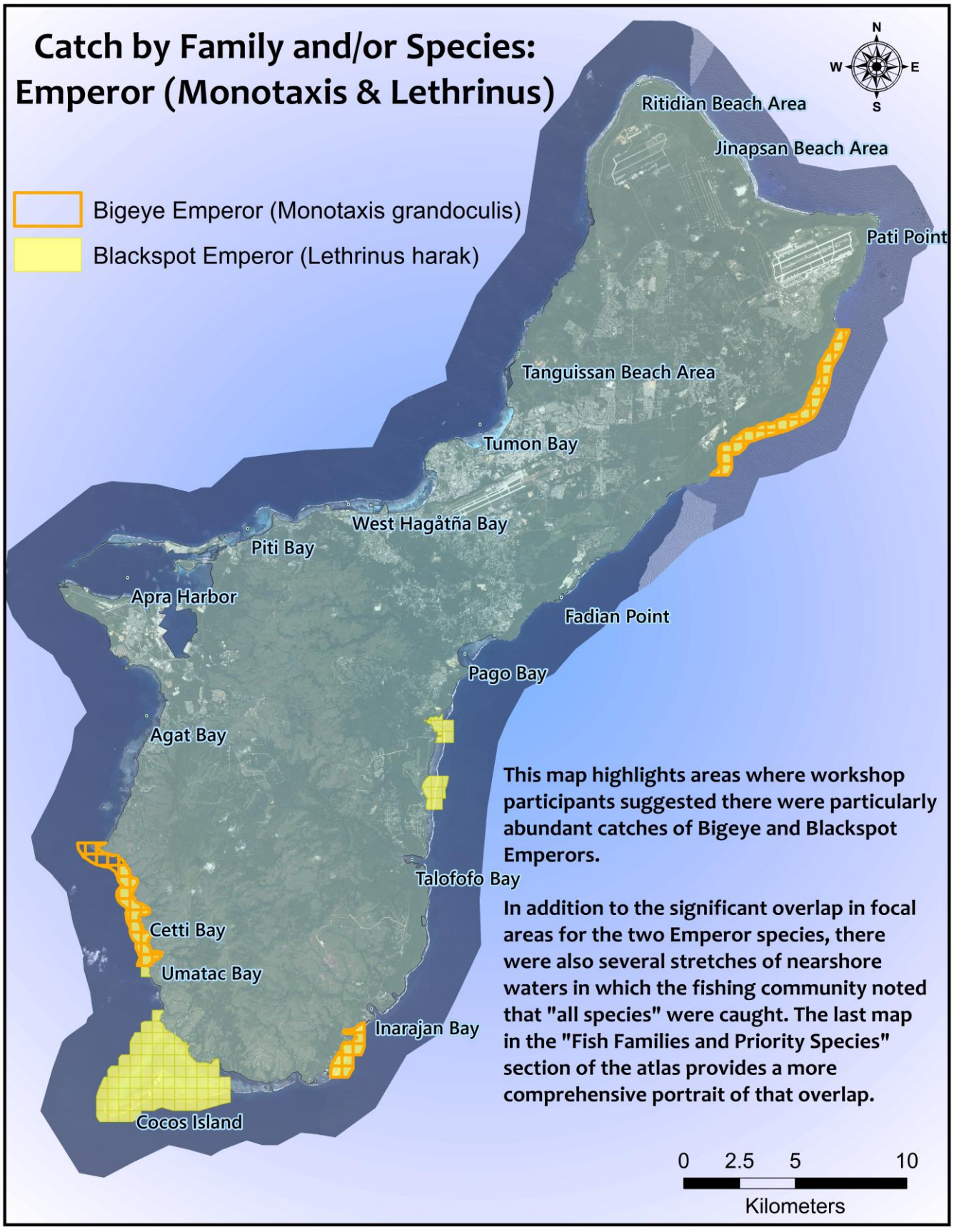

Seasonal Catch:
Atulai (Bigeye Scad)
Atulai Runs
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas in which seasonal catch of atulai was noted by community members. In 2016 the Chamorro Lunar Calendar suggested particularly important runs of atulai from mid-September through mid-November. These periods may shift annually according to lunar cycles.
Regulations concerning the catch of atulai vary by gear method and location, and may not be captured in this generalized map. Likewise, atulai runs were noted by community members in areas throughout the coast, and out to the 300 ft. depth contour.
0 2.5 5 10
Kilometers

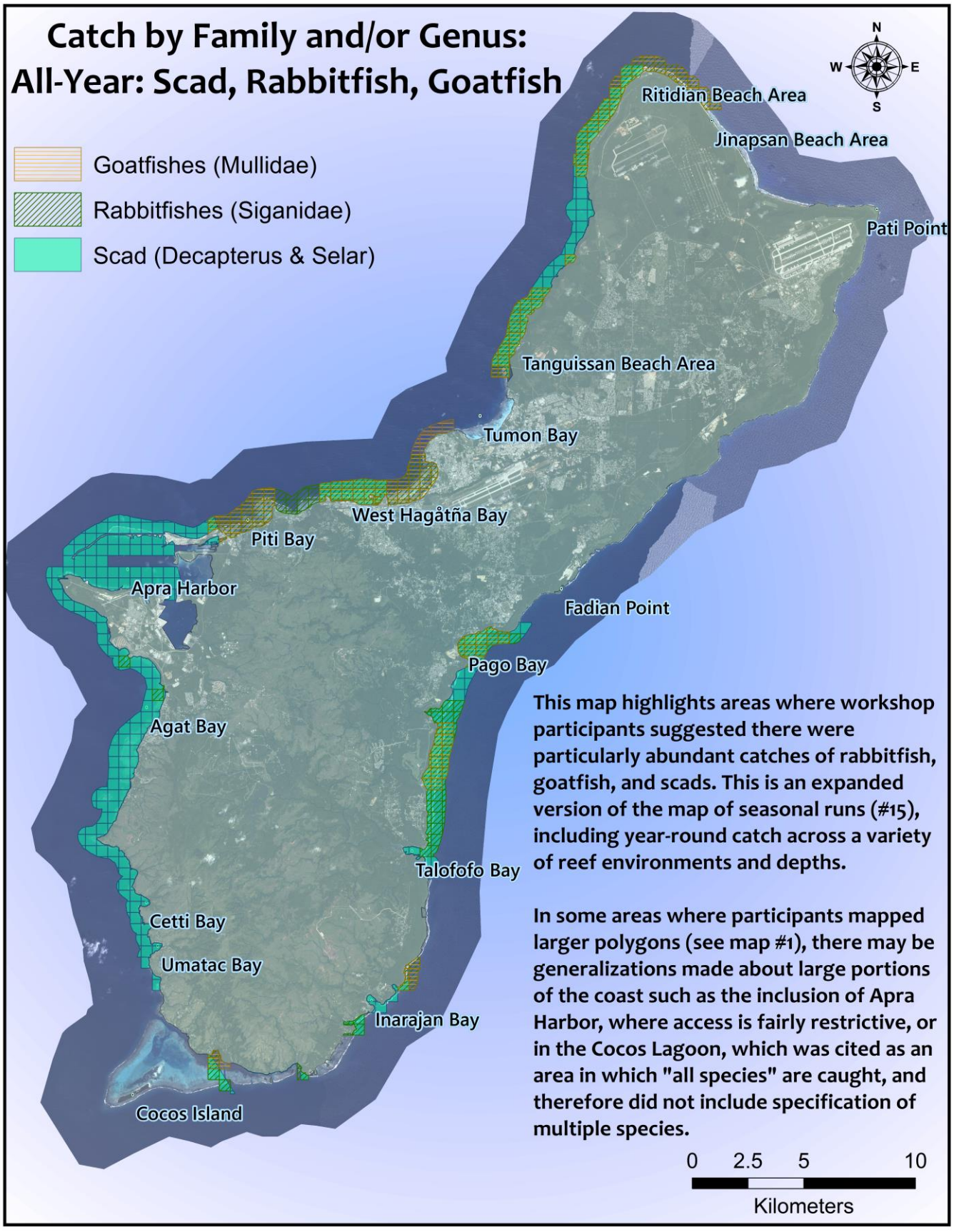

Seasonal Catch:
I'e' (Trevally) and Jacks
I'e' and Jack Runs
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas in which seasonal catch of jack species and i'e' were noted by community members. In 2016 the Chamorro Lunar Calendar suggested particularly important cycles for species of jack from March through early July, and significant i'e' catch from May through early June. These periods may shift annually according to lunar cycles.
It should be noted that catch of jack species often occurs farther offshore and beyond the boundaries of this mapping grid.
0 2.5 5 10
Kilometers

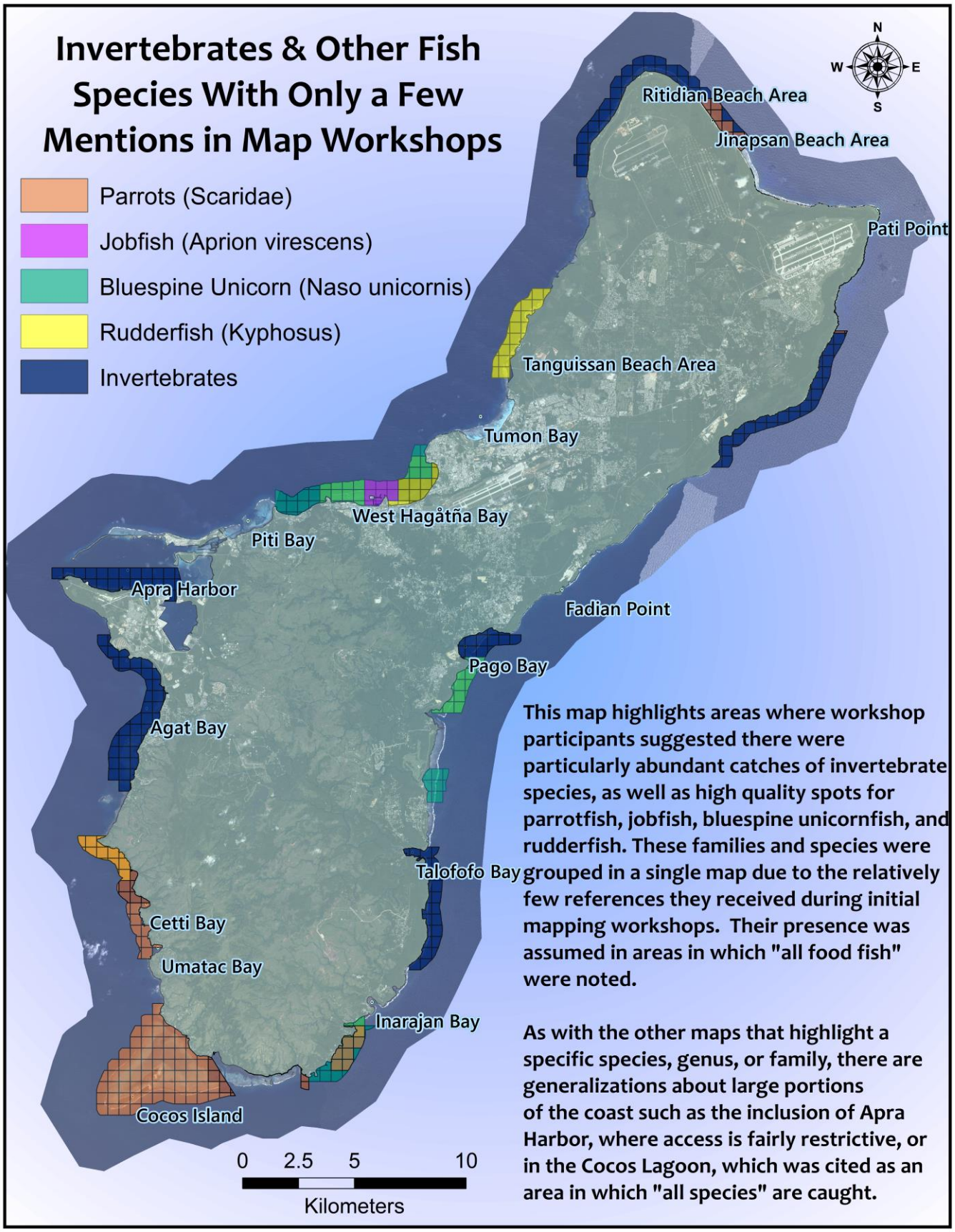

Combined Seasonal Catch
Atulai Runs
I'e' and Jack Runs
Manahak Catch
Tia'o Catch
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map illustrates a combination of areas that community members cited as important seasonal fishing grounds. Culturally significant species are fished in areas that comprise most of Guam's accessible shoreline, including some bays and reef flats with regulatory arrangements that are not reflected in this map.
The four layers of seasonal catch overlap in many locations, suggesting particularly significant hot spots. A separate map illustrates this overlap.
0 2.5 5 10
Kilometers

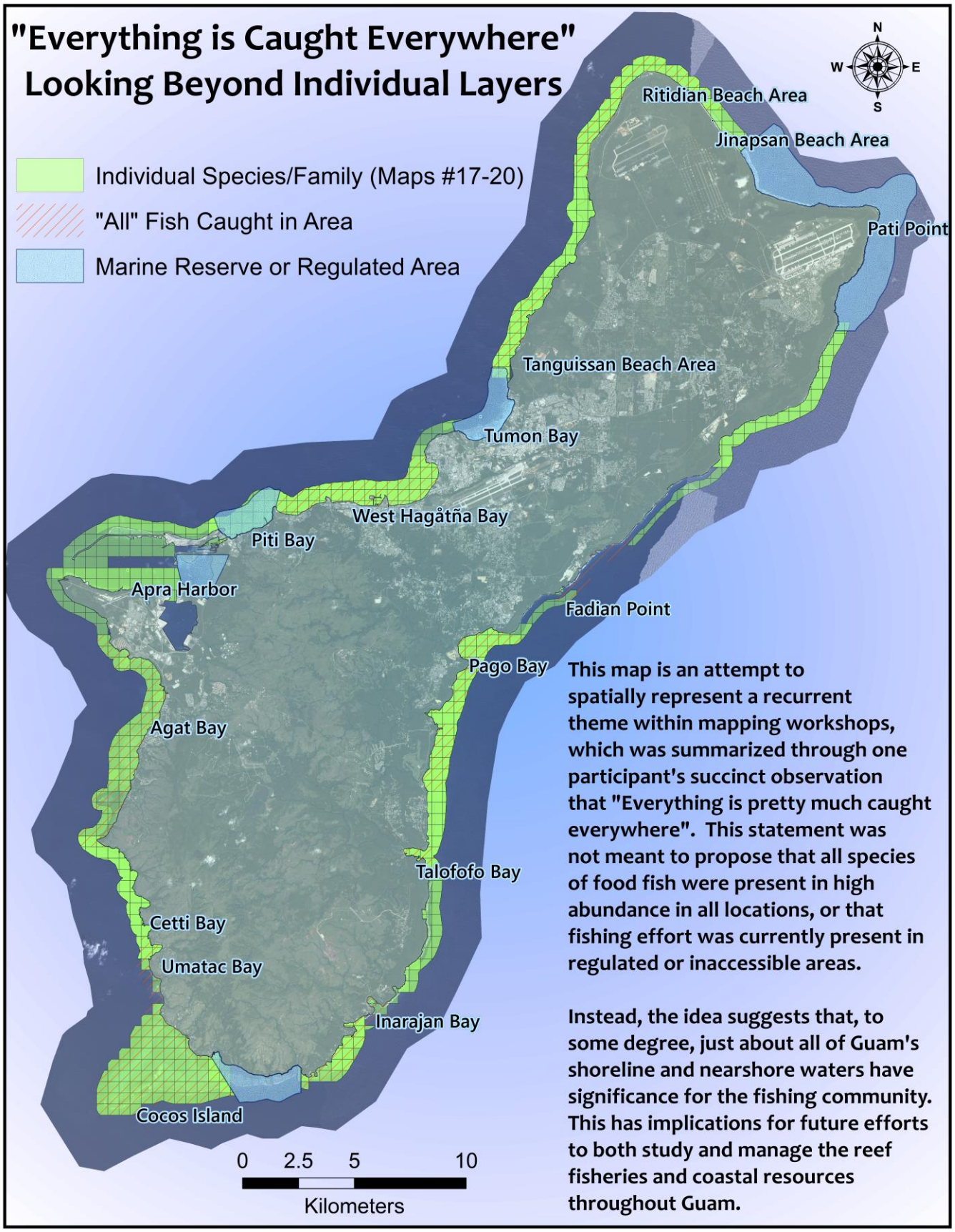

Seasonal Fishing Grounds: Overlapping Areas of Atulai, I'e', Manahak, and Tia'o
N
W
E
S
Culturally Significant Fishing Areas
Area not delineated by participants
Area important for 1 seasonal species or run
Area important for 2 seasonal species
Area important for 3 seasonal species
At least 4 seasonal species targeted
0 2.5 5 10
Kilometers
This map highlights areas where four seasonal species are caught, and is symbolized to show the amount of overlap. Warm colors (orange and red) mark locations where Atulai, Tia'o, I'e', and Manahak are particularly abundant during certain times of the year.
It is important to note that different species occupy different benthic environments, so the overlapping layers on the 500 meter wide map grid create a very generalized picture of seasonal hot spots. In addition, the individual species may be caught in areas that were not mapped.
The map also does not suggest a simultaneous presence of different species in these areas. Rather, the "hot spots" simply imply that some locations are important for multiple seasonal fishing grounds over the course of a year.

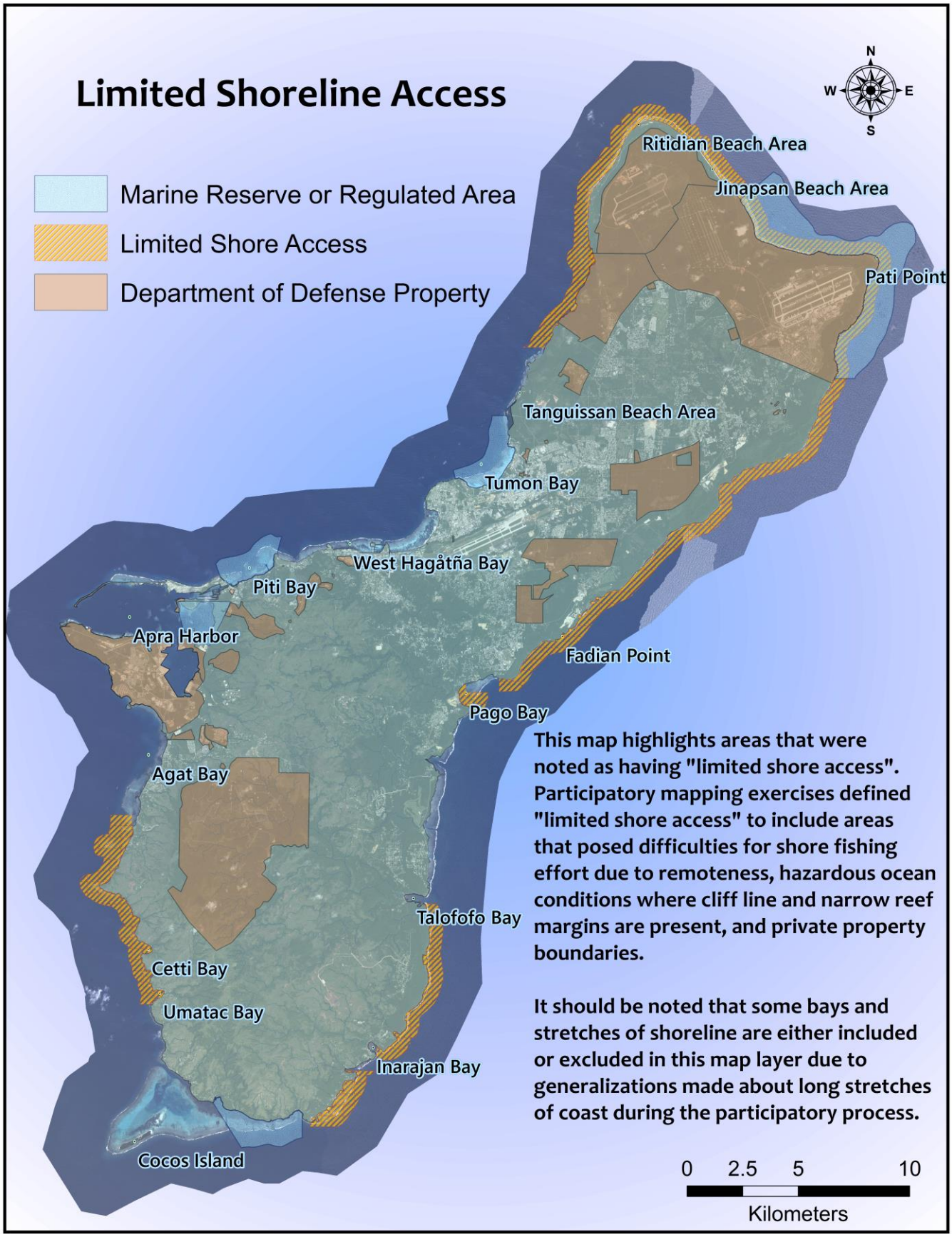

Catch by Family and/or Species:
Barracuda, Jacks, Pelagics
Barracuda (Sphyraena)
Jacks (Carangidae)
Other Pelagic
FADs
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas where workshop participants suggested particularly abundant catches of jack fish and coastal pelagic species, including barracuda, trevallies, and a general "pelagics" category which derived from broad input during mapping exercies (e.g. mahi and wahoo).
There is significant overlap among the areas that were delineated, and much of the boat-based fishing in which these species are caught occurs outside the gridded cells on the map. This is particularly true for the nearshore waters adjacent to and south of Pati Point.
0 2.5 5 10
Kilometers

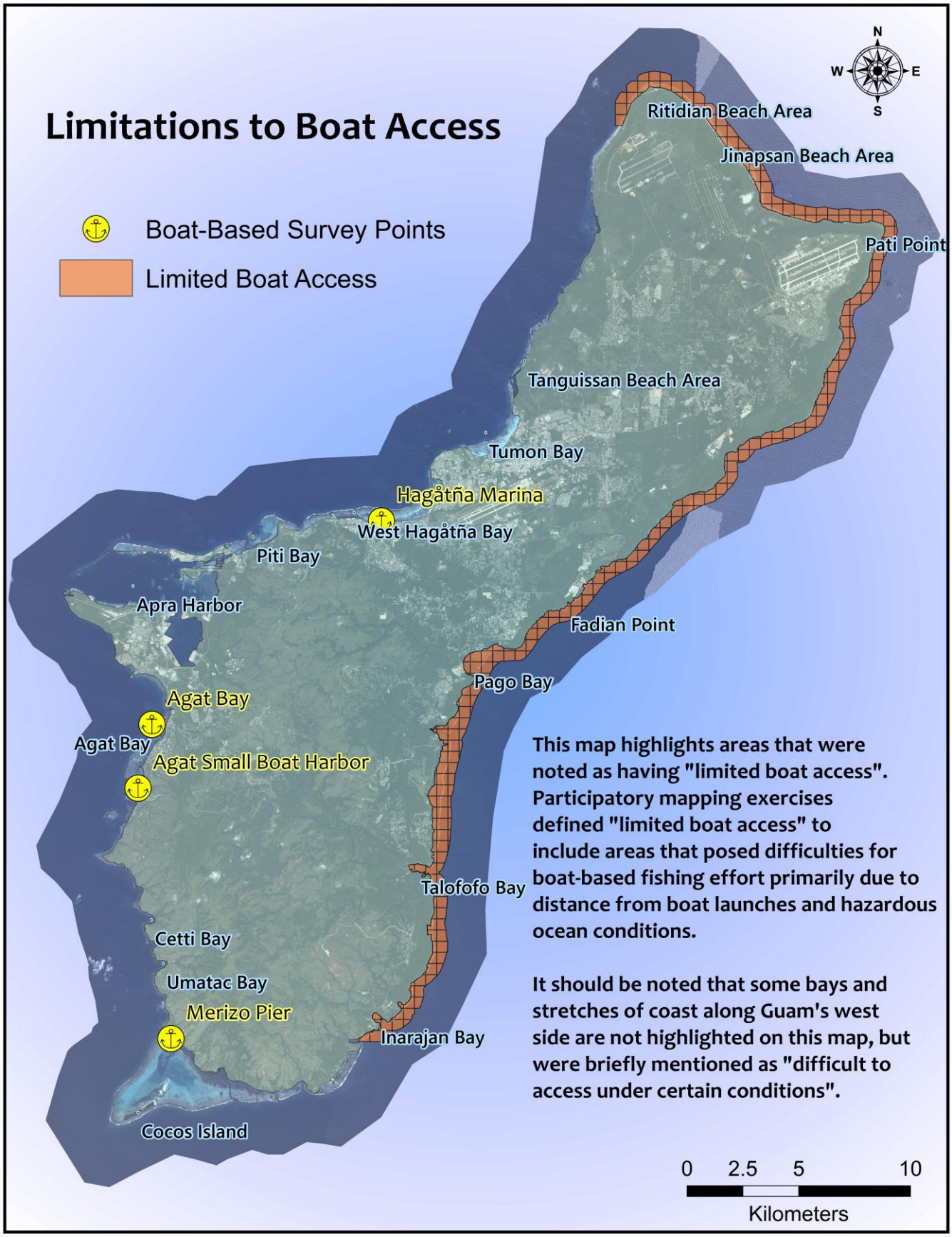

Catch by Family and/or Species:
Emperor (Monotaxis & Lethrinus)
N
W
E
S
Bigeye Emperor (Monotaxis grandoculis)
Blackspot Emperor (Lethrinus harak)
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas where workshop participants suggested there were particularly abundant catches of Bigeye and Blackspot Emperors.
In addition to the significant overlap in focal areas for the two Emperor species, there were also several stretches of nearshore waters in which the fishing community noted that "all species" were caught. The last map in the "Fish Families and Priority Species" section of the atlas provides a more comprehensive portrait of that overlap.
0 2.5 5 10
Kilometers

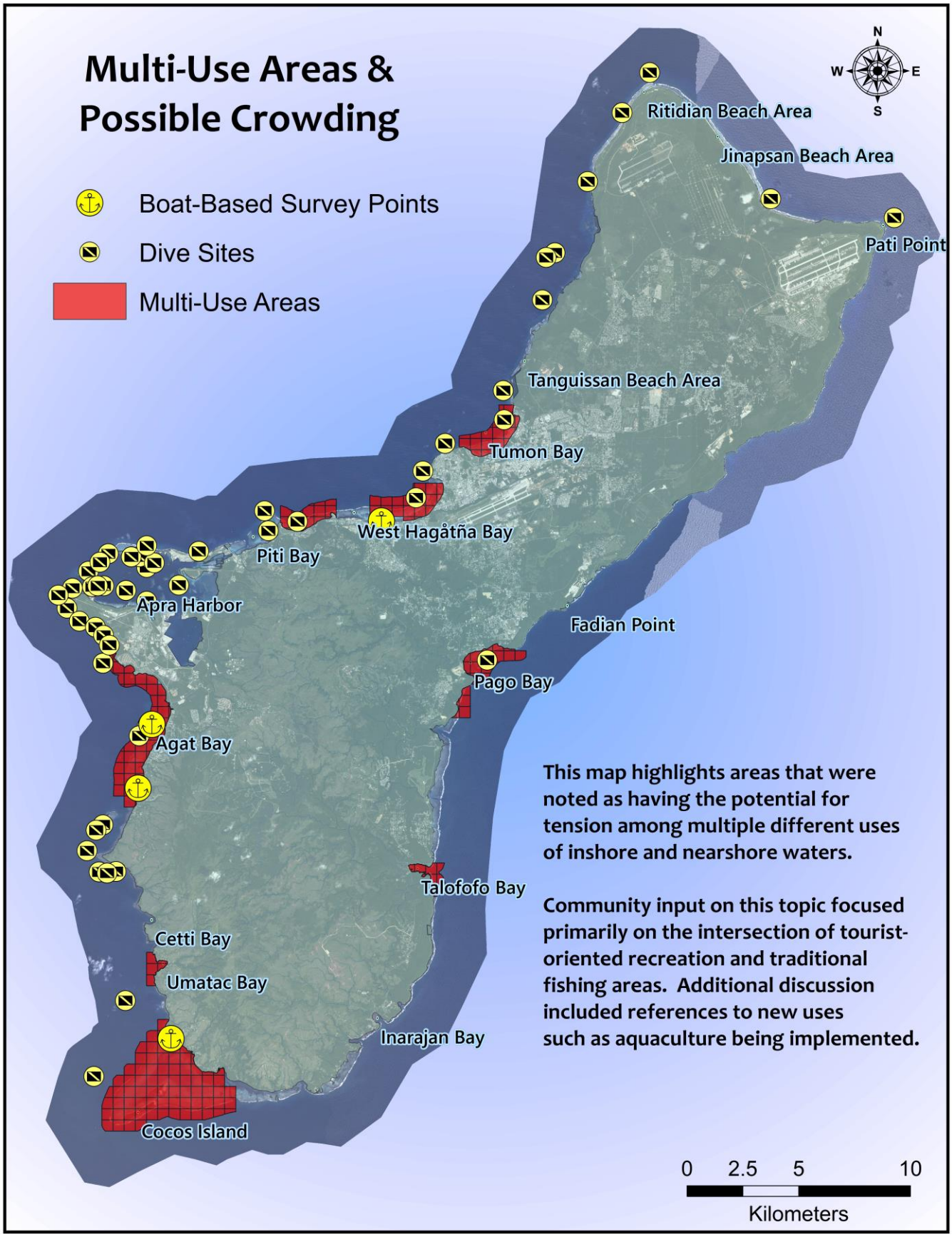

Catch by Family and/or Genus:
All-Year: Scad, Rabbitfish, Goatfish
Goatfishes (Mullidae)
Rabbitfishes (Siganidae)
Scad (Decapterus & Selar)
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas where workshop participants suggested there were particularly abundant catches of rabbitfish, goatfish, and scads. This is an expanded version of the map of seasonal runs (#15), including year-round catch across a variety of reef environments and depths.
In some areas where participants mapped larger polygons (see map #1), there may be generalizations made about large portions of the coast such as the inclusion of Apra Harbor, where access is fairly restrictive, or in the Cocos Lagoon, which was cited as an area in which "all species" are caught, and therefore did not include specification of multiple species.
0 2.5 5 10
Kilometers

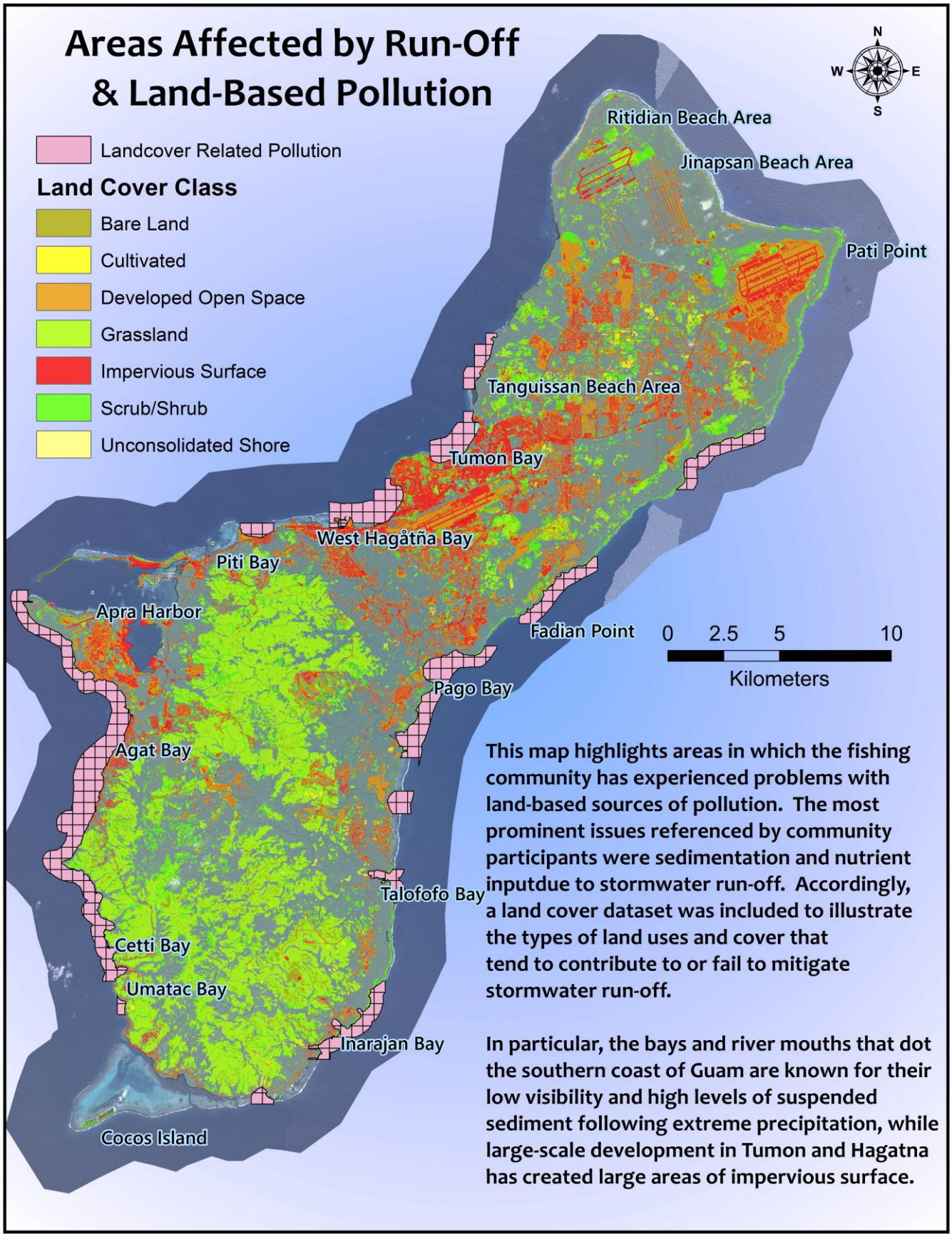

Invertebrates & Other Fish Species With Only a Few Mentions in Map Workshops
Parrots (Scaridae)
Jobfish (Aprion virescens)
Bluespine Unicorn (Naso unicornis)
Rudderfish (Kyphosus)
Invertebrates
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
0 2.5 5 10
Kilometers
This map highlights areas where workshop participants suggested there were particularly abundant catches of invertebrate species, as well as high quality spots for parrotfish, jobfish, bluespine unicornfish, and rudderfish. These families and species were grouped in a single map due to the relatively few references they received during initial mapping workshops. Their presence was assumed in areas in which "all food fish" were noted.
As with the other maps that highlight a specific species, genus, or family, there are generalizations about large portions of the coast such as the inclusion of Apra Harbor, where access is fairly restrictive, or in the Cocos Lagoon, which was cited as an area in which "all species" are caught.

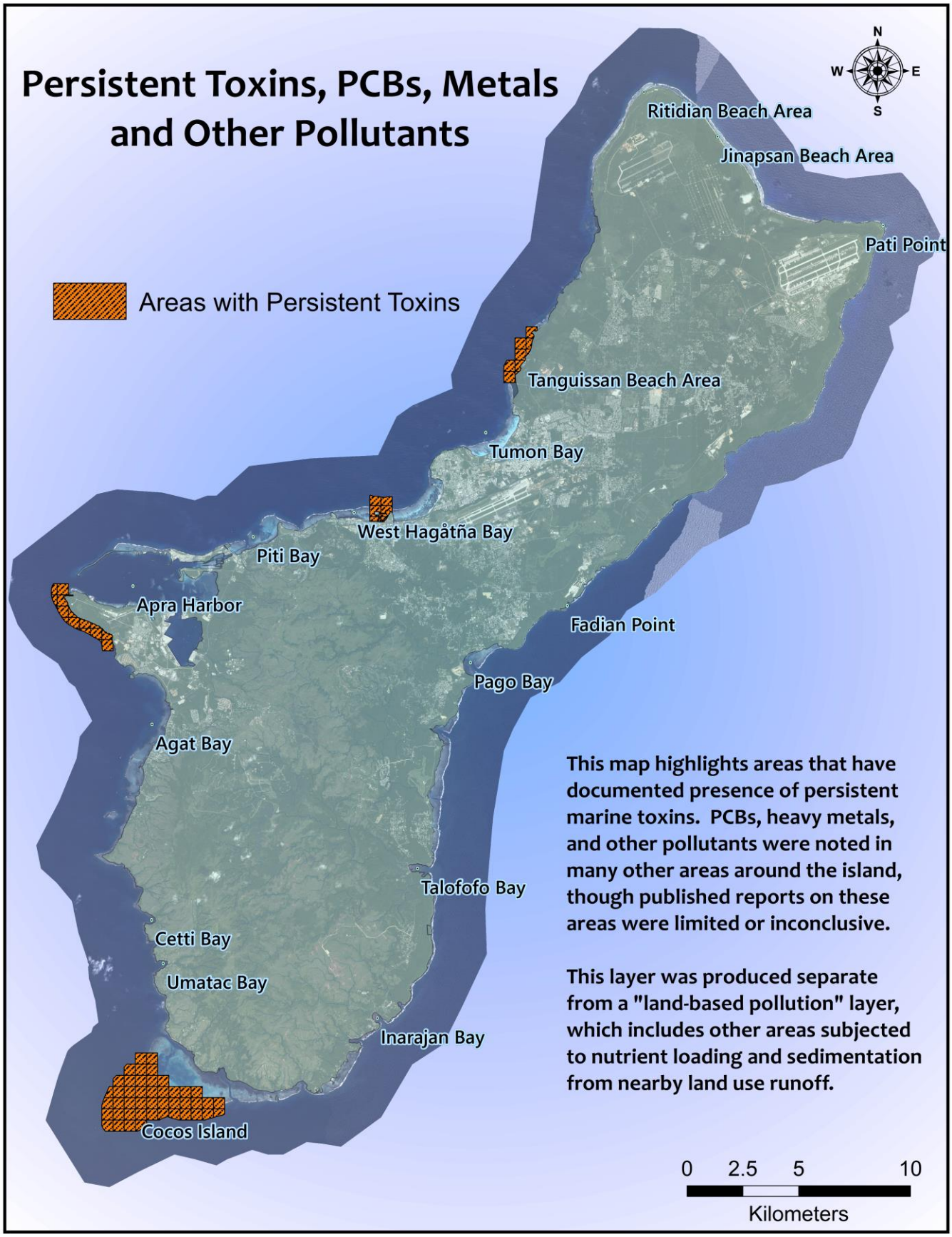

"Everything is Caught Everywhere"
Looking Beyond Individual Layers
Individual Species/Family (Maps #17-20)
"All" Fish Caught in Area
Marine Reserve or Regulated Area
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
0 2.5 5 10
Kilometers
This map is an attempt to spatially represent a recurrent theme within mapping workshops, which was summarized through one participant's succinct observation that "Everything is pretty much caught everywhere". This statement was not meant to propose that all species of food fish were present in high abundance in all locations, or that fishing effort was currently present in regulated or inaccessible areas.
Instead, the idea suggests that, to some degree, just about all of Guam's shoreline and nearshore waters have significance for the fishing community. This has implications for future efforts to both study and manage the reef fisheries and coastal resources throughout Guam.

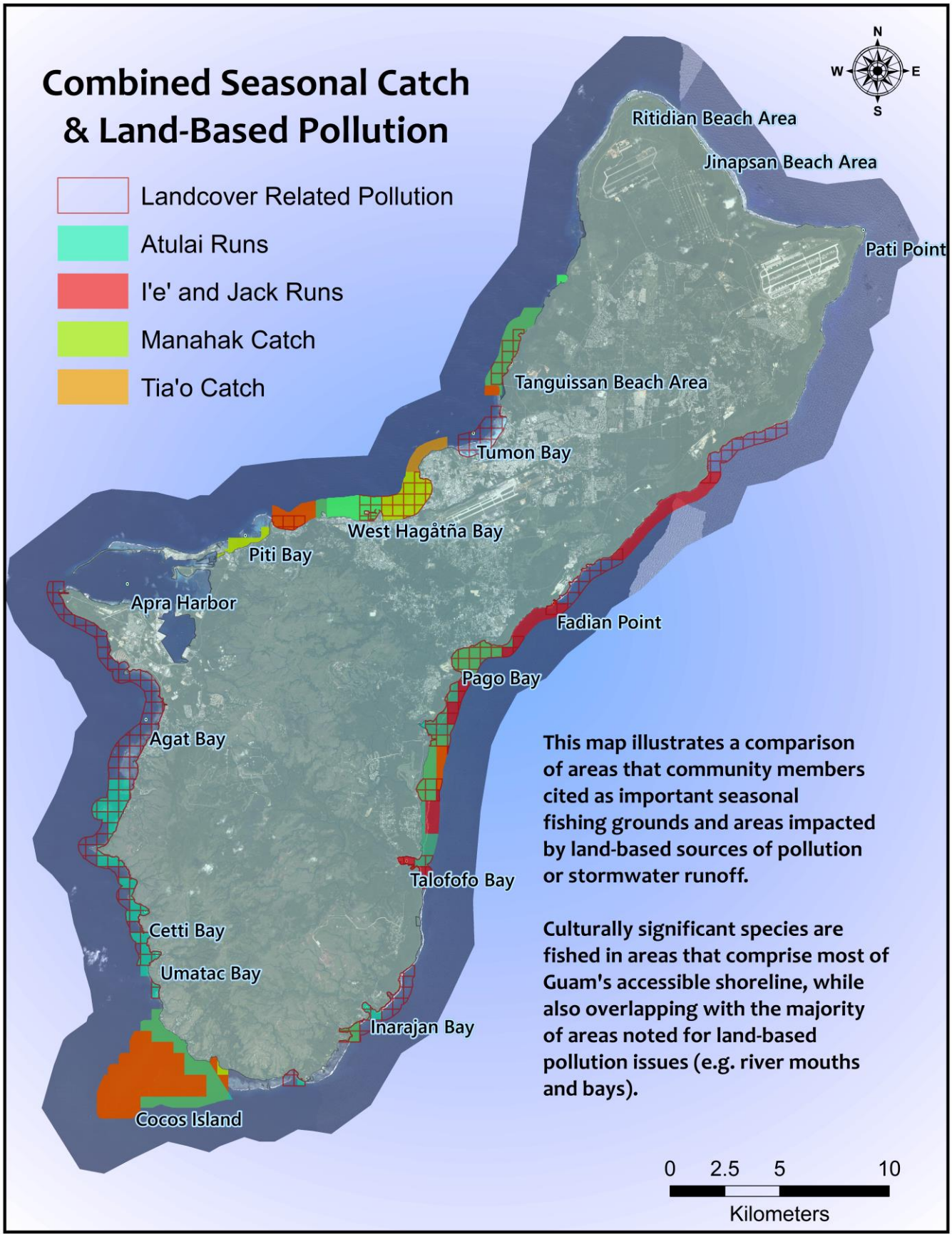

Limited Shoreline Access
N
W
E
S
Marine Reserve or Regulated Area
Limited Shore Access
Department of Defense Property
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas that were noted as having "limited shore access". Participatory mapping exercises defined "limited shore access" to include areas that posed difficulties for shore fishing effort due to remoteness, hazardous ocean conditions where cliff line and narrow reef margins are present, and private property boundaries.
It should be noted that some bays and stretches of shoreline are either included or excluded in this map layer due to generalizations made about long stretches of coast during the participatory process.
0 2.5 5 10
Kilometers

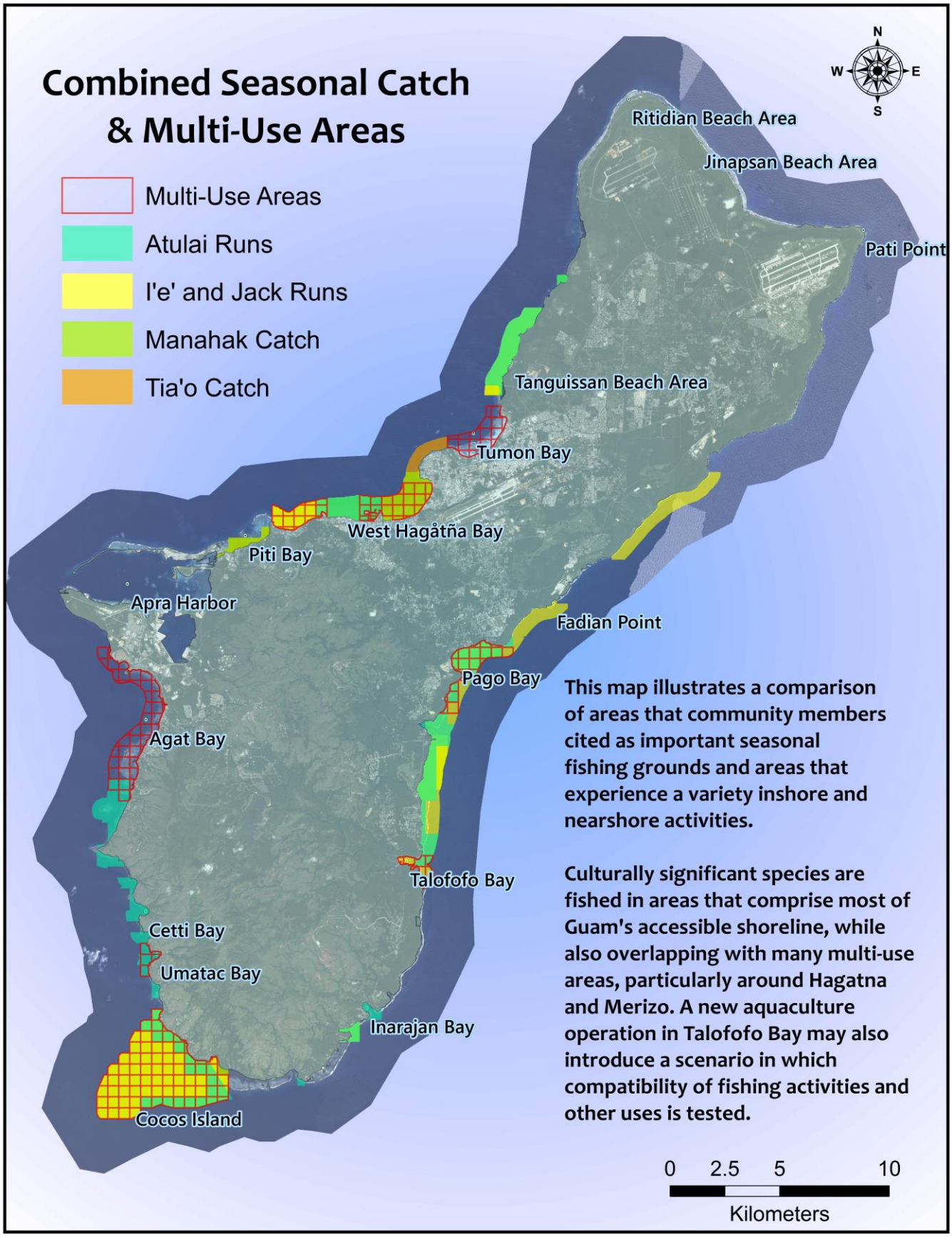

Limitations to Boat Access
Boat-Based Survey Points
Limited Boat Access
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
Hagåtña Marina
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Agat Bay
Agat Small Boat Harbor
Talofofo Bay
Cetti Bay
Umatac Bay
Merizo Pier
Inarajan Bay
Cocos Island
This map highlights areas that were noted as having "limited boat access". Participatory mapping exercises defined "limited boat access" to include areas that posed difficulties for boat-based fishing effort primarily due to distance from boat launches and hazardous ocean conditions.
It should be noted that some bays and stretches of coast along Guam's west side are not highlighted on this map, but were briefly mentioned as "difficult to access under certain conditions".
0 2.5 5 10
Kilometers


Multi-Use Areas & Possible Crowding
Boat-Based Survey Points
Dive Sites
Multi-Use Areas
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas that were noted as having the potential for tension among multiple different uses of inshore and nearshore waters.
Community input on this topic focused primarily on the intersection of tourist-oriented recreation and traditional fishing areas. Additional discussion included references to new uses such as aquaculture being implemented.
0 2.5 5 10
Kilometers

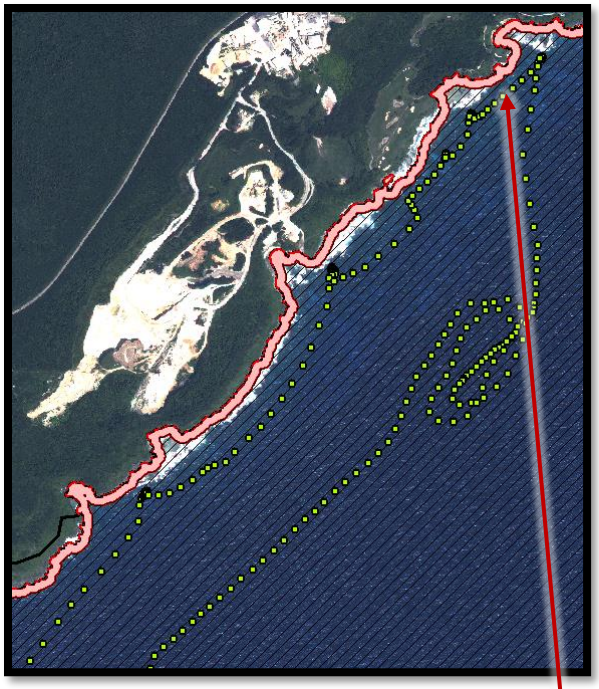

Areas Affected by Run-Off & Land-Based Pollution
Landcover Related Pollution
Land Cover Class
Bare Land
Cultivated
Developed Open Space
Grassland
Impervious Surface
Scrub/Shrub
Unconsolidated Shore
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
0 2.5 5 10
Kilometers
This map highlights areas in which the fishing community has experienced problems with land-based sources of pollution. The most prominent issues referenced by community participants were sedimentation and nutrient inputdue to stormwater run-off. Accordingly, a land cover dataset was included to illustrate the types of land uses and cover that tend to contribute to or fail to mitigate stormwater run-off.
In particular, the bays and river mouths that dot the southern coast of Guam are known for their low visibility and high levels of suspended sediment following extreme precipitation, while large-scale development in Tumon and Hagatna has created large areas of impervious surface.


Persistent Toxins, PCBs, Metals and Other Pollutants
N
W
E
S
Areas with Persistent Toxins
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map highlights areas that have documented presence of persistent marine toxins. PCBs, heavy metals, and other pollutants were noted in many other areas around the island, though published reports on these areas were limited or inconclusive.
This layer was produced separate from a "land-based pollution" layer, which includes other areas subjected to nutrient loading and sedimentation from nearby land use runoff.
0 2.5 5 10
Kilometers


Combined Seasonal Catch & Land-Based Pollution
Landcover Related Pollution
Atulai Runs
I'e' and Jack Runs
Manahak Catch
Tia'o Catch
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map illustrates a comparison of areas that community members cited as important seasonal fishing grounds and areas impacted by land-based sources of pollution or stormwater runoff.
Culturally significant species are fished in areas that comprise most of Guam's accessible shoreline, while also overlapping with the majority of areas noted for land-based pollution issues (e.g. river mouths and bays).
0 2.5 5 10
Kilometers


Combined Seasonal Catch & Multi-Use Areas
Multi-Use Areas
Atulai Runs
I'e' and Jack Runs
Manahak Catch
Tia'o Catch
N
W
E
S
Ritidian Beach Area
Jinapsan Beach Area
Pati Point
Tanguissan Beach Area
Tumon Bay
West Hagåtña Bay
Piti Bay
Apra Harbor
Fadian Point
Pago Bay
Agat Bay
Talofofo Bay
Cetti Bay
Umatac Bay
Inarajan Bay
Cocos Island
This map illustrates a comparison of areas that community members cited as important seasonal fishing grounds and areas that experience a variety inshore and nearshore activities.
Culturally significant species are fished in areas that comprise most of Guam's accessible shoreline, while also overlapping with many multi-use areas, particularly around Hagatna and Merizo. A new aquaculture operation in Talofofo Bay may also introduce a scenario in which compatibility of fishing activities and other uses is tested.
0 2.5 5 10
Kilometers

## Appendix B: GPS Data Processing



**The following steps were taken to process GPS data in preparation for analysis. The output from these processing steps has been incorporated into a geodatabase held by the Western Pacific Regional Fishery Management Council, and is confidential.**

**All GPX track points were converted to feature classes in geodatabase 'GPS_FieldData'**

**All track feature classes (49) were merged**

**All feature classes were clipped to shoreline and water areas. (This step was taken to remove GPS data from terrestrial activities such as boat trailering, hiking to shoreline access sites, etc… ).**

**Boat-based & shore-based track features were identified based on access points (intersections with the shoreline**)

**A 20 nm. Buffer was created outside the shoreline for clipping boat trip data to and providing a bounding geometry for analysis.**

- Output = Marine_Buffer_Clip

**A 30 meter buffer was created outside the shoreline to remove boat launching activities from point density analyses, and select for shore-access (this buffer distance was based on the minimum distance between boat track line and the shoreline).**

- Output = Nearshore_Buffer_ShoreAccess

**The 30 meter shoreline buffer was used as an erase feature to remove the shoreline/boat launch margin from the 20 nm boat trip area buffer.**

- Output = BB_ClipPoly

**All tracks from 30m – 20 nm (BB_ClipPoly) were then extracted.**

- Output = All_Boat_Tracks

**All tracks within 30 m. buffer (Nearshore_Buffer_ShoreAccess) were extracted**

- Output = ShoreTracks_Initial

**Features from ShoreTracks_Initial that were adjacent to boat access points were removed from feature class**

- Output = All_Shore_Tracks (in GPS_FieldData GDB)

**Shore and Boat Track Output Merged for tracks data representing all fishing effort**

- Output = All_Effort_Tracks (in GPS_FieldData GDB)