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AGENCY PRIORITIES FOR MAPPING CORAL REEF ECOSYSTEMS IN GUAM AND THE COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

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For more information on this project, please visit the project hub:
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And the project webpage:
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DISCLAIMER

Agency Priorities for Mapping Coral Reef Ecosystems in Guam and the Commonwealth of the Northern Mariana Islands

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Executive Summary

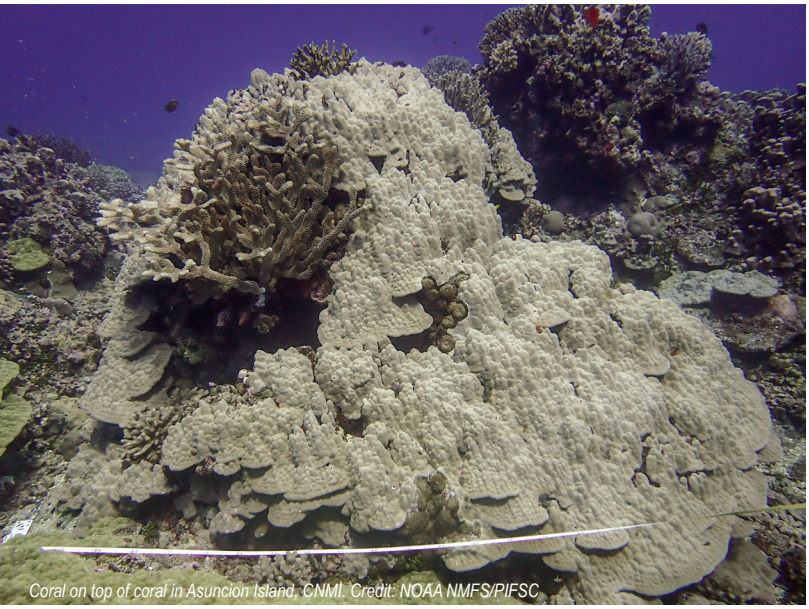
NOAA's Coral Reef Conservation Program (CRCP) utilizes benthic mapping data on coral reef ecosystems to support a diversity of science-based management decisions. To efficiently allocate limited mapping resources, CRCP recognized a need to identify priority locations based on emerging management requirements. Specifically, this effort focuses on coral reef areas up to 40 m deep surrounding the islands of Guam and the Commonwealth of the Northern Mariana Islands (CNMI).

To meet this need, NOAA's National Centers for Coastal Ocean Science (NCCOS) developed a systematic, quantitative approach and online geographic information system (GIS) application to gather seafloor mapping priorities from researchers and coral reef managers. Participants placed virtual coins into a grid overlaid on the project area to express the location and importance of their mapping priorities. They also used pull-down menus to indicate specific mapping data needs and the rationale for their selections. Participants' inputs were compiled and analyzed to identify high-priority areas along with their justifications and data requirements.

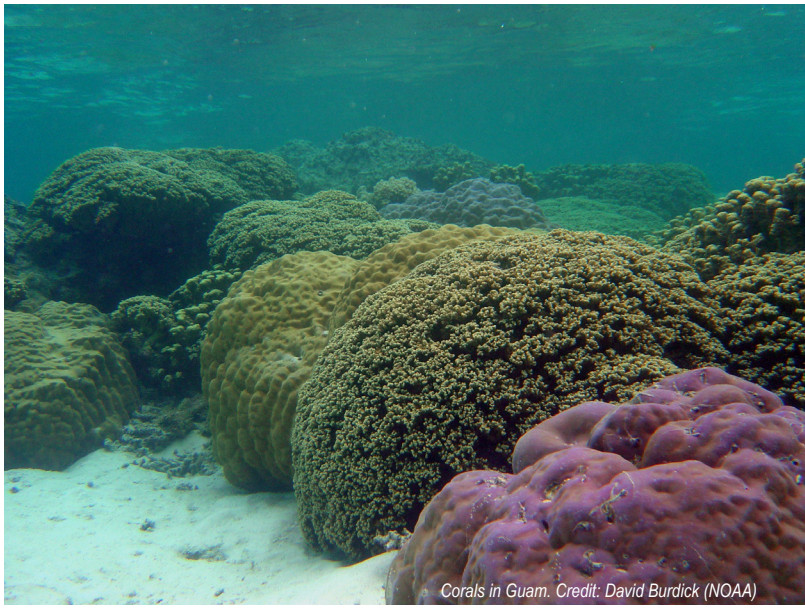
Participants input their mapping priorities for Guam (n=7) and CNMI (n=10) jurisdictions using an online tool from February 22 to March 15, 2023. The most commonly selected Management Use options in Guam were *Habitat Restoration*, *Monitoring*, and *Watershed Management*. In the CNMI, *Coastal Vulnerability and Planning*, *Monitoring*, and *Habitat Restoration* were the top choices. The top Map Product Requirement options revealed three main desired data types in Guam: *Identification of Coral Species*, *Habitat Suitability*, and *Density of Macrobiota*. In the CNMI, the top choices for desired data types were *Density of Macrobiota*, *Identification of Coral Species*, and *Substrate Type*.

To further explore areas of high interest and need by participants, clusters of top-ranking cells, or focal areas, were identified. Focal areas were based on a summary rank which combined ranking by total number of coins, number of participating groups, and number of unique Management Uses. In Guam, Apra Harbor was identified as a focal area due to its summary rank and various activities that occur in the harbor, with *Watershed Management*, *Coastal Vulnerability and Planning*, and *Monitoring* as the top-ranking Management Uses selected. In the CNMI, three focal areas were identified: 1) Liyo region, Rota; 2) Tinian Harbor, Tinian; and 3) Laolao Bay, Saipan. These areas were of interest to participants for various reasons, particularly for *Coastal Vulnerability and Planning* as climate change and coastal development have impacted these regions. Existing bathymetry data and habitat classification maps may not meet the current needs in these identified regions because they predate recent coastal developments and environmental impacts, lack full coverage of the area of interest, and/or do not meet the resolution requirements (1 m or less) needed to support monitoring activities.

This report and its accompanying online maps provide a critical spatial framework for understanding shallow coral reef mapping priorities and data needs in Guam and CNMI. Results from this mapping prioritization effort are summarized in this report, and an inventory of existing mapping data for these two jurisdictions, and past completed jurisdictions, are available at: https://us-shallow-coral-reef-mapping-priorities-noaa.hub.arcgis.com/.



Coral on top of coral in Asuncion Island, CNMI. Credit: NOAA NMFS/PIFSC

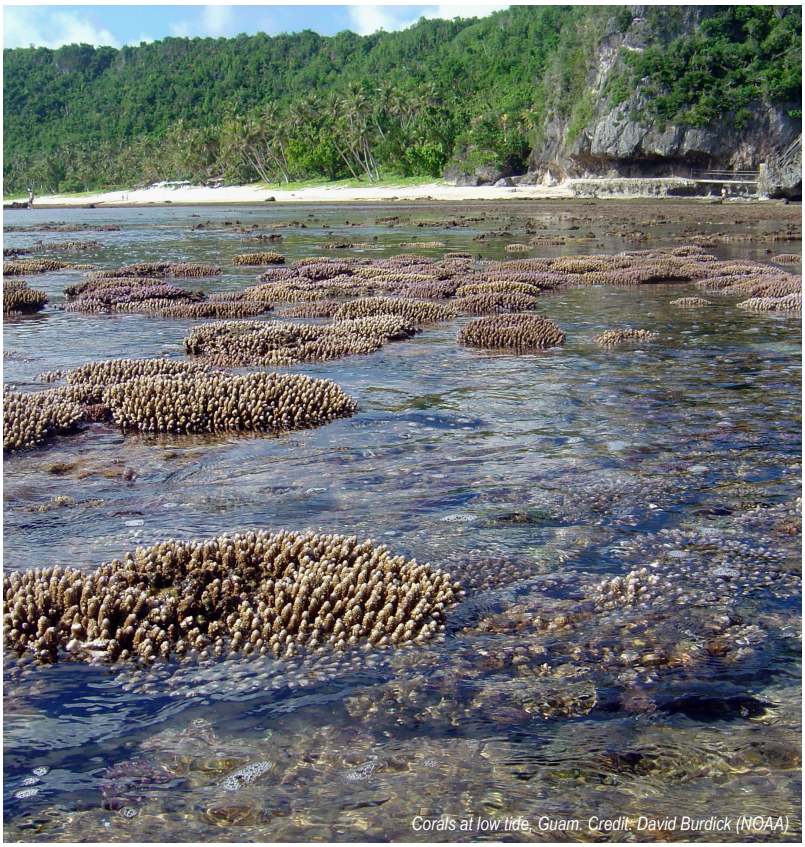


Corals in Guam. Credit: David Burdick (NOAA)

Chapter 1 Background

The health of U.S. coral reef ecosystems relies on the effective use of mapping data, science, tools, and strategies to inform management decisions. Information from local stakeholders and agencies on where and what kind of data are needed for effective coral reef management will help guide and prioritize future benthic mapping efforts. To meet this need, NOAA's Coral Reef Conservation Program (CRCP) requested information on mapping priorities for coral reef areas within 0- to 40-m depth in all seven of the U.S. coral reef management jurisdictions (Figure 1). During 2023, this activity was focused on shallow coral reef areas surrounding Guam and the Commonwealth of the Northern Mariana Islands (CNMI) jurisdictions. CNMI included islands from Rota to Farallon de Pajaros.

The prioritization results directly support the four thematic areas of CRCP's strategic plan, which are to: 1) increase resilience to climate change, 2) reduce land-based sources of pollution, 3) improve fisheries' sustainability, and 4) restore viable coral populations. Results will help CRCP, stakeholders, and participating groups pinpoint locations of mutual interest, leverage expertise and resources, and identify potential partnerships for future mapping efforts.



Corals at low tide, Guam. Credit: David Burdick (NOAA)

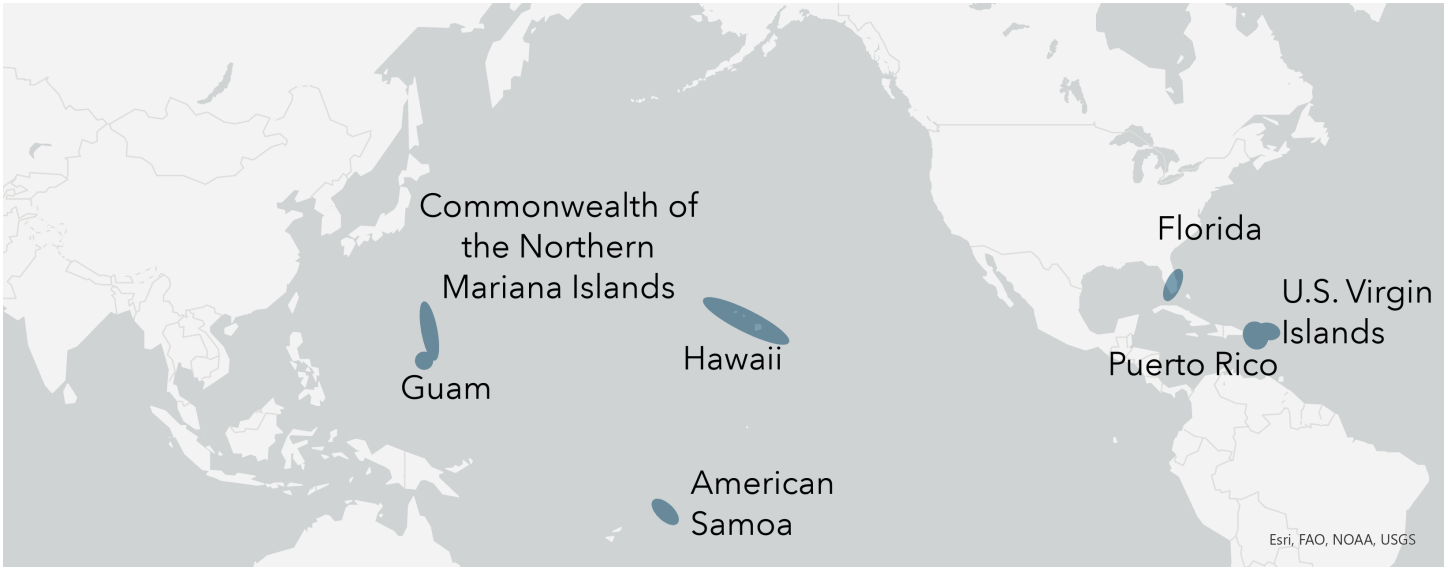


Figure 1. The seven U.S. coral reef jurisdictions that were used in these prioritization efforts.

Chapter 2 Methods

2.1 Advisory Team and Participating Groups

A technical advisory team (TAT) was developed to help identify participating groups and points of contact and provide local knowledge and coordination support. The TAT consisted of two representatives from CRCP and two liaisons from local NOAA offices in the U.S. coral reef jurisdictions (one from Guam and one from the CNMI). The TAT members were selected based on their knowledge of local coral reef and fisheries management groups and their ability to provide key contacts and support coordination. A list of key contacts from state, federal, territorial, academic, and non-governmental organizations was created and approved by the TAT. This list is composed of groups who use mapping data to inform coral reef management in Guam and the CNMI (Table 1). These groups included experts in areas of coral reef management, including reef mapping, conservation, fisheries, and habitat classification. Some participants were the sole respondent for their group, whereas others consulted with colleagues to input a collaborative mapping need.

Table 1. List of groups who provided their coral reef mapping priorities and whose input is reflected in this report. Invited groups included federal, territorial, academic, and non-governmental organizations (NGOs).

Participating Groups	*Guam*	*CNMI*	*Acronym*	*Type*
Commonwealth Ports Authority		X	CPA	Territorial
CNMI Bureau of Environmental and Coastal Quality		X	BECQ	Territorial
CNMI Division of Fish and Wildlife		X	DFW	Territorial
CNMI Office of Homeland Security and Emergency Management		X	HSEM	Territorial
CNMI Office of Planning and Development		X	OPD	Territorial
Guam Bureau of Statistics and Plans	X		BSP	Territorial
Johnston Applied Marine Sciences		X	JAMS	NGO
National Park Service	X		NPS	Federal
NOAA Pacific Islands Fisheries Science Center	X		PIFSC	Federal
NOAA Pacific Islands Regional Office	X	X	PIRO	Federal
University of Guam – Water and Environment Resource Institute	X	X	WERI	Academic
U.S. Fish and Wildlife Service	X	X	USFWS	Federal
U.S. Navy – Naval Facilities Engineering Command - Marianas	X	X	NAVFAC	Federal

The following groups or agencies were contacted but were unable to provide input: University of Guam – Marine Lab, University of Guam – Western Pacific Tropical Research Center, Guam Department of Agriculture, Environmental Protection Agency, Port Authority of Guam, Commonwealth Bureau of Military Affairs, CNMI Indigenous Affairs Office, and the CNMI Historic Preservation Office.

Clownfish and anemone, Tinian. Credit: M. Chauvin (NOAA NMFS/PIFSC)

2.2 Develop Prioritization Framework and Online Application

2.2.1 Develop Framework

The Guam and the CNMI prioritization project areas (Figures 2 and 3) extended around the islands up to 40-m depth and were divided into hexagonal grid cells that were 1-km per side (2.6 km^2 or 1 mi^2 per cell). This cell size was chosen to give participants adequate spatial detail to indicate their priorities, while keeping the number of total cells to choose from manageable. The hexagonal grid shape was chosen to conform more easily to the 40-m depth contour and coastline. Note that for some islands in the CNMI, additional cells beyond the 40-m depth limit were included (29 of 330 total cells) (Figure 3). This was due to an oversight while developing the prioritization grid; however, these additional cells did not impact results for this region.

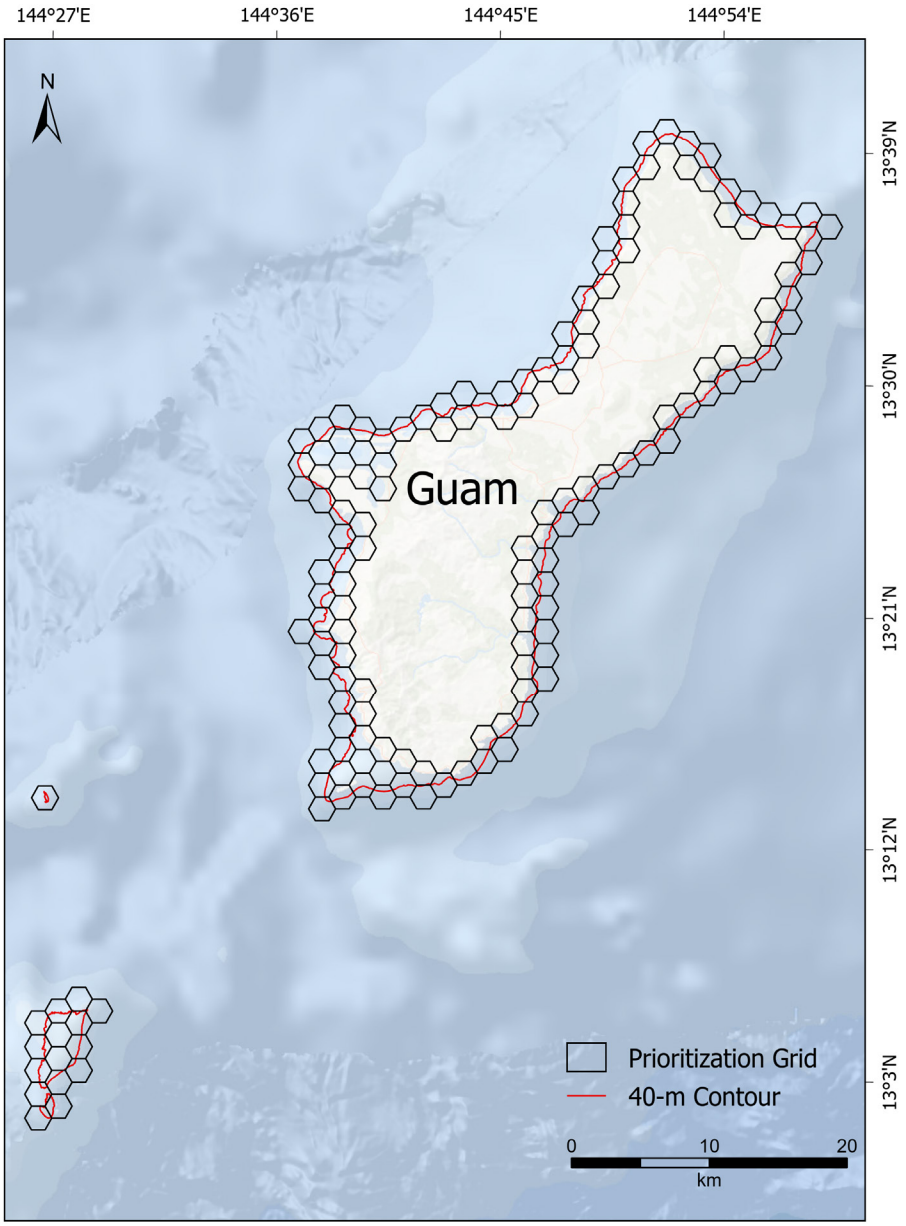


Figure 2. The spatial framework and hexagonal grid (1 km per side with total area of 1 mi^2 or 2.6 km^2) used to identify benthic mapping priorities in the shallow coastal areas around Guam. The 40-m contour was used as the maximum depth for this prioritization effort.

2.2.2 Data Inventory

Existing data were compiled and provided to help participants understand the current extent of available information, locate data gaps, and identify areas to prioritize for future data collection. These data include various types of seafloor mapping data (e.g., multibeam sonar, lidar), political and administrative boundaries (e.g., federal/state waters, marine protected areas), and benthic habitat maps. These datasets and map services were published in an online web map for Guam and the CNMI and served as the basemap for the spatial prioritization application. See Appendix A for a reference list of map services included in the inventory.

2.2.3 Spatial Prioritization Application

Participant needs and priorities were collected using an online application containing the data inventory map and a customized spatial prioritization widget. The application was hosted on the NOAA GeoPlatform and was created using Esri's Web AppBuilder. The spatial prioritization widget is an online graphical user interface for participants to enter their priorities using a designated number of virtual coins and selecting from customized pull-down menus to record specific data needs. Development and use of the widget are detailed in Buja and Christensen (2019), and the tool has already been applied in a variety of regions including Florida (Kraus et al., 2022a), the U.S. Caribbean (Kraus et al., 2020, 2022b), the Main Hawaiian Islands (Kraus et al., 2023), Thunder Bay National Marine Sanctuary (Kendall et al., 2020), the U.S. West Coast (Costa et al., 2019), and the Southeast U.S. (Buckel et al., 2021). This approach allowed participants to assign, edit, and move their coin placement as often as they liked until the deadline. Each participant had password-protected access only to their grid and coins, which prevented accidental overwrite or deletion by other participants.

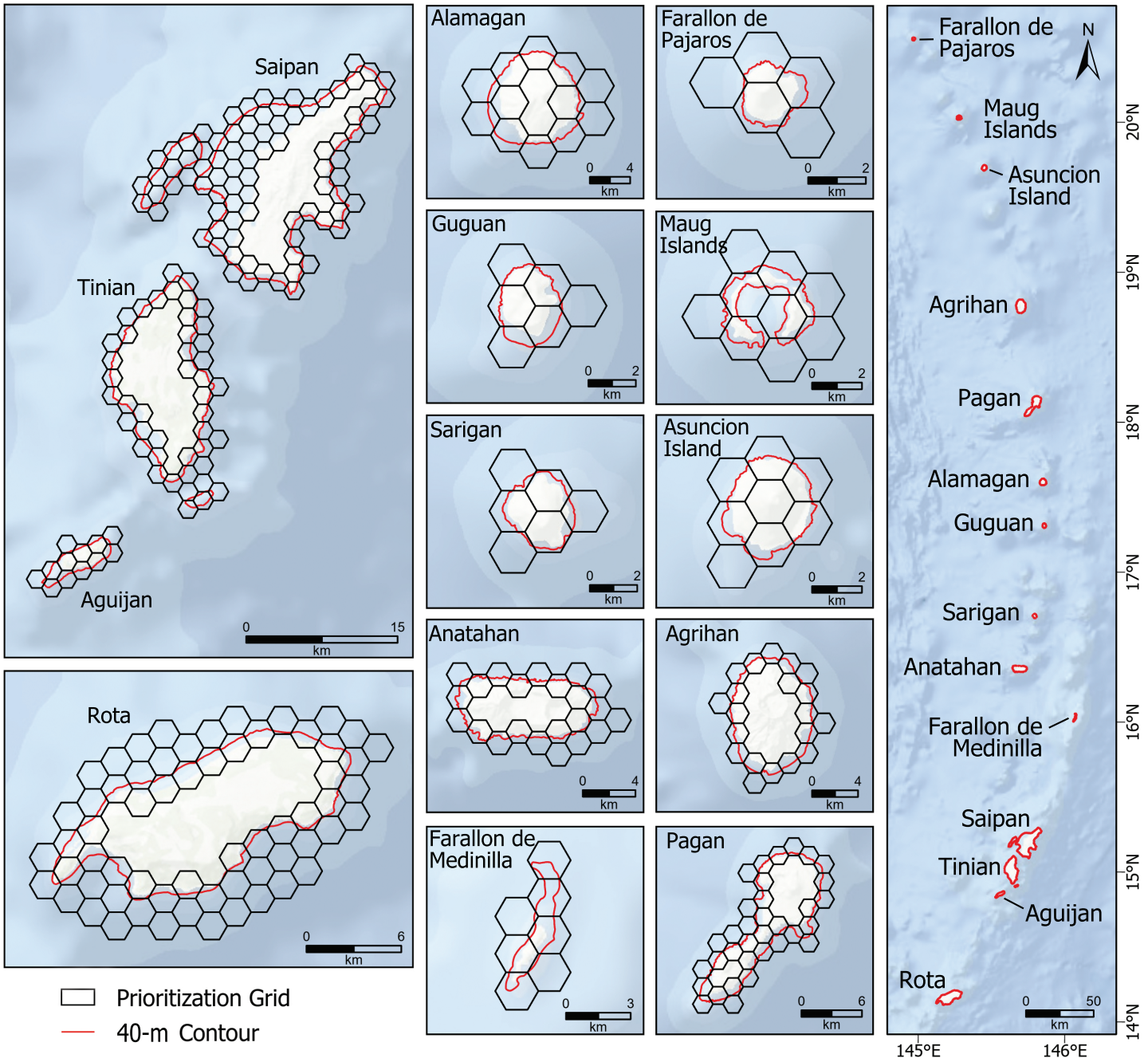


Figure 3. The spatial framework and hexagonal grid (1 km per side with total area of 1 mi^2 or 2.6 km^2) used to identify benthic mapping priorities in the shallow coastal areas around the Commonwealth of the Northern Mariana Islands (CNMI).

Each participating group was given a separate set of virtual coins for Guam (n=50) and the CNMI (n=110), calculated as 30% of the total number of grid cells, to place in the prioritization grid to indicate the locations and importance of their mapping needs (Table 2). The application also did not allow more than 10% of the total number of coins to be input into a single grid cell. Coin restrictions were designed to ensure that participants' needs were comparable (i.e., everyone "spent" the same number of coins), encourage a broad distribution of priorities, and increase the chance of overlap among participant needs.

Table 2. Distribution of virtual coins by region.

Region	*Total # of Cells*	*Total # of Coins per Participant*	*Max # of Coins per Cell*
Guam	153	50	5
CNMI	330	110	11

The number of coins assigned to a cell serves as a proxy to estimate how urgently data were needed in that cell. For example, if a participant places 8%–10% of their total coins into a single cell, it indicates an immediate need for spatial data at that location.

2.2.4 Management Use and Map Product Requirements

In addition to selecting and allocating coins to convey their spatial priorities, participants were asked to identify why these areas were of interest to them and their agency or group. First, participants chose from a list of nine predefined Management Uses (Table 3), which were based on the coral management focus of the project. This selection indicated how participants planned to use the data to inform coral reef management. They could select up to two (primary and secondary) options for each cell selected to input coins, using the drop-down menus in the prioritization widget.

Table 3. List of Management Uses that participants could select from when entering their mapping needs.

Management Use	*Definition*
1. *Endangered Species Management*	Including consultations, recovery planning, and implementation
2. *Habitat Restoration*	Restoration planning and implementation of coastal and marine habitats such as corals, submerged aquatic vegetation, etc.
3. *Monitoring*	Long-term biophysical monitoring, discrete management/restoration assessments, or emergency/disaster response assessment
4. *Coastal Vulnerability and Planning*	Planning to mitigate for climate change impacts and other coastal hazards
5. *Watershed Management*	Planning and implementation of watershed management and restoration projects to improve coastal water quality
6. *Fisheries Management*	Planning, enforcement, and assessment of fisheries management actions
7. *Consultations and Permitting*	Planning and assessment for federal and/or state permits and environmental compliance with other federal regulations (e.g., National Environmental Policy Act, Endangered Species Act, etc.)
8. *Emergency Response*	Rapid response to coastal and marine emergencies that require immediate assessment, triage, and/or remediation activities, such as storms, vessel groundings, bleaching events, disease, and/or invasive species outbreaks
9. *Spatial Protection and Management*	Planning, enforcement, and assessment of spatially managed areas, such as marine protected areas, marine managed areas, etc.

For each selected area, participants were also asked to describe specific data requirements for cells where coins were allocated. These were referred to as Map Product Requirements. For each cell receiving coins, participants could assign up to two (primary and secondary) requirements from a list of seven options (Table 4). This category was used to help determine the type of spatial scale, product resolution, and suggested platform required to meet data needs. Spatial scales were determined based on a set of predefined recommended resolutions for each Map Product Requirement. These were created to help define the best resolution and suggested platform that may be considered for fulfilling each Map Product Requirement. These are grouped into three categories—regional, mesoscale, and microscale—and can be used to inform project planning and execution.

Table 4. List of Map Product Requirements and their associated recommendations for resolution, scale, and platform. ROV = remotely operated vehicle; DEM = digital elevation model; AUV = autonomous underwater vehicle.

Map Data Requirement	*Definition*	*Spatial Scale*	*Resolution/Product*	*Suggested Platform*
1. *Delineations of large topographic features (e.g., pinnacle)*	Includes escarpments, pinnacles, valleys, basins, and other large-scale bottom features detected	Regional	>10-m resolution, coarse imagery	Ship/ROV
2. *Delineations of hard vs. soft bottom*	Data will be used to determine the hardness or reflectivity of the seafloor (i.e., rock vs. soft sediment)	Regional	>10-m resolution, coarse imagery	Ship/ROV
3. *Models of habitat suitability for key taxa or communities*	Models of habitat suitability using coarse (> 10 m) resolution imagery	Regional	>10-m resolution, coarse imagery	Ship/ROV
4. *Delineations of substrate types (e.g., sand, mud, coral, rock)*	Locate and define seafloor types including sand, mud, rock outcrops, coral caps, pavement, etc.	Mesoscale	2- to 10-m resolution DEM/ photomosaics	Towed AUV/ROV
5. *Models of presence/absence or density of corals*	Modeled percent cover and density of macrobiota	Mesoscale	2- to 10-m resolution DEM/ photomosaics	Towed AUV/ROV
6. *Identification of coral species and their local environments*	Locate and identify species of corals and document their local environments (e.g., slope, rugosity)	Microscale	<1-m point clouds or DEM (high-resolution imaging)	AUV/ROV
7. *Documentation of individual specimen condition*	Identify the condition or health (e.g., injury, bleaching) of individual corals	Microscale	<1-m point clouds or DEM (high-resolution imaging)	AUV/ROV

2.3 Priority Summaries and Spatial Analysis

As participants entered and edited their selections, their responses were continuously saved to their user-specific online data file. At the end of the data entry period, this information was downloaded, quality controlled, and analyzed to identify collective priorities within each jurisdiction. All quality control and data summaries were performed in R statistical software (version 4.1.0, R Core Team, 2021).

2.3.1 Quality Control

The quality control process confirmed that each participant allocated all their coins, no participant allocated more than 10% of their coins into a single cell, and that there were no duplicate values in a single cell between primary and secondary levels of Management Uses and Map Product Requirements. It also ensured that all cells with coins had at least a primary Management Use and Map Product Requirement assigned. Once cells with coins passed this quality check, any Management Use and Map Product options assigned to cells with zero coins were removed. This situation typically occurred when a participant assigned coins to a cell, changed their mind, and reallocated the coins elsewhere.

2.3.2 Data Analysis and Summary

Coin allocation into Guam and the CNMI were independently conducted using separate web tools. Data analyses were conducted separately for each region, and results were summarized for each region independent of each other. To understand how coins were allocated spatially, the number of coins from all participant groups were summed in each grid cell. The total number of coins allocated toward each Management Use and Mapping Product Requirement from each participant group was also summed in each grid cell to understand where different types of data are needed and why. To determine which Management Use and Map Product Requirement options were most frequently selected across the entire study area, the total number of coins were summed for each selection at the primary, secondary, and overall levels. The number of coins for each Map Product Requirement scale (regional, mesoscale, microscale) were also summed to understand the spatial scale at which data were needed. For each grid cell, the number of groups allocating at least one coin, the number of different Management Uses, and the number of different Map Product Requirements were tallied. For each metric, the top 10% of cells with coins were identified and highlighted using the quantile function in R.

2.3.3 Summary Rank and Focal Areas

A summary rank for each cell was calculated to identify areas of greater importance for multiple rationales. Cells selected by multiple participants and with various management uses are an opportunity for collaboration and highlight where data collection would satisfy the needs of several groups. To calculate summary rank, first, each cell was ranked by its total number of coins, number of participating groups allocating at least one coin, and number of Management Uses for each of these categories. Cells with the same value were given an average rank among the cells. The rank values for each of these three metrics were then summed to calculate an overall summary rank for each cell. The top 10% of cells based on summary rank was calculated using the quantile function.

Focal areas were selected by first identifying clusters of cells that were composed of several adjacent cells and in the highest summary rank category (top 10%). These areas of five or more cells represented a manageable extent for mapping missions and improved efficiency of mission planning to meet multiple stakeholder needs (e.g., minimized transit time). For most of the study area, however, clusters of five adjacent cells were not available, given the narrow shelf in these jurisdictions. Rota and Tinian were the only islands in the study area with clusters of at least five adjacent cells. The remaining focal areas were identified using clusters of smaller numbers of adjacent cells that were clustered near high-ranking but not top 10% cells.

2.4 Project Timeline

In January 2023, participating groups were contacted via email and asked to confirm their participation and provide any additional contacts from their group. An introductory webinar was held on February 22, 2023, to cover details on the project background, methods, outcomes, and use of the web tool, and to answer questions. The data inventory was finalized prior to coin allocation. Participants were asked to input their priorities any time between February 22 and March 15, 2023. After the inputs were analyzed, participants were briefed on the preliminary results during a webinar on August 22, 2023, and were given the opportunity to comment on the results.

Chapter 3 Guam Results

3.1 Most Common Management Uses

The top Management Use selected by participants in Guam was *Habitat Restoration* followed closely by *Monitoring* with 31% and 28% of the total coins allocated, respectively (Figure 4). *Watershed Management* made up 17% of allocated coins overall but was selected exclusively as a secondary Management Use, whereas *Endangered Species Management* represented 7% of all coins allocated but was selected exclusively as a primary Management Use. Six out of the seven participating groups selected only two different Management Uses, while one group selected seven different options (Figure 5). Five of the seven participating groups selected *Habitat Restoration* as their primary or secondary Management Use. Coin distribution maps for each Management Use can be found in Appendix B.

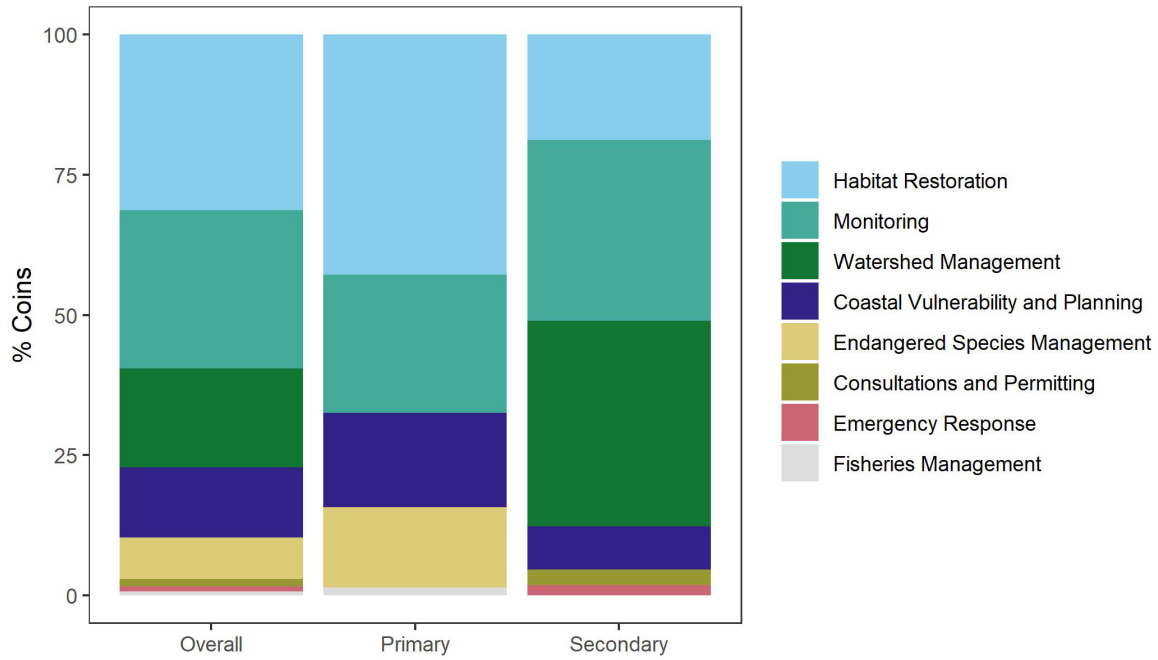


Figure 4. The percentage of coins for each Management Use selected at the overall, primary, and secondary levels in Guam.

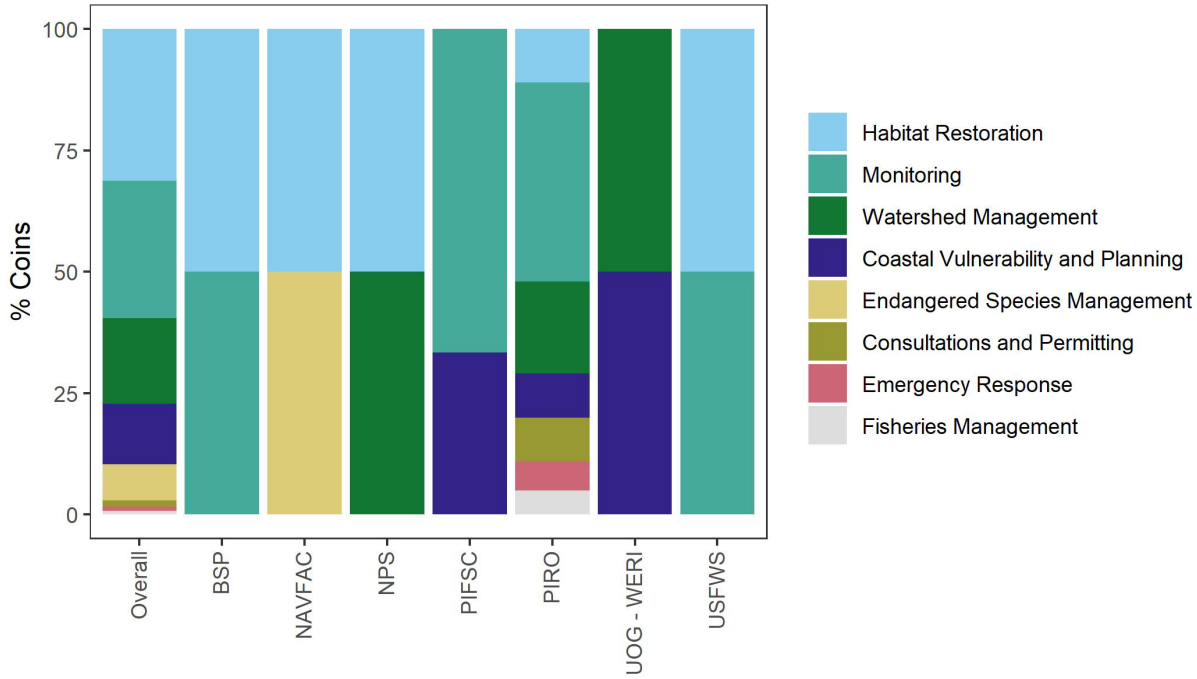


Figure 5. The percentage of coins for each Management Use selected per participant group at the primary and secondary levels in Guam. Table 1 lists participant group descriptions.

3.2 Most Common Map Product Requirements

Two top Map Product Requirements for coral management were identified in Guam: *Identification of Coral Species* and *Habitat Suitability* (Figure 6). Of the seven options available, these two comprised 59% of all coins. *Density of Macrobiota* was the third most commonly selected option, totaling 17% of all coins. *Topographic Features* and *Substrate Type* were exclusively selected as primary Map Product Requirements. *Habitat Suitability* was the most commonly selected secondary option representing 40% of allocated coins. *Substrate Type* and Topographic Feature were each selected by only one group (Figure 7). Coin distribution maps for each Map Product Requirement can be found in Appendix C.

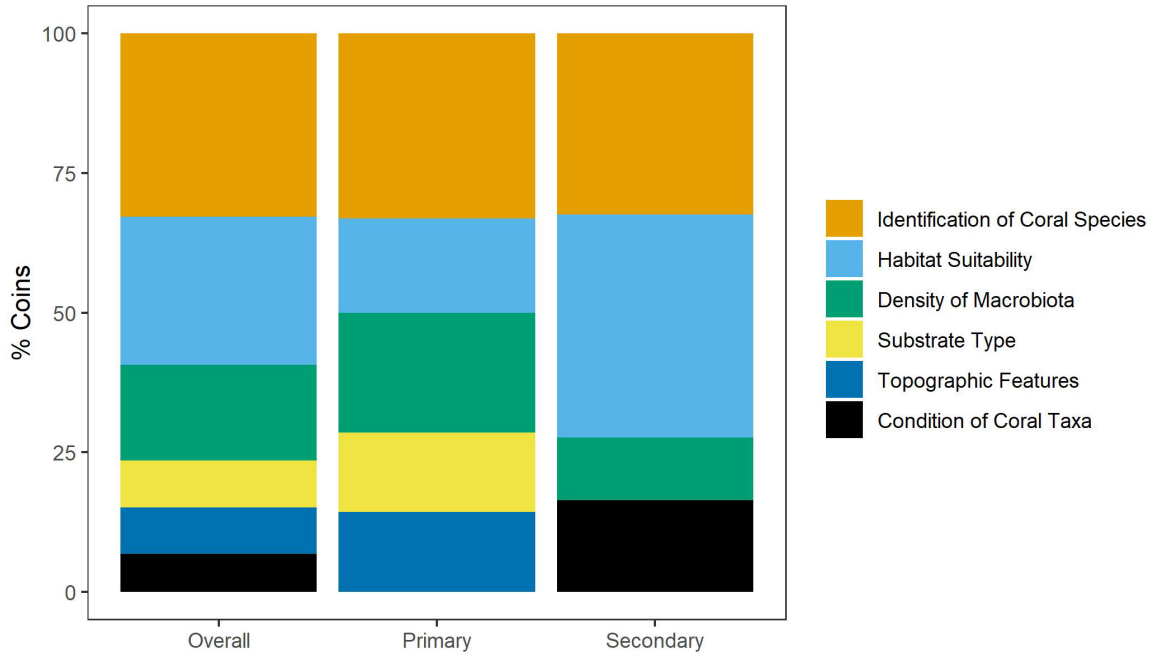


Figure 6. The percentage of coins for each Map Product Requirement selected at the overall, primary, and secondary levels in Guam.

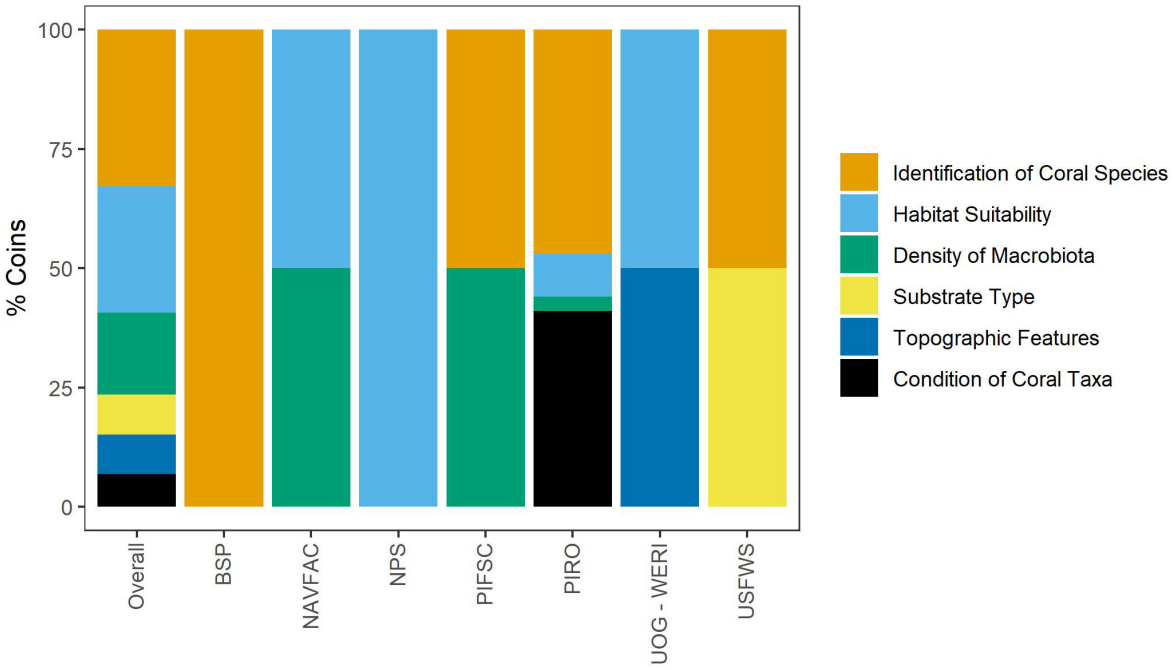


Figure 7. The percentage of coins for each Map Product Requirement selected per participant group at both the primary and secondary levels in Guam.

Guam Results

Additionally, the percentage of coins that were assigned using the Map Product Requirement options were summarized by the spatial scale at which data were collected (i.e., regional, mesoscale, microscale; Table 4). The percentage of coins overall revealed data at the microscale were selected most often (40%), followed by regional scale (35%), and mesoscale (25%) data (Figure 8). Mesoscale was the most commonly selected primary option and the least commonly selected secondary option. Coin distribution maps for each Map Product Requirement spatial scale can be found in Appendix C.

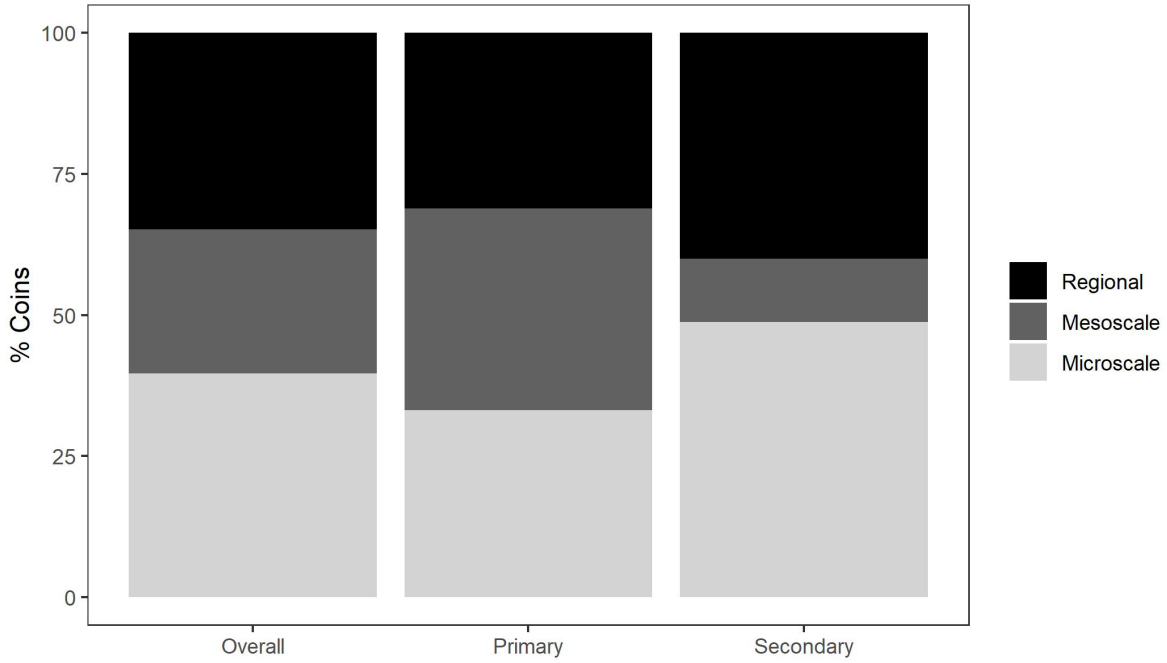


Figure 8. The percentage of coins for each Map Product Requirement spatial scale selected at the overall, primary, and secondary levels in Guam.

Crown-of-thorns sea star, Guam. Credit: NOAA NOS/NCCOS

3.3 Summary of Spatial Priorities

Total Coins

The following map displays the number of total coins summed in each cell from all participants. There were small clusters of adjacent cells (two or more) with the highest total number of coins (top 10%) around Pago Bay, Apra Harbor, and Agat Bay (Figure 9). There were individual top 10% cells in Tumon Bay, Orote Point, and Haputo Ecological Reserve Area (ERA), all with multiple adjacent cells with high coin totals, but not in the top 10%. These locations align with marine protected areas except for Pago Bay (Guam's Marine Preserves); as well as lands under the jurisdiction of the National Park Service within the Agat Bay region (War in the Pacific National Historic Park). Cells containing the top 10% of coins covered an area of 26 km^2.

Agat World War II Amtrac off Ga'an Point,Agat Bay, Guam. Credit: Curt Storlazzi (USGS)

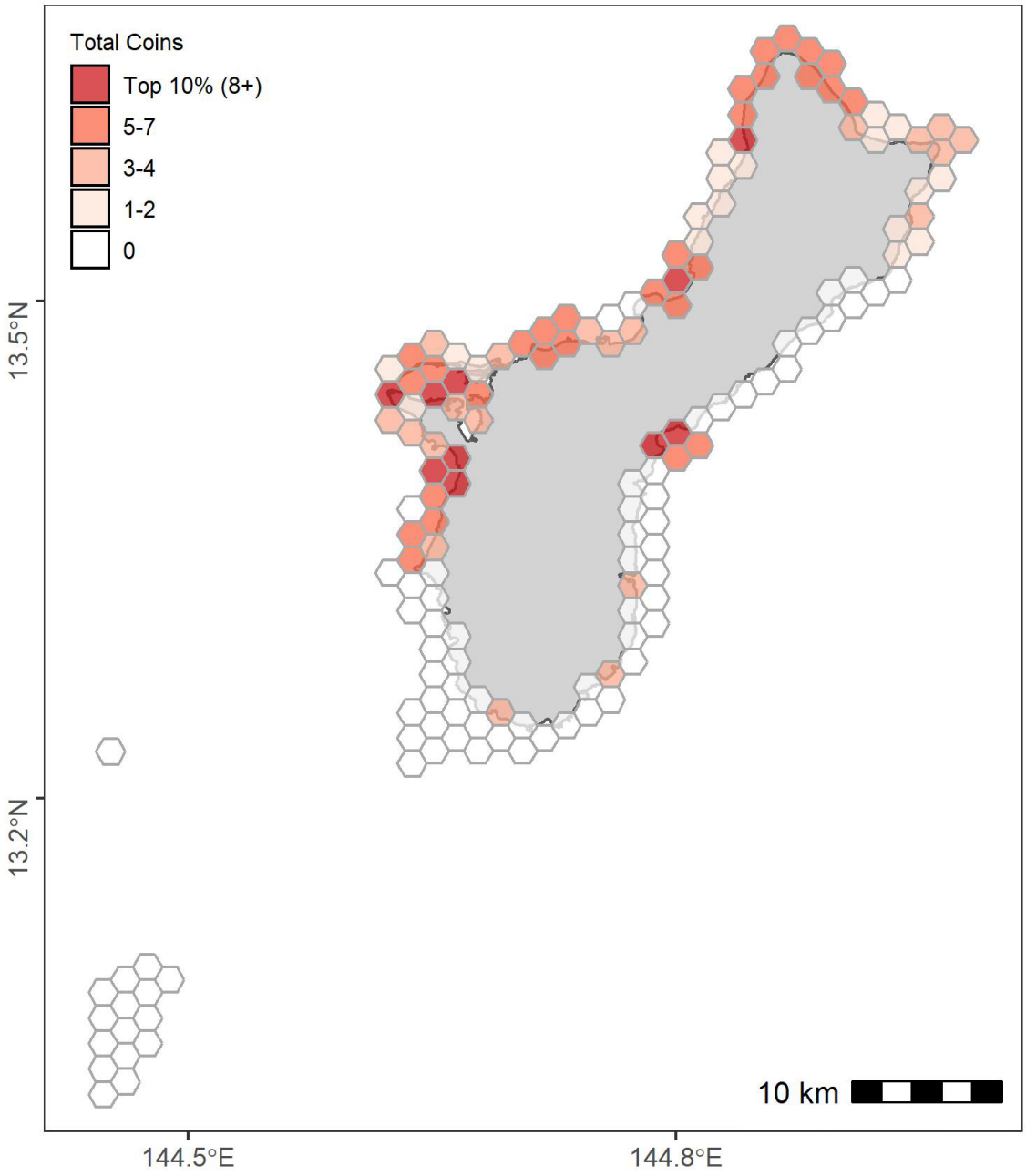


Figure 9. Map of total coins in Guam.

Participating Groups

The number of groups that allocated coins into a single cell ranged from one to four (Figure 10). Large clusters of cells with three to four participant groups (top 10%) occurred in Apra Harbor and at Pati Point on the north side of the island. Cells selected by multiple participant groups are an opportunity for collaboration and highlight where data collection would satisfy the needs of several agencies and/or missions.

Pati Point Preserve, Guam. Credit: Guam Coral Reef Initiative

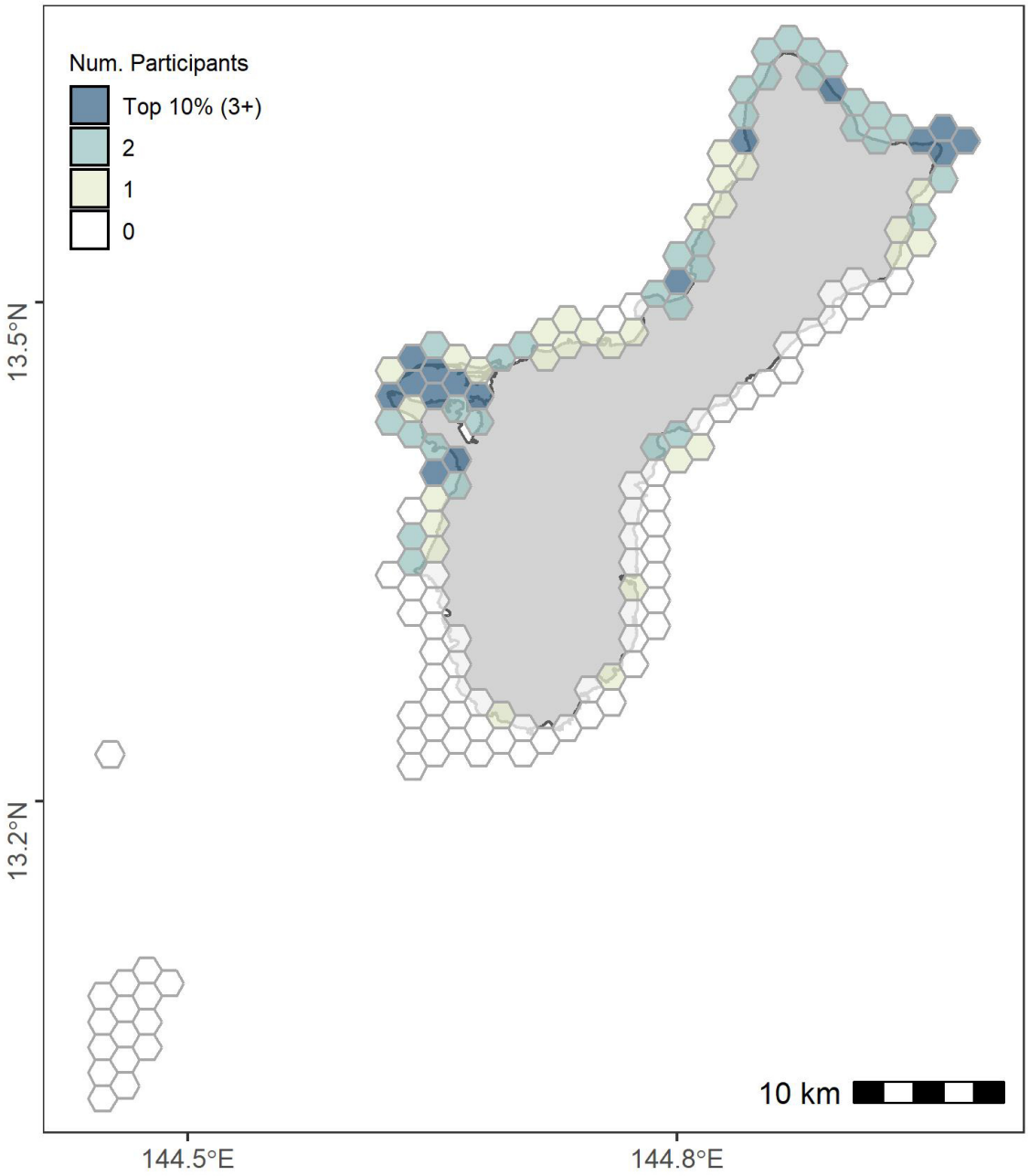


Figure 10. Number of groups who allocated at least one coin into each cell in Guam. A maximum of four participant groups input into a single cell.

Number of Management Uses

The number of Management Uses selected in a single cell highlight several unique areas where a variety of mandates and management actions would be served by collecting the required data (Figure 11). There was one large cluster of seven cells of high-priority (top 10%) cells, based on the number of Management Uses selected, within Apra Harbor, Tumon Bay, Agat Bay, and Pago Bay; each had two adjacent top 10% cells where four different Management Uses were selected. Haputo ERA and the south end of Pati Point Preserve had one top 10% cell based on the number of Management Uses. Other than Pago Bay and south Pati Point, there were no cells with more than two Management Uses selected by participants on the east or south shores of the island.


Pago Bay, Guam. Credit: PacIOOS and NOAA

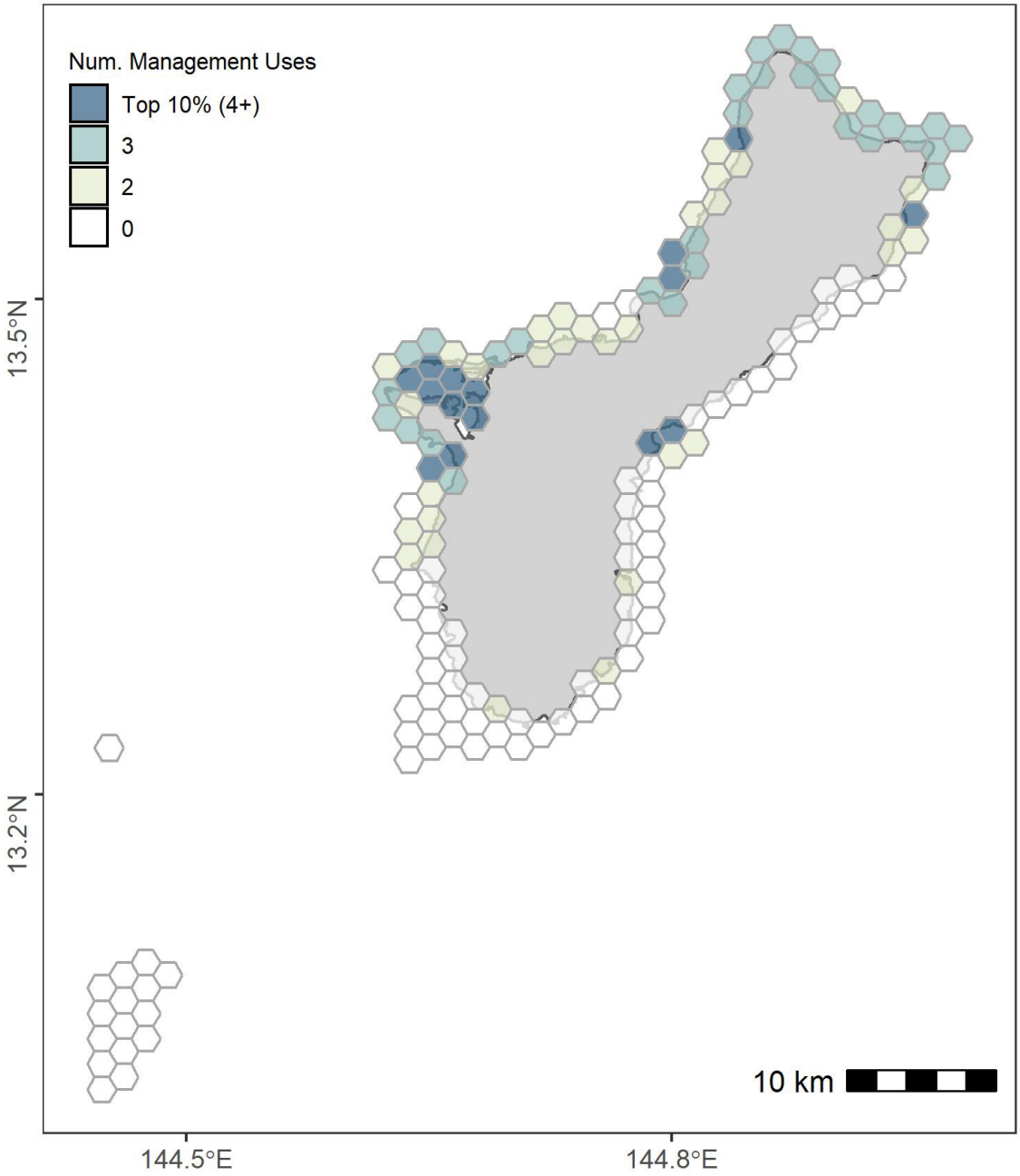


Figure 11. Number of Management Use options that were selected in each cell in Guam.

Map Product Requirements

The number of Map Product Requirements selected by participants in each cell highlights areas where a significant number of different data types were needed (Figure 12; Table 4). Clusters of cells with values in the top 10%, based on the number of selected Map Product Requirements, indicate areas where a variety of data needs will be met. This would involve collaboration among managers and stakeholders to ensure data collected can satisfy the diverse needs of data requirements in these areas. High-priority areas, based on the number of data types needed (top 10%), were within Apra Harbor on the west coast and along the northern point of the island from Haputo ERA, around Ritidian Point, to the Guam National Wildlife Refuge. One single top 10% cell with four or more Map Product Requirements selected was located at the south end of Pati Point Preserve on the east side of Guam.

Corals and diver, Ritian Point, Guam. Credit: NOAA NMFS/PIFSC

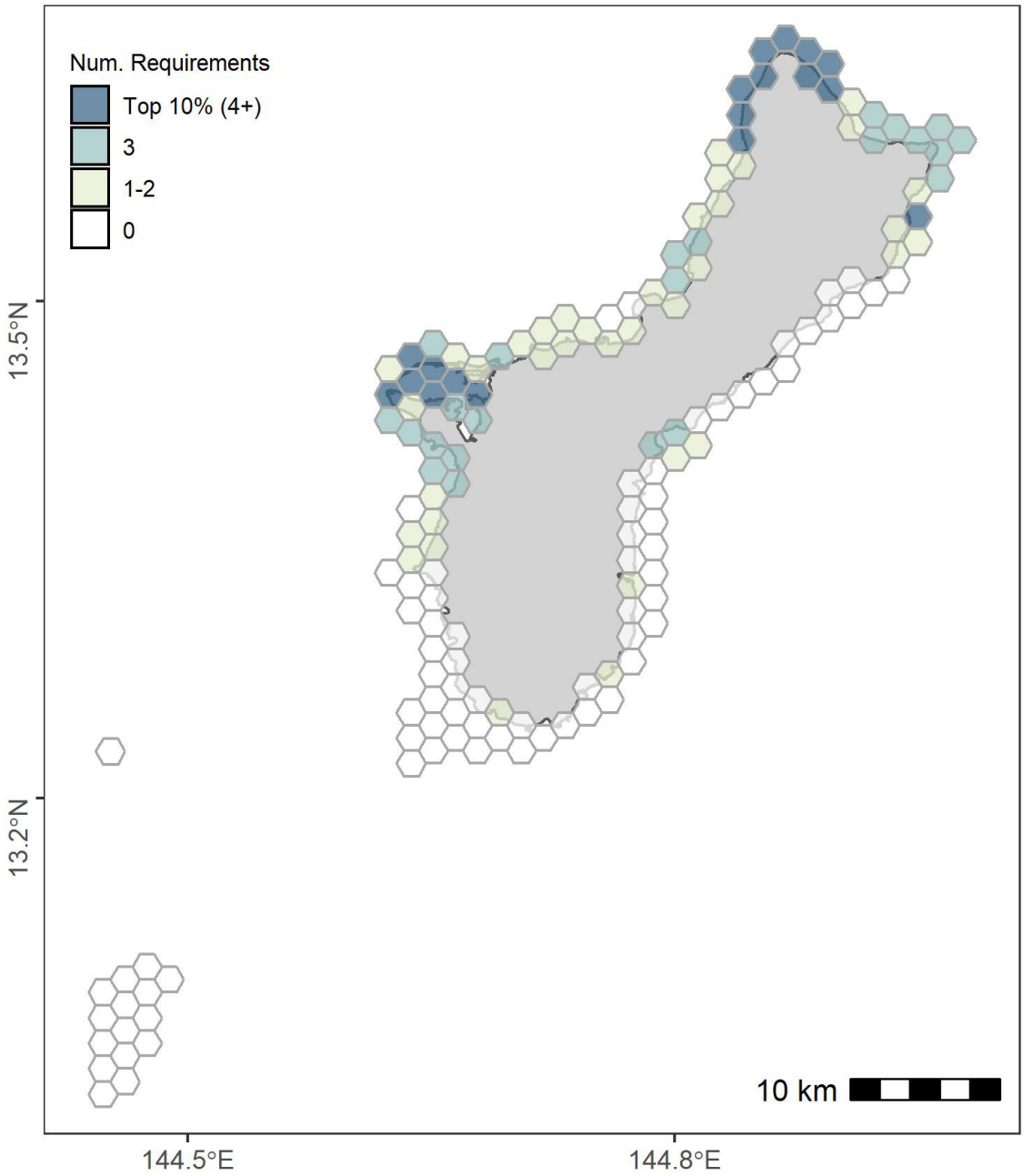


Figure 12. Number of Map Product Requirement options that were selected in each cell in Guam.

Summary Rank

By combining the total number of coins, number of participating groups, and number of Management Uses into a single metric, a summary rank was calculated to highlight cells that were of greater importance based on the combination of these categories (Figure 13). The largest cluster (four cells) in the top 10% based on summary rank occurred in Apra Harbor. This cluster of cells is further discussed in section 3.4 Gap Analysis and Focal Areas. A smaller group in Agat Bay, around the National Historic Park, had two of the top 10% cells, and one each in Haputo ERA and Tumon Bay.

Apaca Point, Agat Bay, Guam. Credit: Scott Cameron (Wikipedia Commons)

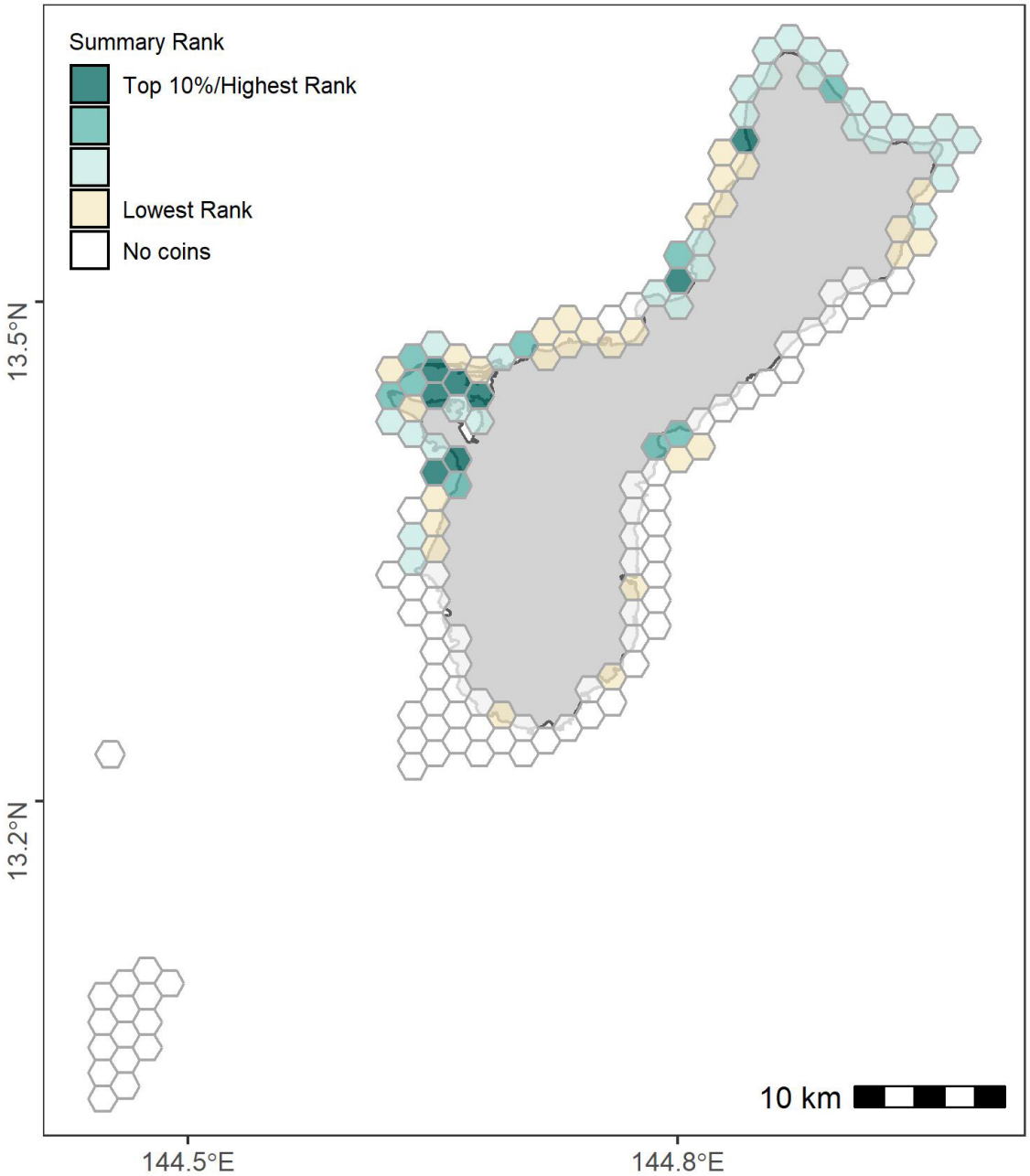


Figure 13. Summary rank based on total coins, number of participating groups, and number of Management Uses in each cell in Guam. Highest Rank identifies Top 10% of summary rank cells.

3.4 Gap Analysis and Focal Area: Apra Harbor

One focal area, Apra Harbor, was identified in Guam, based on the number of adjacent grid cells in the top 10% of summary ranks, and the lack of existing and/or contemporary data in this area (Figure 14).

On the west coast of Guam, four cells (total area of 10.4 km^2) were prioritized in Apra Harbor by four participating groups (Figure 15). The top three Management Uses identified in this focal area were *Watershed Management*, *Coastal Vulnerability and Planning*, and *Monitoring* (Table 5). Apra Harbor hosts multiple management-relevant activities and uses, including commercial and military operations, coastal development, and coral restoration. Apra Harbor is vulnerable to a variety of climate-related threats such as tsunamis, typhoons and other major storms, extreme heat, severe bleaching events, coastal erosion, increased sedimentation, and coastal flooding. Climate threats to Guam's coral reefs (including those within Apra Harbor), such as sea surface temperature, extreme weather events, and number of "wet-days," have significantly increased within the last seven decades (Yeo et al., 2023; M-H. Yeo, Pers. comm.).

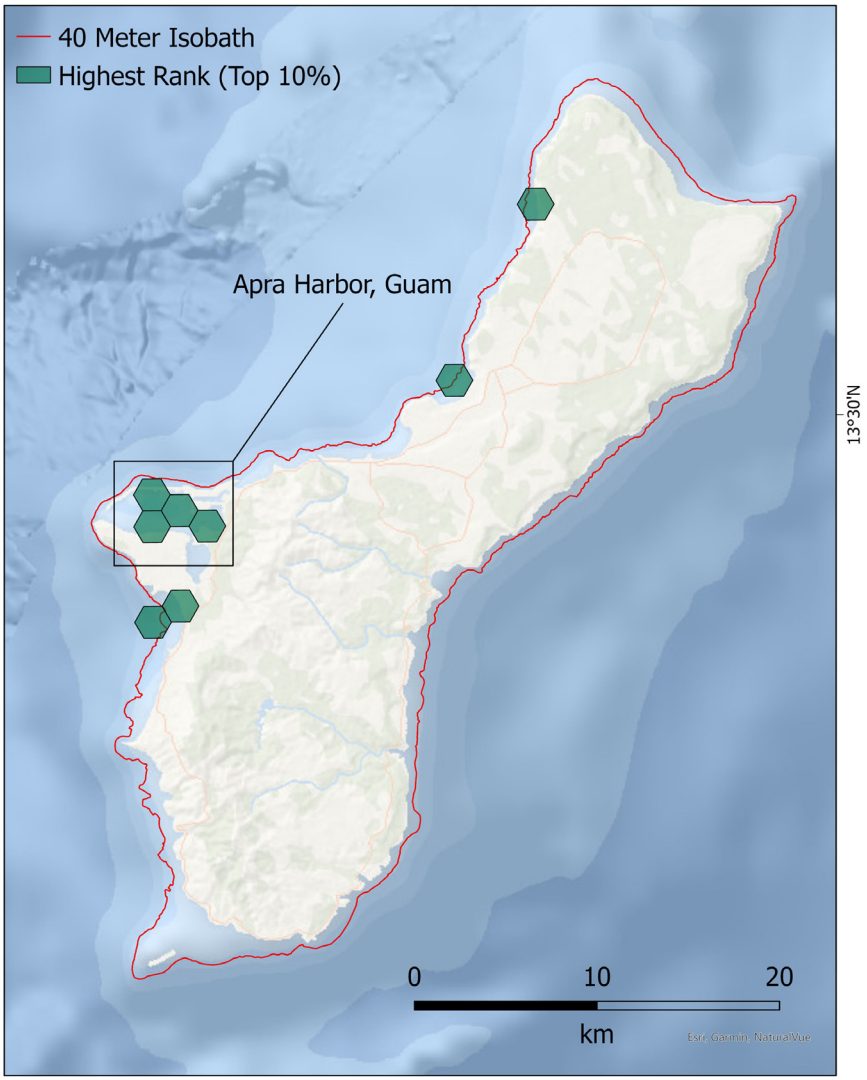


Figure 14. Overview of Apra Harbor focal area in Guam identified using the highest summary rank. Only the top 10% summary rank cells are shown.

Mangroves in Sasa Bay Marine Preserve, Apra Harbor, Guam. Credit: David Burdick (NOAA)

Not only is Apra Harbor the largest U.S. deepwater port in the Western Pacific and the busiest in Micronesia but it also contains reefs with some of the highest coral cover on the island (Burdick et al., 2008; Nelson et al., 2016). It's also home to Sasa Bay Marine Preserve, which contains the largest area of mangrove habitat in the Mariana Islands (Guam DOAG, 2021). The harbor is under the jurisdiction of the Port Authority of Guam and the U.S. Navy, with the U.S. Navy responsible for the conservation and management of marine resources within the harbor. Vessel traffic has increased significantly in recent years due to defense operations in the Pacific region, resulting in potential negative impacts such as vessel groundings, boat strikes with endangered species, and other increased disturbances to marine resources within the harbor (A. Reyes, Pers. Comm.)

Participant groups identified *Habitat Suitability* as a top Map Product Requirement, followed by *Topographic Features* and *Identification of Coral Species*. This aligns with past and planned coral restoration and monitoring activities, such as the University of Guam's Long-term Monitoring Program, and next year's GovGuam coral restoration efforts, which will involve coral nursery siting and installation (A. Williams, Pers. Comm.). Existing data may not meet the management needs for coral monitoring and restoration efforts. These data could be sporadic, contain gaps in coverage, or not be at the fine scale needed (ideally less than 1 m) for coral species identification and condition, documenting diversity/ coral cover changes, or monitoring potential introductions of marine invasive species (such as sponges and algae) and diseases (e.g., stony coral tissue loss disease) (A. Williams, Pers. Comm). Recent acquisition of 10-m resolution multibeam data collected in 2022 by NOAA Ship Rainier (Appendix A) may help meet the needs requiring mesoscale (2- to 10-m resolution) data for delineations of substrate types or coral density. However, for finer-scale data needed for species identification and/or condition, < 1-m lidar data would be a more appropriate resolution where available within the focal area. Current lidar and multibeam data cover parts of the harbor but may not be at the appropriate scale or encompass the areas of interest (see Appendix A). Benthic habitat mapping products for the harbor are being developed by NOAA National Centers for Coastal Ocean Science (NCCOS) and are expected early 2024.

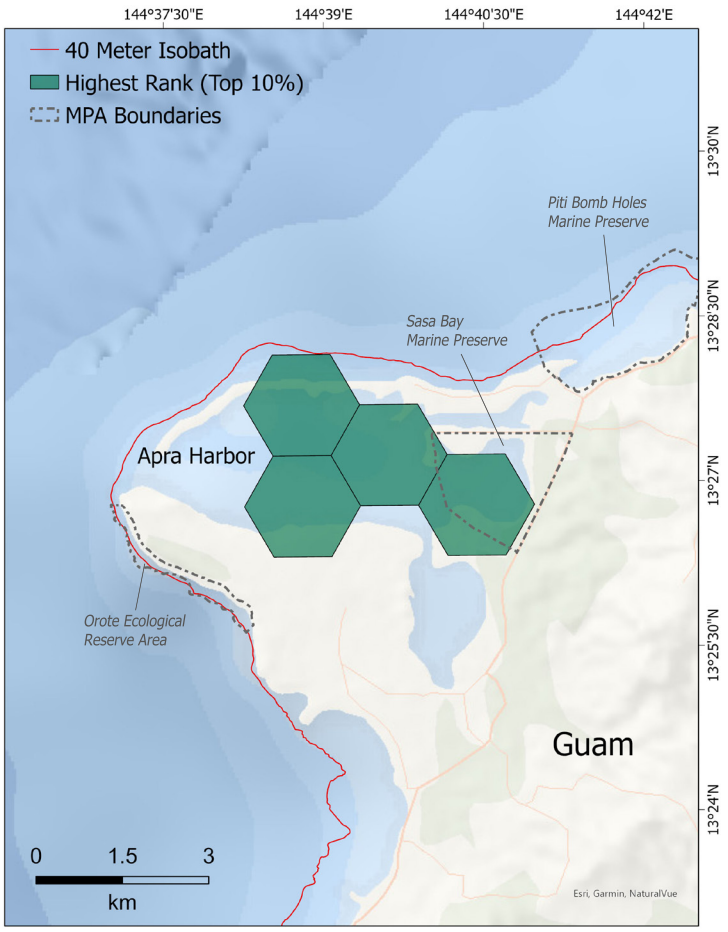


Figure 15. Highest summary rank cells within Apra Harbor, Guam.

Table 5. Data summary of participant input for the Apra Harbor focal area. Percent coins are calculated based on the Management Use, Map Product Requirement, and Spatial Scale coin totals within these four hexagons only. The Number of Groups reflects how many participant groups assigned coins to any portion of the area.

Total Coins (# hexagons)**:**	**Rank** (# hexagons)**:**	**Number of Groups:**
Top 10% (2)	Top 10% (4)	4
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Watershed Management (28%)	Habitat Suitability (32%)	Regional (57%)
Coastal Vulnerability and Planning (23%)	Topographic Features (25%)	Microscale (37%)
Monitoring (20%)	Identification of Coral Species (22%)	Mesoscale (7%)
Habitat Restoration (13%)	Condition of Coral Taxa (15%)	
Emergency Response (9%)	Density of Macrobiota (7%)	
Endangered Species Management (6%)		


Corals in Apra Harbor. Credit: NOAA NOS/NCCOS


Black saddled toby *n Apra Harbor. Credit: NOAA NMFS/PIFSC*

4.1 Most Common Management Uses

The top three Management Use categories selected by participants in the CNMI were *Coastal Vulnerability and Planning*, *Monitoring*, and *Habitat Restoration*, making up 24%, 22%, and 17% of the total coins allocated, respectively (Figure 16). The remaining six Management Use categories ranged between 5% and 6% of the total coins allocated. Two categories, *Spatial Protection and Management* and *Watershed Management*, were exclusively selected at the secondary level (Figure 16). Nine out of 10 participating groups selected at least two different Management Uses (typically a primary and secondary) and included *Coastal Vulnerability and Planning*, *Monitoring*, and/or *Habitat Restoration* as one of their selected options. One group selected only one Management Use, *Emergency Response* (Figure 17). CNMI coin distribution maps for each Management Use can be found in Appendix D.

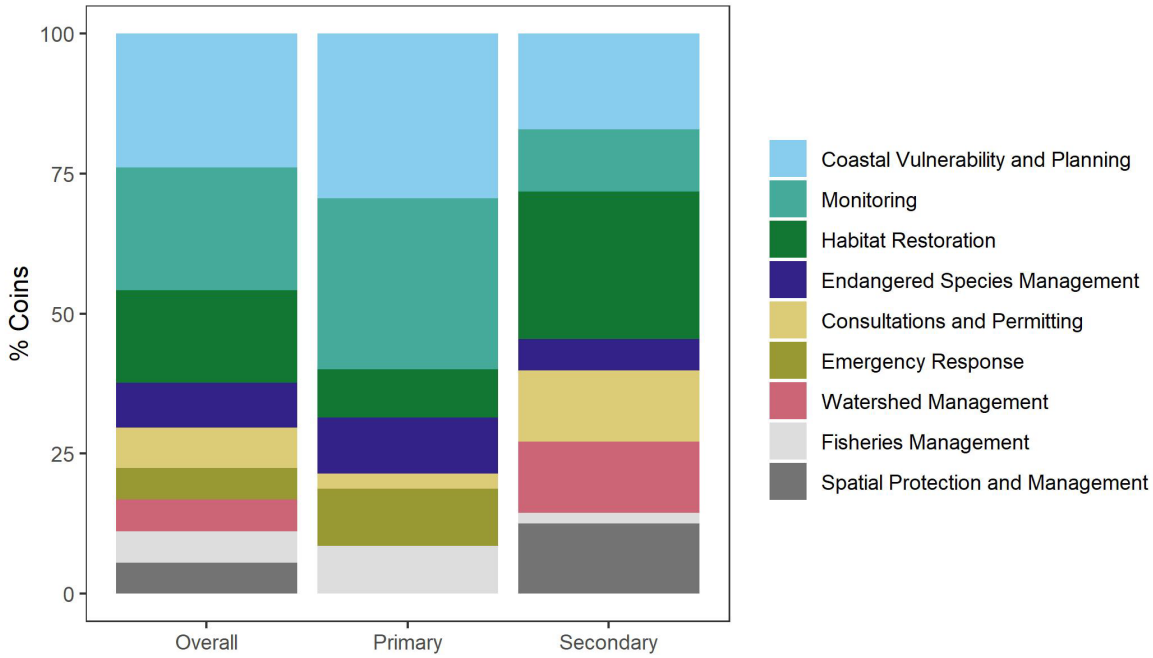


Figure 16. The percentage of coins for each Management Use selected at the overall, primary, and secondary levels in the CNMI.

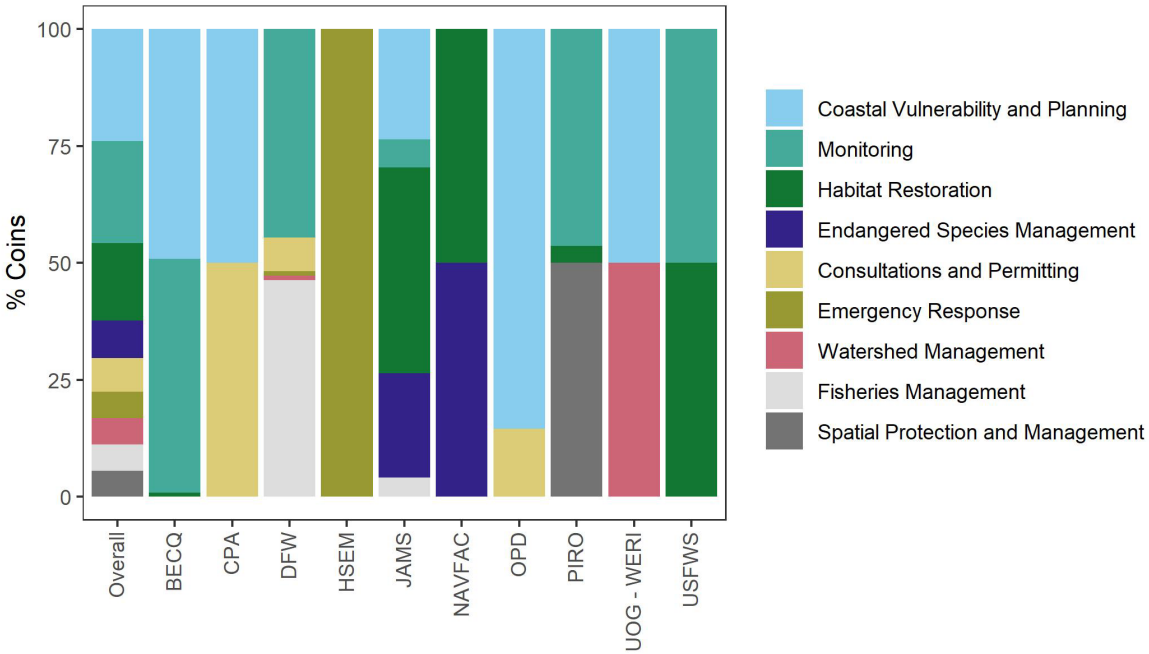


Figure 17. The percentage of coins for each Management Use selected per participant group at the primary and secondary levels in the CNMI. Table 1 lists participant group descriptions.

4.2 Most Common Map Product Requirements

The percentage of coins allocated in the CNMI using the Map Product Requirement options at the primary and secondary levels were relatively evenly distributed between *Density of Macrobiota* (26%), *Identification of Coral Species* (21%), and *Substrate Type* (21%; Figure 18). Of the seven options available, these three comprised 68% of overall coins. *Identification of Coral Species* was identified most often at the primary level (30% of primary coins), while *Density of Macrobiota* was selected most often at the secondary level (44% of secondary coins). None of the participating groups selected *Condition of Coral Taxa* as a data requirement. Out of the 10 participating groups, nine identified only two options as data requirements for future action (Figure 19). CNMI coin distribution maps for each Map Product Requirement can be found in Appendix E.

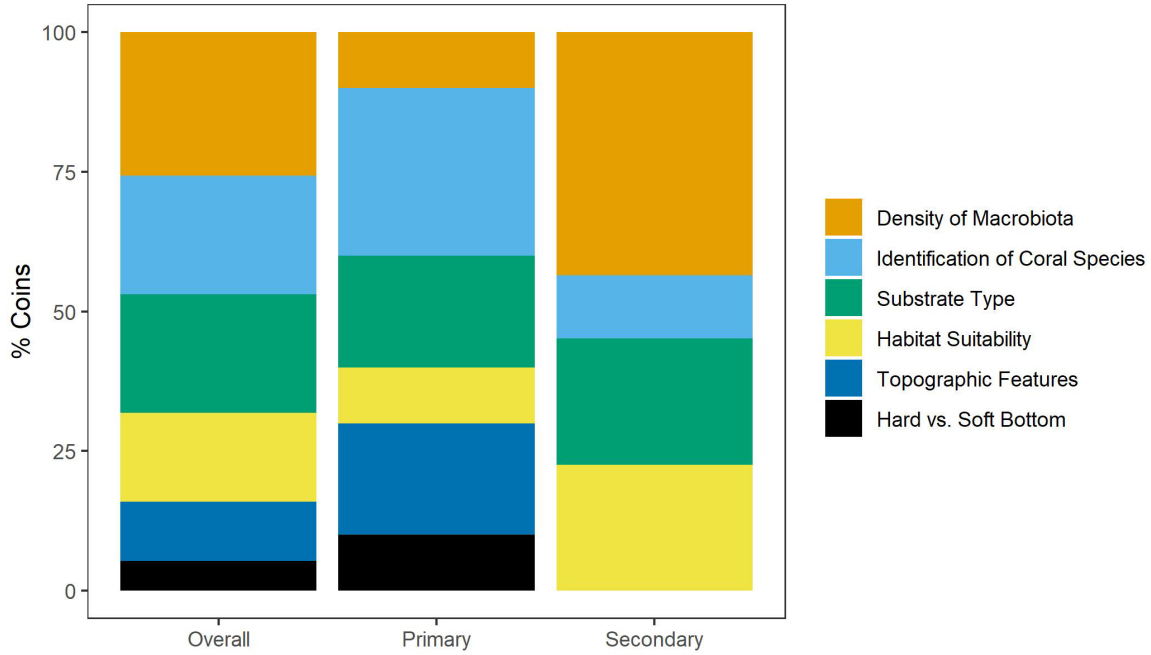


Figure 18. The percentage of coins for each Map Product Requirement selected at the overall, primary, and secondary levels in the CNMI.

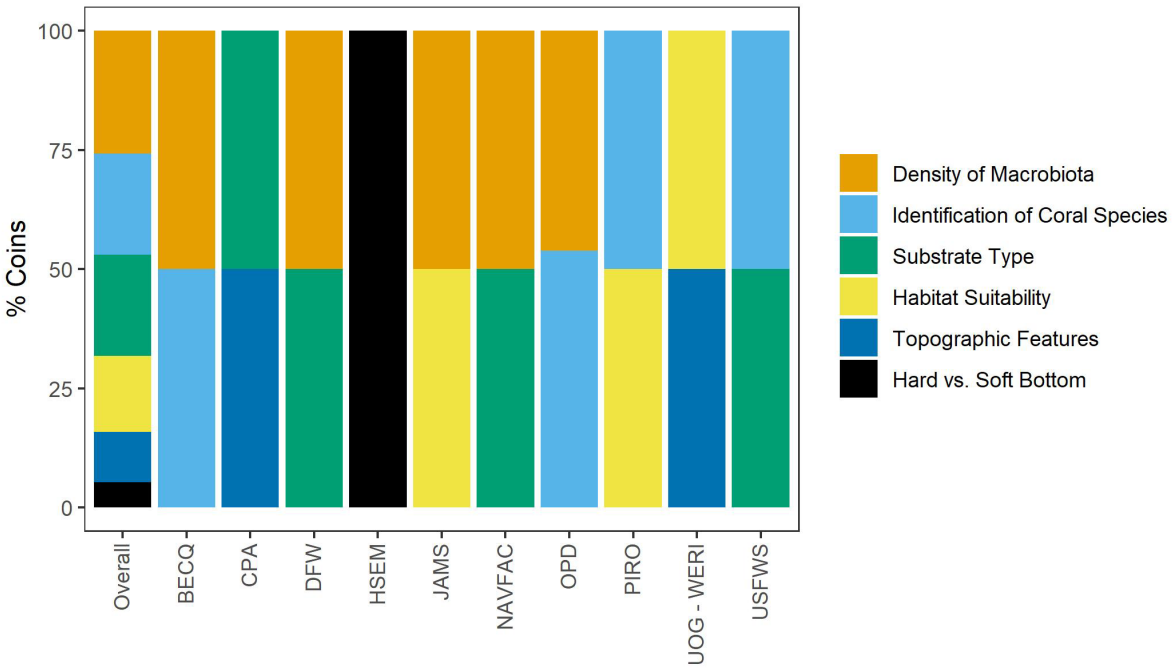


Figure 19. The percentage of coins for each Map Product Requirement selected per participant group at both the primary and secondary levels in the CNMI.

Additionally, the percentage of coins that were assigned using the Map Product Requirement options were summarized by the spatial scale at which data are collected (i.e., regional, mesoscale, microscale; Table 4). Map Product Requirement selections revealed mesoscale data were needed most often (47%), followed by regional (32%) and microscale (21%) data (Figure 20). Despite mesoscale data being the most commonly identified spatial scale overall, regional scale data were chosen the most often at the primary level by participants. Mesoscale data, however, were most commonly associated with map products at the secondary level. CNMI coin distribution maps for each Map Product Requirement spatial scale can be found in Appendix E.

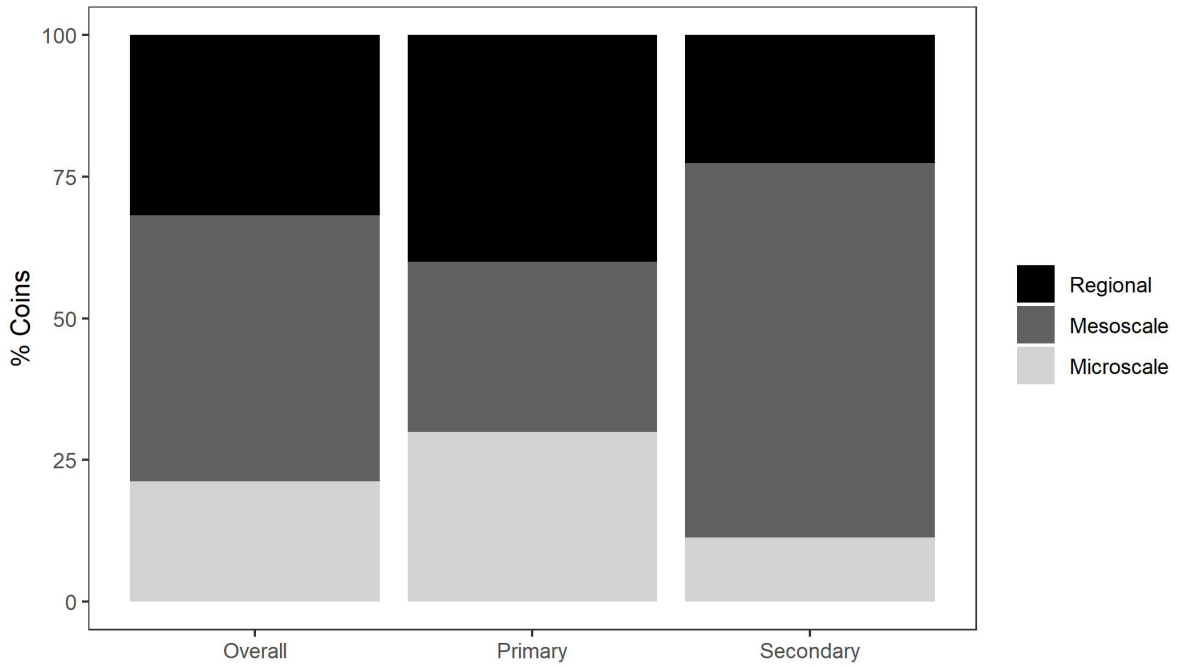


Figure 20. The percentage of coins for each Map Product Requirement spatial scale selected at the overall, primary, and secondary levels in the CNMI.


Forbidden Island, Saipan. Credit: David Burdick (NOAA)

4.3 Summary of Spatial Priorities

Total Coins

Cells with the highest total number of coins (top 10%) covered nearly 60 km^2 and occurred in several locations in the CNMI (Figure 21), including Rota, Tinian, Saipan, and Pagan (Figure 21: A, B, and E). However, clusters of four or more adjacent cells with the highest number of coins occurred only on Rota, Tinian, and Saipan. A cluster of top 10% cells was located along the southwest coast of Rota, in an area comprising the nearshore coastal areas on both east and west side of the village of Songsong and the Wedding Cake Conservation Area peninsula, hereafter referred to as the Liyo region (Figure 21A). There were two clusters of top 10% cells on Tinian around Tinian Harbor and the Tinian Marine Reserve (five cells), and Asiga Bay (four cells), followed by a smaller cluster (two cells) along the northwest coast (Figure 21B). In Saipan, a group of five cells in the top 10% were located around the Mañagaha Marine Conservation Area and Tanapag Harbor (Figure 21B), and one cell on the opposite coast in the Laolao Bay Sea Cucumber Reserve (Figure 21B; CNMI MPAs). There was one top 10% cell on Pagan, located off the northwest coast of the island (Figure 21E). No cells in the top 10% of total coins occurred around Farallon de Medinilla, Sarigan, Asuncion, Maug, or Farallon de Pajaros. There were four islands (Anatahan, Guguan, Alamagan, and Agrihan) where no coins were allocated.

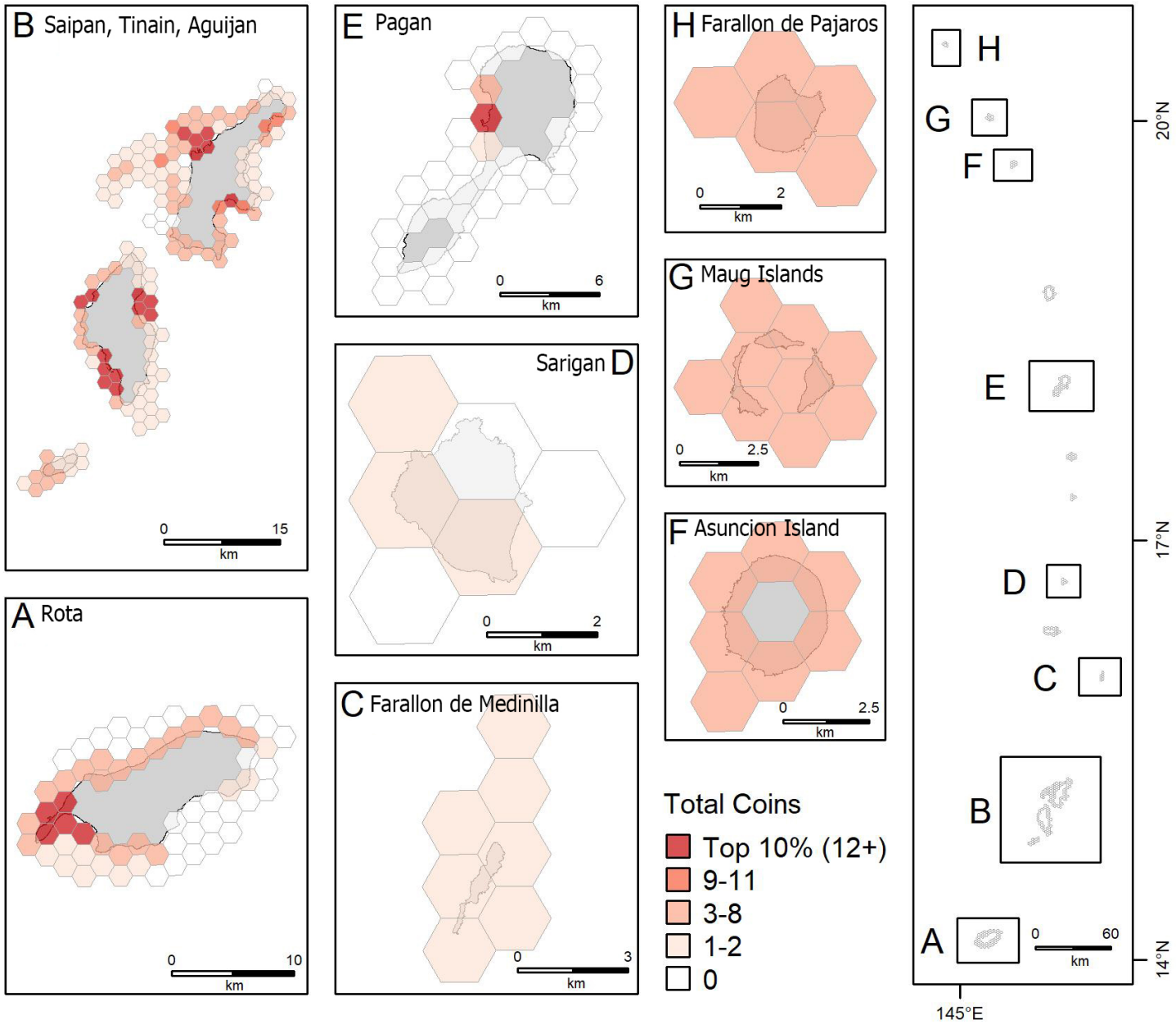


Figure 21. Map of total coins in the CNMI. No coins were allocated to the islands Anatahan, Guguan, Alamagan, and Agrihan.

Participating Groups

The number of groups that allocated coins into each cell ranged from one to nine (Figure 22). Large clusters of cells in the top 10% based on number of participant groups occurred along the southwest coast of Rota in the Liyo region, the majority of Tinian's west coast and Asiga Bay on the east coast, two clusters on the northwest coast and Laolao Bay regions of Saipan, and one cell on the southwest tip of Aguijan. One cell within Tinian Harbor had an allocation of coins by every single participant. Cells selected by multiple participants are an opportunity for collaboration and highlight where data collection could satisfy the needs of several groups.


School of surgeonfish and tangs in Aguijan. Credit: M. Chauvin (NOAA NMFS)

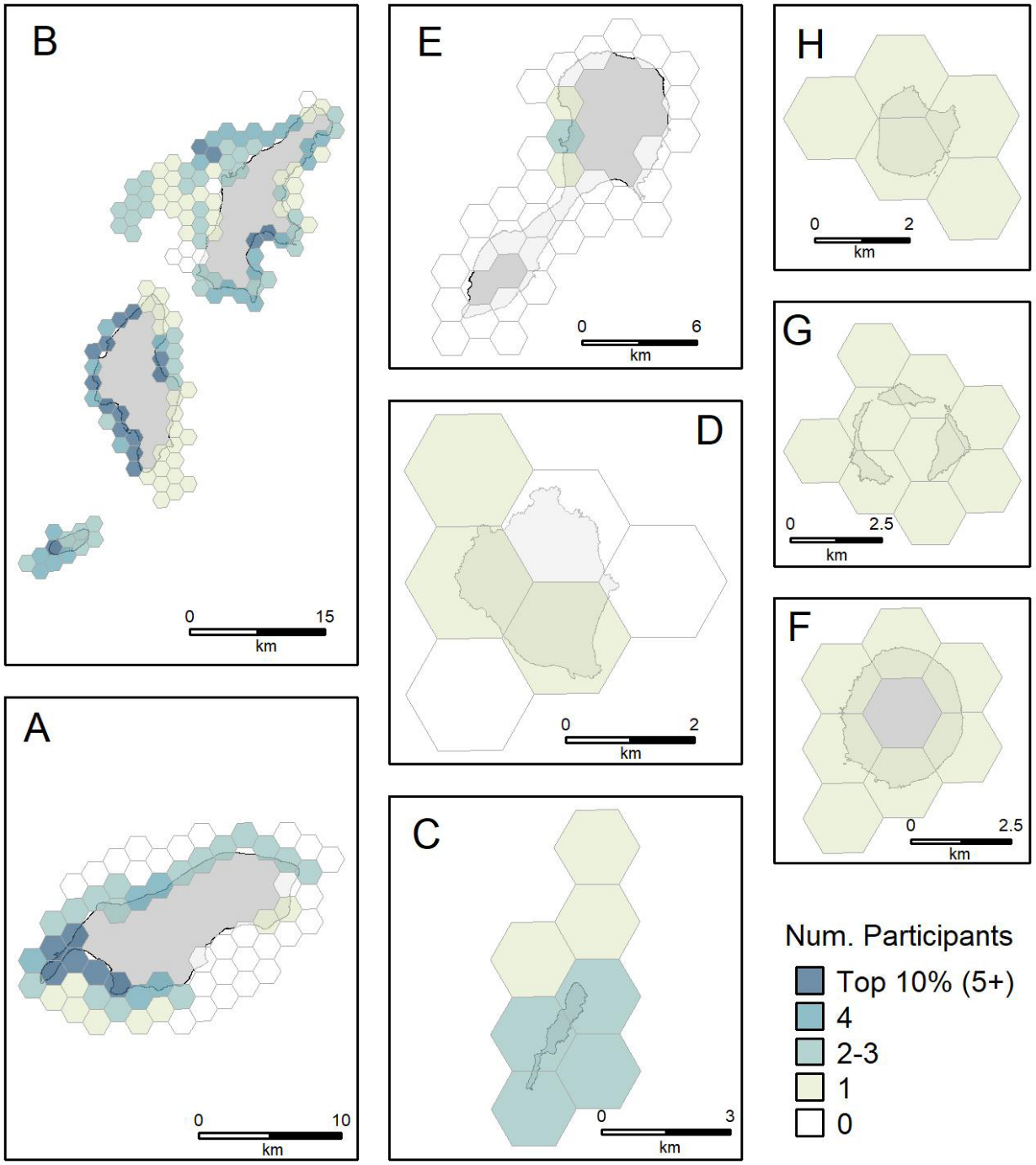


Figure 22. Number of participant groups that allocated at least one coin into each cell. A maximum of nine participant groups input coins into a single cell. No coins were allocated to the islands Anatahan, Guguan, Alamagan, and Agrihan.

Management Uses

The total number of Management Uses selected for each cell highlights several unique areas where a variety of mandates and management actions would be served by collecting the required data (Figure 23). There were several large clusters of cells where six to nine (top 10%) different Management Uses were selected by participants. On the southwest coast of Rota, cells in the top 10%, based on the number of Management Uses, stretched along the entire south shore from Sasanhaya Bay Fish Reserve, and the fringing reefs along the west coast of Songsong (Figure 23A). A few locations along the east coast of Tinian contained Management Uses in the top 10% selected, particularly around Tinian Harbor, with smaller clusters to the north; and two cells in Asiga Bay (Figure 23B). In Saipan, clusters of 3–5 top 10% cells, were located around Laolao Bay, Bird Island, and Obyan Beach; and one top 10% cell in the Mañagaha Marine Conservation Area (Figure 23B).

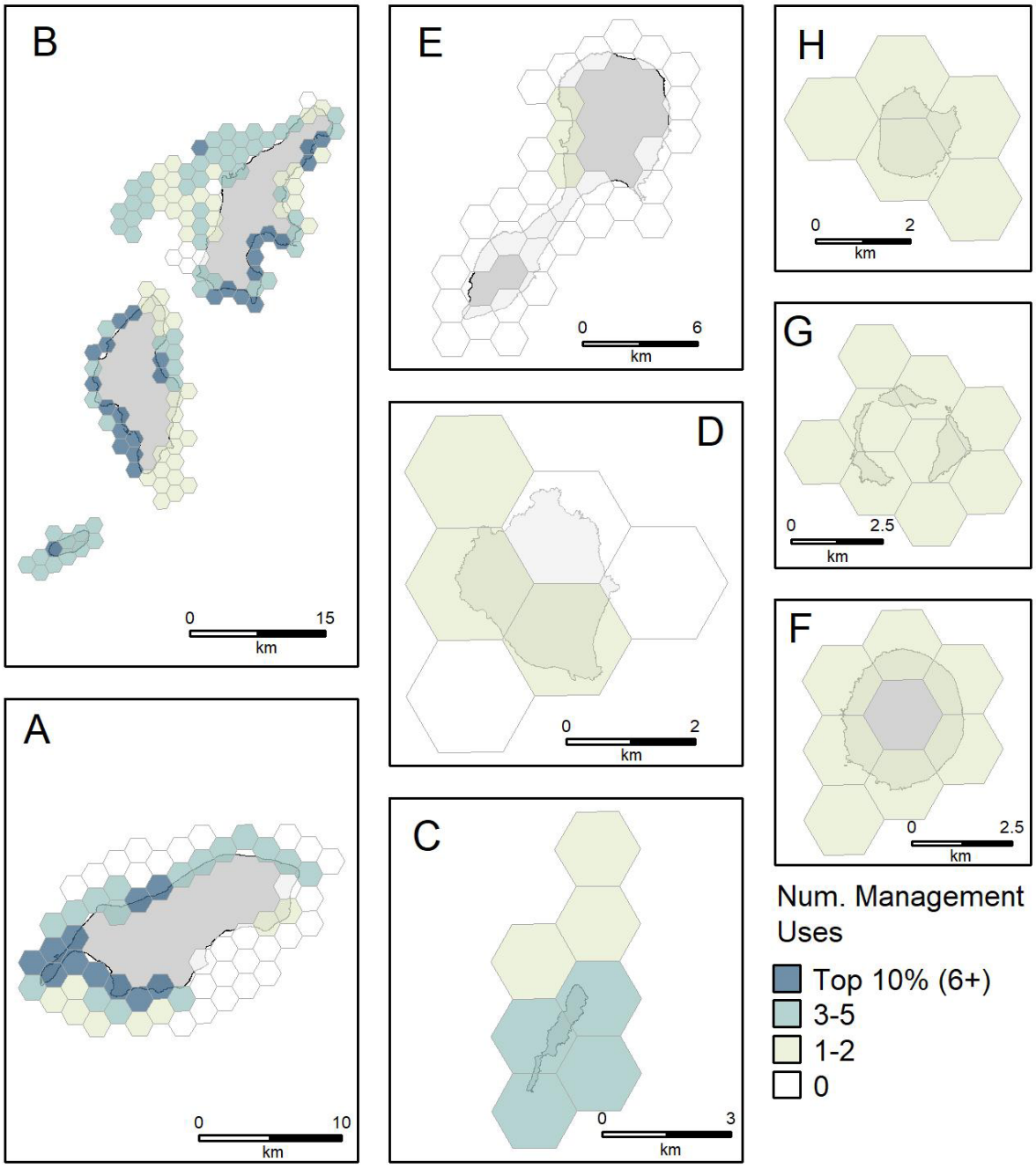


Figure 23. Number of Management Use options that were selected in each cell. No coins were allocated to the islands Anatahan, Guguan, Alamagan, and Agrihan.

Map Product Requirements

The number of Map Product Requirements selected by participants highlights the areas where a significant number of different data needs were selected (Figure 24). Clusters of cells with values in the top 10% based on the number of selected Map Product Requirements indicate areas where a variety of data needs could be met. This would involve collaboration among managers and stakeholders to ensure data collected can satisfy the diverse needs of data requirements in these areas. Areas with large continuous clusters of cells in the top 10% of number of Map Product Requirements were located in Rota (Figure 24A), Aguijan, Tinian, and Saipan (Figure 24B). There were continuous clusters of top 10% cells in Rota from west of Puntan Malilok to west coast of Songsong village, encompasing the Liyo region, with a smaller cluster up along the north east coast by Teteto Beach (Figure 24A). On Aguijan, a large cluster of six top 10% cells were located along the west end of the island out to Naftan Rock to the southwest (Figure 24B). All but two of the cells along Tinian's west coast were in the top 10%, stretching from Tinian Marine Reserve at Punta Lalo to Unai Lamlam; and another group of five cells was located in Asiga Bay (Figure 24B). Saipan had multiple clusters of top 10% cells, primarily located along the northwest coast offshore from Mañagaha Marine Conservation Area to Tanapag, along the south coast, and on the east side around Laolao Bay Sea Cucumber Sanctuary, Forbidden Island Sanctuary, and Bird Island Sanctuary regions (Figure 24B).

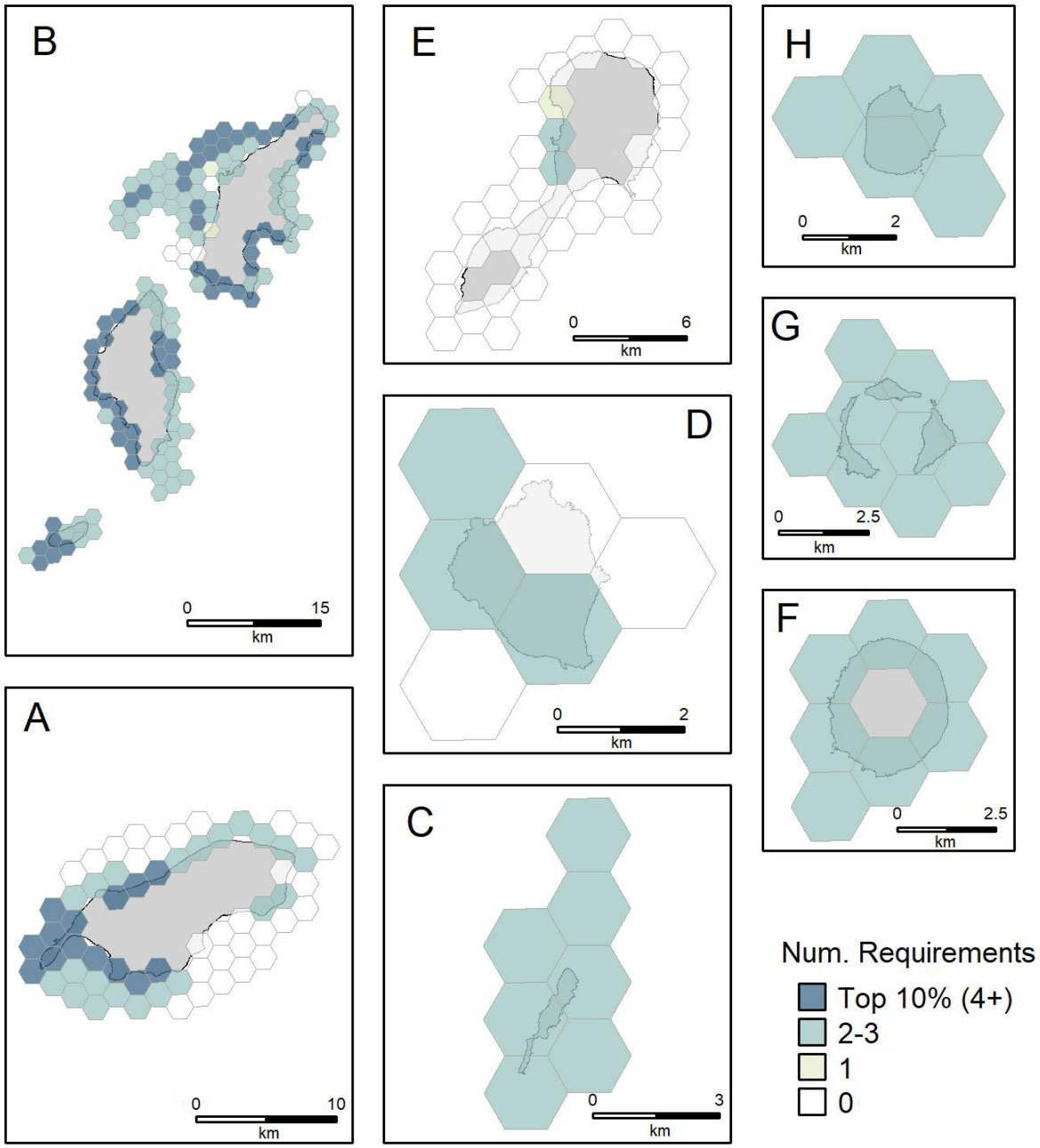


Figure 24. Number of Map Product Requirement options that were selected in each cell. No coins were allocated to the islands Anatahan, Guguan, Alamagan, and Agrihan.

Summary Rank

By combining the total number of coins, number of participating groups, and number of Management Uses into a single summary rank metric, cells of greater importance for multiple reasons were highlighted. Highest-ranked cells (top 10%) occurred only in Rota, Aguijan, Tinian, and Saipan (Figure 25). A cluster of six cells in the top 10% of summary ranks occurred around Tinian Marine Reserve and Tinian Harbor, a smaller group around Tanapag Harbor, and one cell in Asiga Bay (Figure 25B). Additionally, a group of five cells in the top 10% occurred in the Liyo region, southwest Rota (Figure 25A). These large clusters of cells around Songsong and the Liyo region, Tinian Harbor, and Laolao Bay are further discussed in section 4.4 Gap Analysis and Focal Areas. Several smaller groups of highest-ranking cells surrounded the island of Saipan, many overlapping with the CNMI's MPAs (Mañagaha Marine Conservation Area, Laulau Bay Sea Cucumber Reserve, Forbidden Island Marine Sanctuary, Bird Island Marine Sanctuary, and Bird Island Sea Cucumber Reserve; Figure 25B).

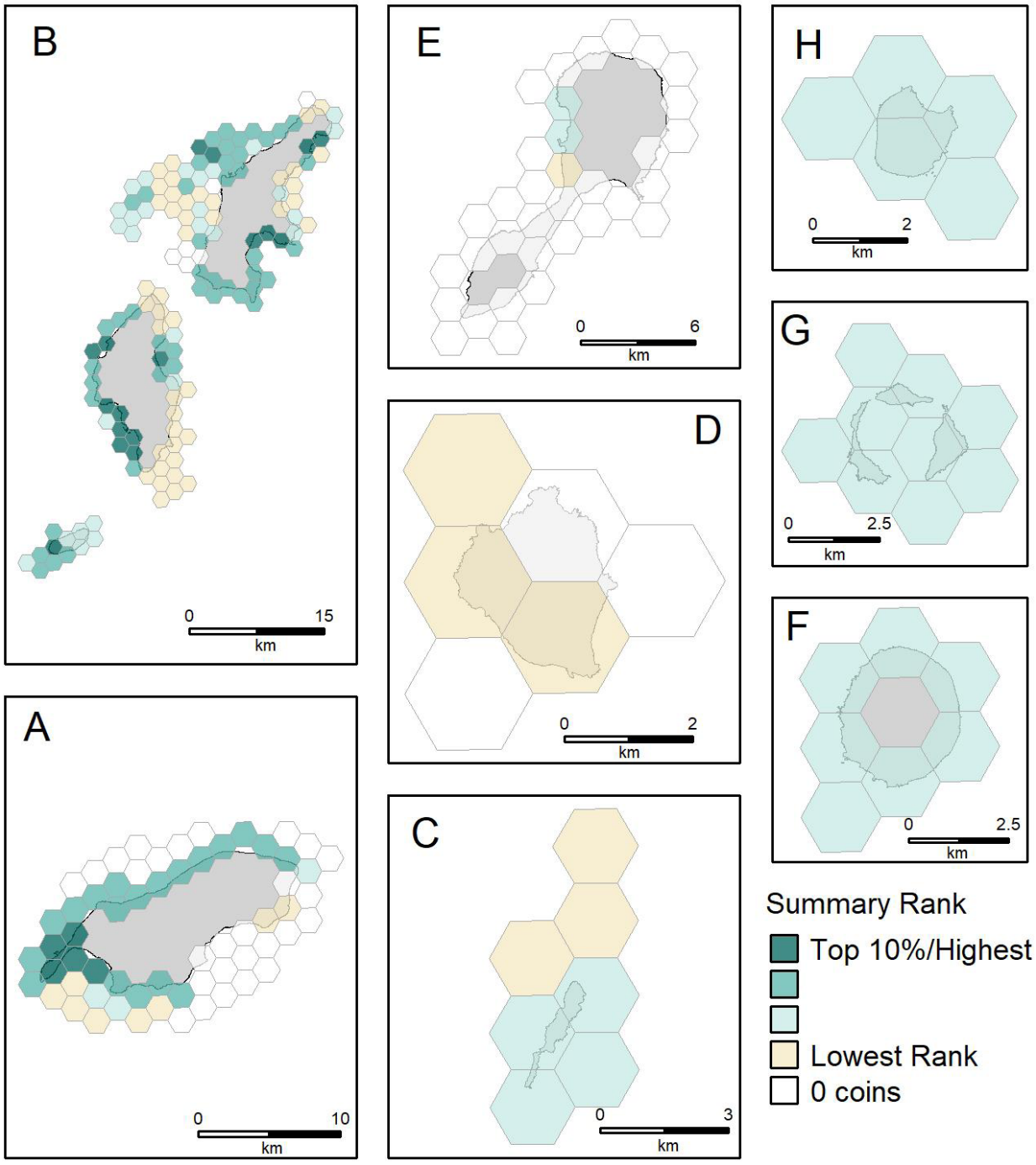


Figure 25. Summary rank based on total coins, number of participating groups, and diversity of Management Uses in each cell. Highest Rank identifies top 10% of summary rank cells. No coins were allocated to the islands Anatahan, Guguan, Alamagan, and Agrihan.

4.4 Gap Analysis and Focal Areas

Three focal areas were identified in the CNMI through this prioritization effort: 1) Liyo region, Rota; 2) Tinian Harbor, Tinian; and 3) Laolao Bay, Saipan (Figure 26). These focal areas were selected because they contained numerous adjacent cells within the top 10% of summary ranks and lacked existing data. Each focal area is described in more detail below.

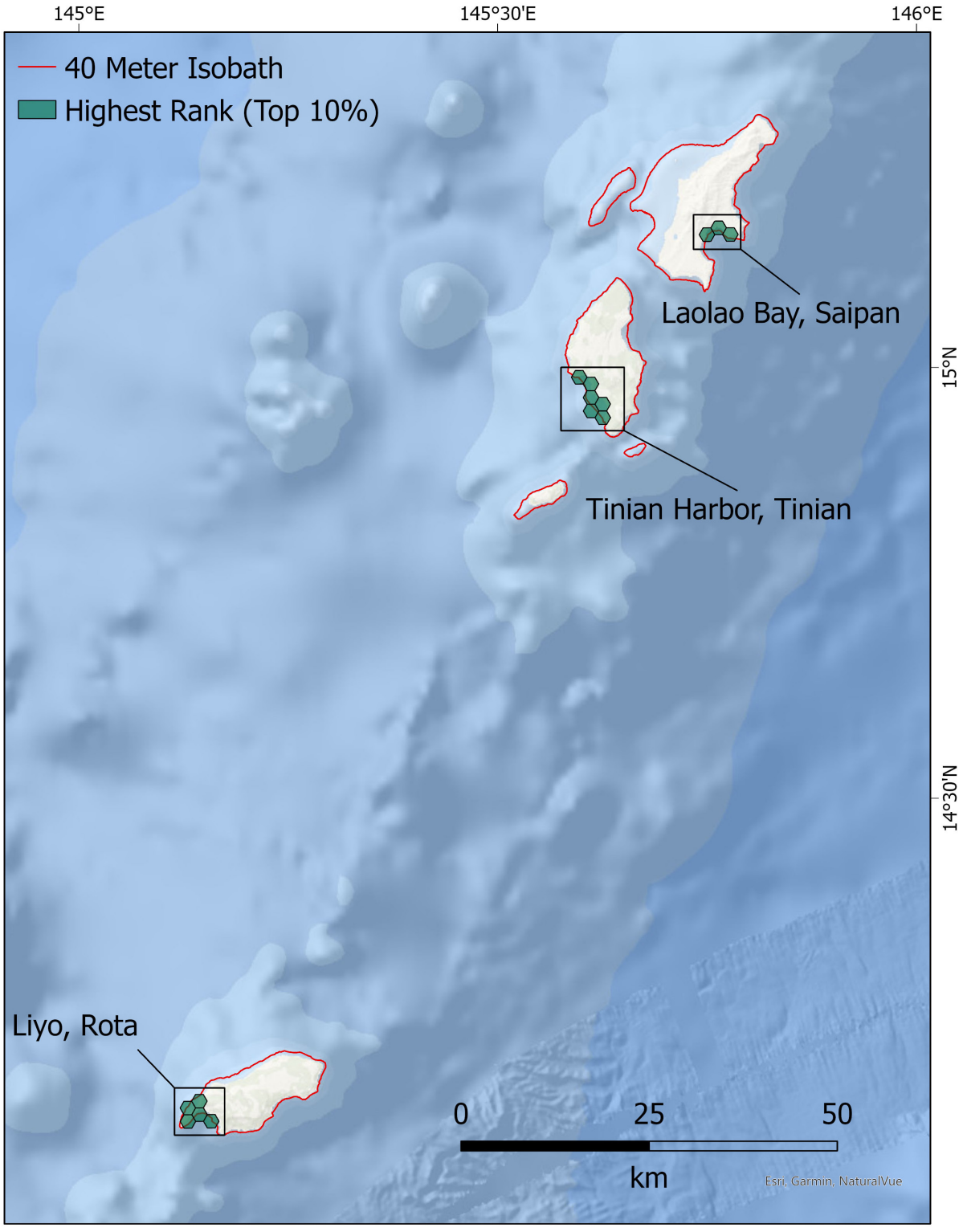


Figure 26. Overview of focal areas in CNMI identified using the highest summary rank. Only the top 10% cells are shown.

4.4.1 Liyo Region, Rota

On the southwestern coast of Rota, in the Liyo region, a total of five hexagons (13 km^2) were selected by eight participant groups. This region, known locally as Ori'yan Liyo' yan Bån'dan i Tasi, loosely translated to "Around the Liyo," covers the Songsong districts and Sasanhaya Bay to the east, the the peninsula (including coastal areas), and the fringing reefs on the west (Figure 27). The top Management Use selected in this area was *Coastal Vulnerability and Planning* and made up 42% of the coins allocated in this region (Table 6), which aligns with the need for targeted management actions in response to impacts from climate change, pressures from development, and supporting coral reef resilience (Dobson et al., 2020; NOAA CRCP, 2018; USACE, 2022a,b). This focal area has been identified by CNMI's Office of Planning and Development as an area of interest by stakeholders for priority management targets. New mapping data in this area would be used to enhance data collection and analysis for filling the existing gaps in monitoring efforts as they relate to these identified Management Uses (E. Derrington, Pers. Comm.).

Within this focal area, *Density of Macrobiota* followed by *Identification of Coral Species* and *Substrate Type* were the top Map Product Requirements desired. *Density of Macrobiota* and *Substrate Type* require mesoscale (2- to 10-m resolution) data, which may be partially covered by the existing 10-m multibeam data collected in 2022 by NOAA Ship Rainier (Appendix A). *Identification of Coral Species* (second most selected) typically requires microscale (<1-m resolution) data and may also be partially covered by the 0.2-m resolution data (NOAA OCM, 2023). However, gaps in spatial coverage of lidar and multibeam data exist in these locations less than 40 m in depth and may require in situ data collection to obtain the level of detail required for identification of corals. These gaps include habitats between the west coast of the Songsong districts and the fringing reefs that run parallel to it, as well as nearshore habitats within Sasanhaya Bay. Additional habitat classification maps from 2005 (NOAA NCCOS, 2005) exist in this region but are outdated when considering climate change and coastal development impacts within the last decade. These map products could potentially be used to support coastal vulnerability and planning management needs.

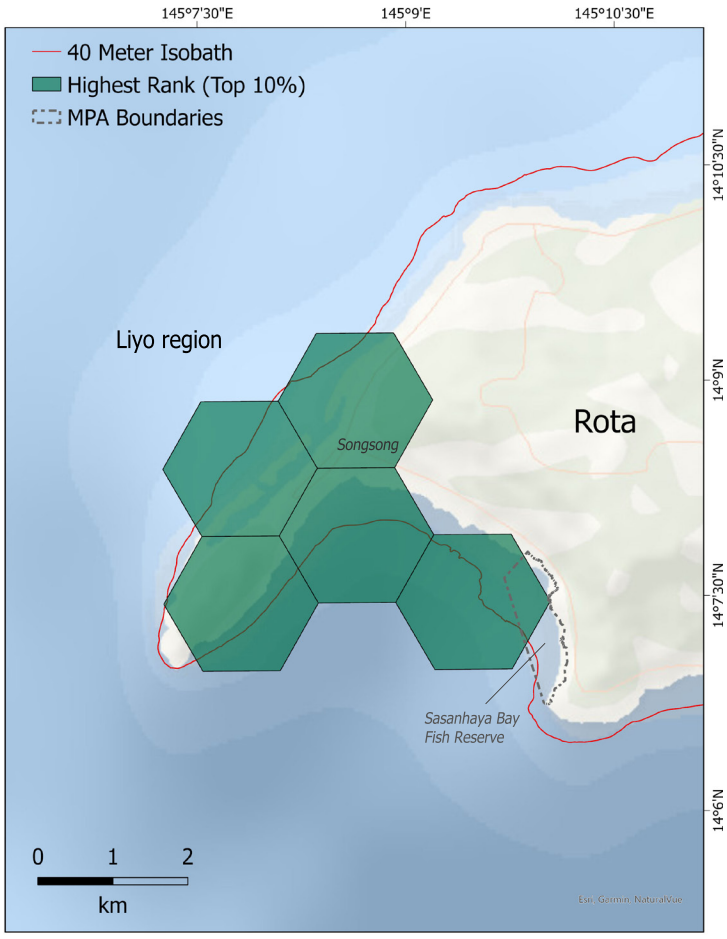
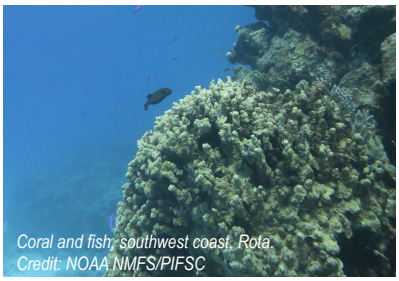


Figure 27. Focal area in the Liyo region of Rota, locally known as Ori'yan Liyo' yan Båndan i Tasi. Only cells in the highest summary rank are shown.

Table 6. Data summary of participant input for the Liyo region focal area. Percentage of coins are calculated based on the Management Use, Map Product Requirement, and Spatial Scale coin totals within these five hexagons only. The Number of Groups reflects how many participant groups assigned coins to any portion of the area.

Total Coins (# hexagons):	**Rank (# hexagons):**	**Number of Groups:**
Top 10% (5)	Top 10% (5)	8
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Coastal Vulnerability and Planning (42%)	Density of Macrobiota (26%)	Mesoscale (47%)
Consultations and Permitting (19%)	Identification of Coral Species (21%)	Regional (32%)
Emergency Response (14%)	Substrate Type (21%)	Microscale (21%)
Monitoring (10%)	Topographic Features (16%)	
Habitat Restoration (6%)	Hard vs. Soft Bottom (12%)	
Fisheries Management (5%)	Habitat Suitability (8%)	
Endangered Species Management (3%)		
Spatial Protection/Management (3%)		


Coral and fish, southwest coast, Rota.
Credit: NOAA NMFS/PIFSC


Coral Gardens within Sasanhaya Marine Fishing Reserve Rota.
Credit: Department of Coastal Resources Management

4.4.2 Tinian Harbor, Tinian

Six highest-ranking cells (15.6 km^2) occurred in Tinian Harbor, which is located on the west coast of Tinian and encompasses most of the island's coral reef habitats (Figure 28). This area was prioritized by nearly every single participating group, with eight of the nine participant groups allocating coins here. *Coastal Vulnerability and Planning* was identified as the primary Management Use in this region, exceeding all other options by twofold (Table 7). This aligns with planned port expansion, repair, and maintenance activities (CNMI CPA, 2023) and increased urban development in coastal areas (USACE, 2022a). Tinian Harbor coral reef habitats, like all coral reefs in CNMI, are vulnerable to impacts from tsunamis and other significant natural events; however, these reef communities are also vulnerable to coastal- and harbor-based impacts, as Tinian Harbor is the primary port of entry into the CNMI and have greater vessel activity (Whitall et al., 2016; USACE, 2022b).

Within this focal area, the top Map Data Requirement selected by participants was *Density of Macrobiota*, typically requiring mesoscale (2- to 10-m resolution) data, which may be covered partially by the multibeam data collected in 2022 by NOAA Ship Rainier (Appendix A). However, regional data were also needed, making up to 46% of the coins through selections *Topographic Features* (second most selected) and *Habitat Suitability* (third most selected) Map Data Requirements (Table 7). Coarse-resolution imagery from 2001 to 2022 multibeam data could be used to meet region-level needs

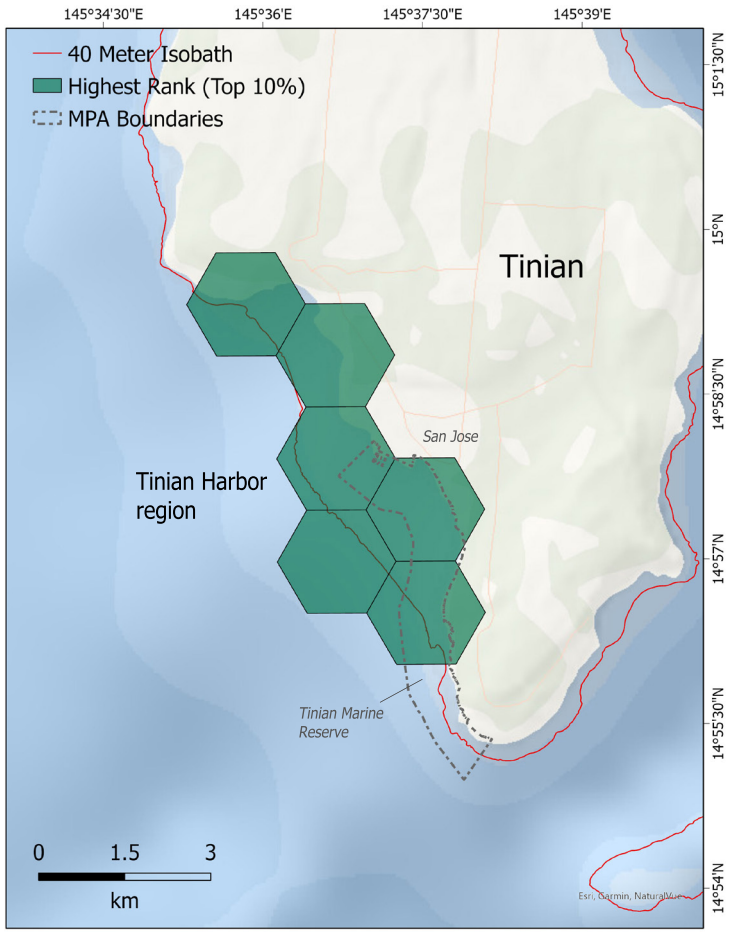
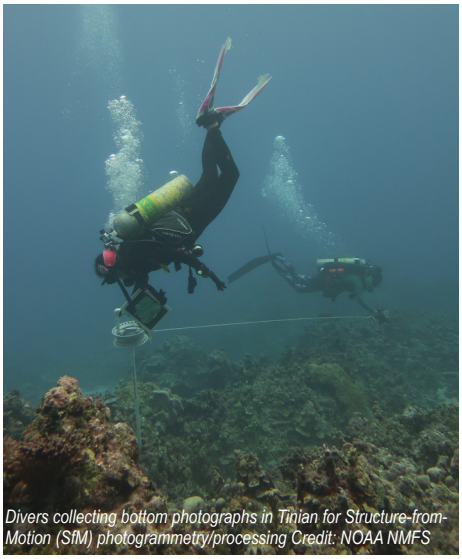


Figure 28. Focal area of Tinian Harbor area, Tinian. Only cells in the highest summary rank are shown.



Divers collecting bottom photographs in Tinian for Structure-from-Motion (SfM) photogrammetry/processing Credit: NOAA NMFS

Table 7. Data summary of participant input for Tinian Harbor focal area. Percent coins are calculated based on the Management Use, Product Requirement, and Spatial Scale coin totals within these six hexagons only. The Number of Groups reflects how many participant groups assigned coins to any portion of the area.

Total Coins (# hexagons):	**Rank (# hexagons):**	**Number of Groups:**
Top 10% (5) Medium (1)	Top 10% (6)	9
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Coastal Vulnerability and Planning (42%)	Density of Macrobiota (22%)	Regional (46%)
Watershed Management (16%)	Topographic Features (21%)	Mesoscale (35%)
Monitoring (13%)	Habitat Suitability (20%)	Microscale (18%)
Consultations and Permitting (8%)	Identification of Coral Species (18%)	
Emergency Response (6%)	Substrate Type (13%)	
Fisheries Management (4%)	Hard vs. Soft Bottom (6%)	
Habitat Restoration (4%)		
Spatial Protection and Management (4%)		
Endangered Species Management (2%)		

4.4.3 Laolao Bay, Saipan

Laolao Bay, located on the east coast of Saipan, had three cells in the top 10% of summary rank (total area 7.8 km^2) and was prioritized by six participant groups (Figure 29). This location overlaps with the Laolao Bay Sea Cucumber Reserve and Forbidden Island Marine Sanctuary and was the only focal area that didn't encompass a harbor/port or a populous area. The top two Management Uses identified in this focal area were *Emergency Response* and *Coastal Vulnerability and Planning* (Table 8), which correspond with the recent management focus on coastal development and land-based sources of pollution (DCRM, 2018; Horsley Witten Group, 2020; USACE, 2022b). The high coral diversity and year-round accessibility of the bay makes it one of Saipan's most popular shore dive locations. Recent interest by various groups to develop this location, with projects ranging from floating docks and restaurants to installation of artificial reef structures, has led to the need for updated and high-resolution mapping data so that potential impacts to the marine environment from these development decisions can be evaluated and inform upcoming permitting requests (N. Van Ee, Pers. Comm.).

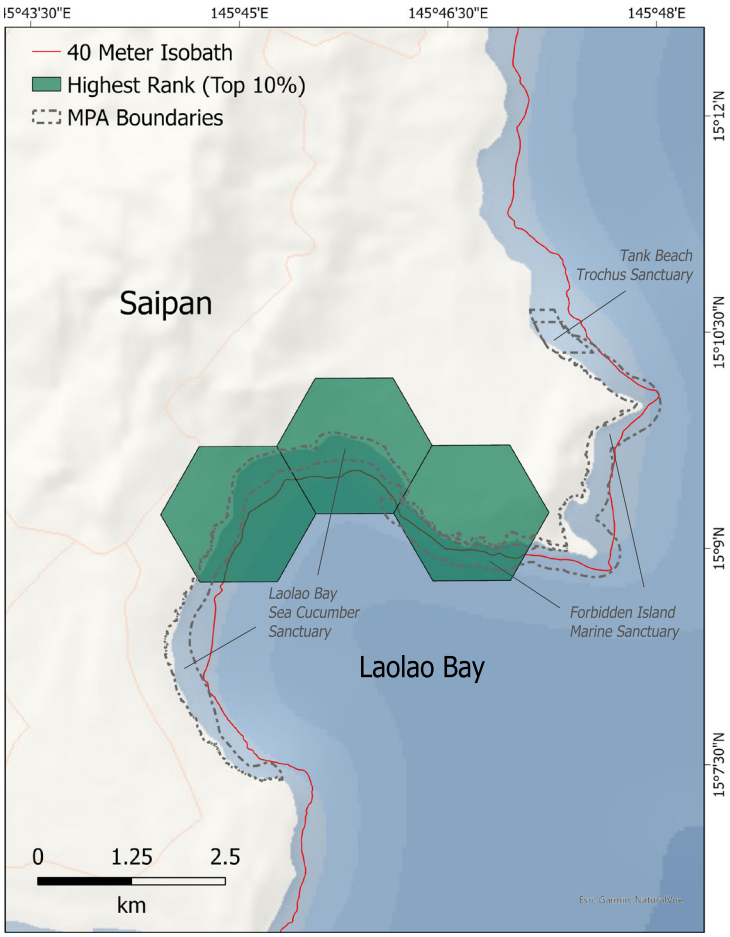


Figure 29. Focal area of Laolao Bay, Saipan. Only cells in the highest summary rank are shown.

Existing habitat maps from the 2000s (Anderson, 2004), that are currently being used for monitoring in this area, are outdated and at too coarse of a resolution to be used for habitat-level information. *Density of Macrobiota*, *Hard vs. Soft Bottom*, and *Identification of Coral Species* were the top Map Product Requirement options selected, indicating a need for mapping products at a variety of spatial resolutions (Table 8). Recent acquisition of 10-m resolution multibeam data collected in 2022 by NOAA Ship Rainier (Appendix A) may help meet the needs for mesoscale (2- to 10-m resolution) data; however, for finer-scale data, the 2020 <1-m lidar data (NOAA OCM and USGS, 2023) may fall short in submeter precision for microscale-level products, such as coral condition and identification purposes, and would likely require additional or supplementary in situ data collection. Existing long-term monitoring efforts by the CNMI's Division of Coastal Resources Management at coral reef sites within the bay would likely benefit mapping data to fill gaps in coverage and scale. NCCOS is currently planning future mapping data collection in this area. Available 0.2-m resolution lidar data collected in 2019–2020 may meet the needs of microscale-level requirements that can be used to define seafloor habitat types and continue to monitor the condition of coral species (see Appendix A for dataset information).


Coral reef in Laolao Bay. Credit: NOAA Research

Table 8. Data summary of participant input for Laolao Bay focal area. Percent coins are calculated based on the Management Use, Product Requirement, and Spatial Scale coin totals within these three hexagons only. The Number of Groups reflects how many participant groups assigned coins to any portion of the area.

Total Coins (# hexagons):	**Rank (# hexagons):**	**Number of Groups:**
Top 10% (1) High (2)	Top 10% (3)	6
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Emergency Response (36%)	Density of Macrobiota (32%)	Mesoscale (38%)
Coastal Vulnerability and Planning (25%)	Hard vs. Soft Bottom (27%)	Regional (36%)
Monitoring (15%)	Identification of Coral Species (26%)	Microscale (26%)
Endangered Species Managementgmt (5%)	Habitat Suitability (9%)	
Spatial Protection and Management (5%)	Substrate Type (6%)	
Habitat Restoration (5%)		
Fisheries Management (4%)		
Watershed Management (4%)		

Chapter 5 Conclusion

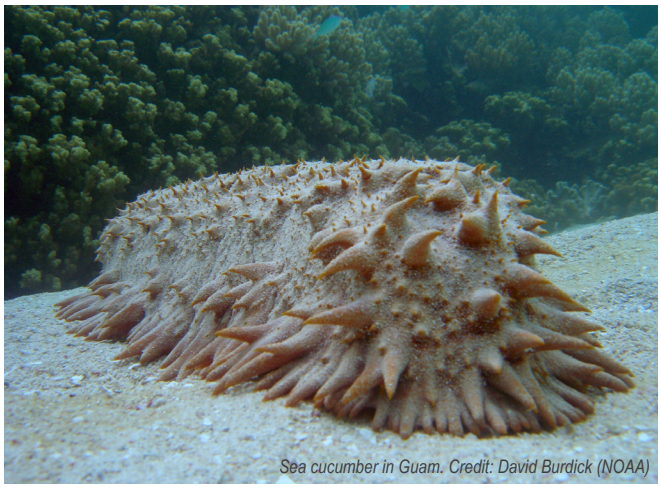
An online application was used to gather information from local experts in Guam and the CNMI regarding their priority needs for benthic mapping data to support coral reef management. This system allowed participants to indicate where mapping data are needed, the type of data needed, the immediacy of the need, management actions supported, and what type of objectives could be met with new data. There are several areas (referred to as focal areas) that participants identified as a high priority for future mapping. Four focal areas were identified based on the top 10% of cells for summary rank: 1) Apra Harbor, Guam; 2) Liyo region, Rota; 3) Tinian Harbor, Tinian; and 4) Laolao Bay, Saipan.


Mañagaha Marine Conservation Area, Saipan. Credit: NOAA and Nature Conservancy

These four focal areas highlight some of the best opportunities for collaboration, with the potential to meet a variety of coral reef management goals. All focal areas except Laolao Bay are areas of high population density and contain major ports. All of these locations are susceptible to land-based sources of pollution and coastal development and vulnerable to tsunamis and climate change impacts. Therefore, many of the requirements identified by participants indicate a need for management actions related to port commerce, coastal development, increased tourism, and military operations and activities, while protecting and restoring coral reef habitats and associated ecosystems. Furthermore, climatic events such as more frequent tropical cyclones (typhoons) and elevated water temperatures leading to coral bleaching have affected this region in both offshore and coastal environments, necessitating coastal vulnerability and watershed management planning. Within the past 10 years, Guam and the CNMI have been impacted by multiple coral bleaching events between 2013 and 2017, resulting in reef destruction, mass coral mortality, and increased risk to long-term viability in impacted coral species (Raymundo et al., 2019). Furthermore, increased frequency of intense wave action and wind speeds associated with tropical cyclones in this region have resulted in increased stress to coral reef ecosystems (Dobson et al., 2020, 2021).


Tires being hauled out of Tinian Harbor as part of a debris removal activities in the aftermath of Super Typhoon Yutu in 2018. Credit: Mariana Islands Nature Alliance

It is also important to recognize that data planning efforts should be informed by the top 10% summary rank while considering other data metrics. Targeting a top 10% area and adjacent areas as time and money allow, will yield a larger return on investment. For example, some places were identified as high priority for multiple metrics, but only consisted of single or pairs of cells, falling outside of the focal areas. Data planning efforts in these locations, such as Agat Bay (Guam), would benefit multiple groups and meet a variety of management uses in a “smaller” spatial area than the focal areas. Additionally, the distribution and diversity of Management Use selections can highlight important areas where a variety of goals can be met. For example, much of the west coast of Tinian had 4-6 different Management Uses selected. Many of these cells were also in the top two categories of summary rank. Aguijan also had a variety of Management Uses selected, ranging from 3–7 different options


Sea cucumber in Guam. Credit: David Burdick (NOAA)

selected (out of a total nine). However, these cells contained a relatively low number of coins. This indicates that although there were a variety of management goals selected, participants did not indicate an urgent data need. These examples illustrate the diversity of goals across participating groups and, in some cases, the uniqueness of participant group needs. It is also important to recognize that the prioritized areas are directly dependent on the participants that provided input. Not all invited groups participated in the effort, and priorities could be different for other groups not represented here.

For future mapping planning efforts, targeting cells within the highest summary ranks (top 10%) will ensure that data collection will fulfill a variety of coral reef management purposes, address a need for several participating groups, and satisfy high-priority needs for updated information. However, refining the area based on survey optimization and finer-scale considerations is necessary to address specific needs and mandates, such as habitat suitability, coral density, and coral species identification. For example, the tools and effort needed to map various grid cells differ depending on depth and water clarity. Benthic sonar and lidar mapping technologies are typically focused on gathering data over large geographic areas and features. Conversely, models of habitat suitability are often targeted at finer-scale areas such as a specific reef feature. A cursory review of gaps in existing data and high-priority cells shows that some cells contain extensive survey data (i.e., lidar and/or multibeam), but the data may be of too coarse resolution, limited by depth (i.e., greater than 40 m), or lack ancillary data such as habitat or bottom type. Future surveys may exclude these areas that have already been mapped, but whether these existing data meet the needs of local agencies should be considered.

Bird Island, Saipan. Credit: David Burdick (NOAA)

Coral reef, Rota Credit: NOAA NMFS/PIFSC

Divers and a wall of corals in Maug Islands, CNMI. Credit: NOAA NMFS/PIFSC

Chapter 6 Links to Data

Final maps and results were published online at several repositories to ensure ease of access. Online dashboards were created to showcase the results, with selectors and functions to allow the user to easily turn on and off layers. The resulting maps and data were also submitted to Zenodo, an online data repository approved by NOAA, for long-term preservation and public access. Finally, these web mapping services from the data inventory were published in NOAA's Integrated Ocean and Coastal Mapping (IOCM) U.S. Mapping Coordination website (NOAA IOCM, 2023). See links below for access to reports, data viewers, and downloads.

Datasets, Data Web Services, and Metadata:

- 2023: Agency priorities for mapping coral reef ecosystems in Guam and the Commonwealth of the Northern Mariana Islands, 2023-02-22 to 2023-06-12
  - Zenodo Accession (Hile et al., 2023)
- 2022: Dashboard – Guam and CNMI Coral Reef Mapping Prioritization Results
- 2021: Project Website – Coral Reef Prioritization | A Roadmap for Future Data Collection
- 2021: NCCOS Website – Defining Future Seafloor Mapping Priorities to Inform Shallow Coral Reef Management
- U.S. Mapping Coordination Website: SeaSketch

Tumon Bay, Guam. Credit: David Burdick (NOAA NMFS)

Divers conducting coral surveys in Pagan. Credit: NOAA NMFS/PIFSC

Diver and school of fish off Bird Island, Saipan. Credit: Jeff Milisen (NOAA NMFS)

References

Anderson, M. (2005). Benthic Habitats of the Saipan, Southern Mariana Archipelago 2001-2003, Derived from IKONOS Imagery. Analytical Laboratories of Hawaii and NOAA National Centers for Coastal Ocean Science. https://www.coris.noaa.gov/metadata/records/html/habitat_saipan_2003.html

Buckel, C. A., Taylor, J. C., and Bollinger, M. (2021). Prioritizing areas for future seafloor mapping, research, and exploration for the southeast U.S. Atlantic Coast. NOAA Technical Memorandum NOS NCCOS 289. https://doi.org/10.25923/qh2c-hs73

Buja, K., and Christensen, J. (2019). Spatial Prioritization Widget: A Tool to Identify Mapping Priorities. Retrieved from: https://coastalscience.noaa.gov/project/spatial-prioritization-widget

Burdick, D., Brown, V., Asher, J., Gawel, M., Goldman, L., Hall, A., Kenyon, J., Leberer, T., Lundblad, E., McIlwain, J., Miller, J., Minton, D., Nadon, M., Pioppi, N., Raymundo, L., Richards, B., Schroeder, R., Schupp, P., Smith, E., and Zgliczynski, B. (2008). The state of coral reef ecosystems of Guam. In: Waddell, J. E., and Clarke, A. M. (Eds.), The state of coral reef ecosystems of the United States and Pacific Freely Associated States, 2008 (pp. 465–509). NOAA Technical Memorandum NOS NCCOS 73. https://repository.library.noaa.gov/view/noaa/17794/

CNMI CPA. (2023, July 6). DoD joint area design concept [Press release]. CNMI Commonwealth Ports Authority. https://cnmiports.com/news/20230706-dod.pdf

CNMI DPL. (2019). CNMI comprehensive public land use plan update for Rota, Tinian, Saipan, and the Northern Islands. Department of Public Lands Commonwealth of the Northern Mariana Islands. https://www.dpl.gov.mp/wp-content/uploads/2019/03/DPL-Plan-3.13.2019.pdf

Costa, B. M., Battista, T. A., and Pittman, S. J. (2009). Comparative evaluation of airborne lidar and ship-based multibeam sonar bathymetry and intensity for mapping coral reef ecosystems. *Remote Sensing of the Environment*, 113(5): 1082–1100. https://doi.org/10.1016/j.rse.2009.01.015

Costa, B. M., Buja, K., Kendall, M. S., Williams, B., and Kraus, J. (2019). Prioritizing areas for future seafloor mapping, research, and exploration offshore of California, Oregon, and Washington. NOAA Technical Memorandum NOS NCCOS 264. https://doi.org/10.25923/wa5c-vn25

DCRM. (2018). Laolao Bay monitoring. CNMI Department of Resources Management, Marine Monitoring Team. https://dcrm.gov.mp/our-programs/marine-monitoring-program/marine-monitoring-sites/laolao-bay-monitoring/

Derrington, E. CNMI Office of Planning and Development. Personal communication. August 25, 2023

Dobson, J. G., Johnson, I. P., Rhodes, K. A., Lussier, B. C., and Byler, K. A. (2020). Commonwealth of the Northern Mariana Islands coastal resilience assessment. UNC Asheville National Environmental Modeling and Analysis Center, Asheville, NC. Prepared for the National Fish and Wildlife Foundation. https://www.nfwf.org/programs/national-coastal-resilience-fund/regional-coastal-resilience-assessment

Dobson, J. G., Johnson, I. P., Kowal, V. A., Rhodes, K. A., Lussier, B. C., and Byler, K. A. (2021). Guam coastal resilience assessment. UNC Asheville National Environmental Modeling and Analysis Center, Asheville, NC. Prepared for the National Fish and Wildlife Foundation. https://www.nfwf.org/programs/national-coastal-resilience-fund/regional-coastal-resilience-assessment

Guam DOAG. (2021). Sasa Bay Marine Preserve fact sheet. Guam Department of Agriculture. https://doag.guam.gov/wp-doag-content/uploads/2021/10/Sasa-Bay-fact-sheet.pdf

Horsely Witten Group. (2020). Laolao Bay watershed existing conditions and opportunities interim report, September 2020 draft. Prepared for CNMI Bureau of Environmental and Coastal Quality Division of Coastal Resource Management. https://horsleywitten.com/cnmiwatersheds/pdf/LaolaoExistingConditions.pdf

Houk, P., and van Woesik, R. (2008) Dynamics of shallow-water assemblages in the Saipan Lagoon. *Marine Ecology Progress Series*, 356: 39–50. https://doi.org/10.3354/meps07252

Kendall, M. S., Buja, K., Menza, C., Gandulla, S., and Williams, B. (2020). Priorities for lakebed mapping in Lake Huron's Thunder Bay National Marine Sanctuary. NOAA Technical Memorandum NOS NCCOS 276. https://doi.org/10.25923/qyrf-tq71

Kraus, J., Williams, B., Hile, S. D., Battista, T., and Buja, K. (2020). Prioritizing areas for future seafloor mapping and exploration in the U.S. Caribbean. NOAA Technical Memorandum NOS NCCOS 286. https://doi.org/10.25923/w6v3-ha50

References

Kraus, J., Buckel, C. A., Williams, B., Ames, C., Dorfman, D., Pagan, F., and Towle, E. K. (2022). Agency priorities for mapping South Florida's coral reef ecosystems. NOAA Technical Memorandum NOS NCCOS 304. https://doi.org/10.25923/qc9e-gt19

Kraus, J., Buckel, C. A., Williams, B., Ames, C., Dorfman, D., Pagan, F., Towle, E. K., and Hile, S. D. (2022). Agency priorities for mapping coral reef ecosystems in Puerto Rico and the U.S. Virgin Islands. NOAA Technical Memorandum NOS NCCOS 305. https://repository.library.noaa.gov/view/noaa/48477

Kraus, J., Buckel, C. A., Williams, B., Urquart, K., Dorfman, D., Pagan, F., Towle, E. K., and Hile, S. D. (2023). Agency priorities for mapping coral reef ecosystems in the Main Hawaiian Islands. NOAA Technical Memorandum NOS NCCOS 311. https://doi.org/10.25923/csw1-xw45

Nelson, D. S., McManus, J., Richmond, R. H., King, D. B., Gailani, J. Z., Lackey, T. C., and Bryant, D. (2016). Predicting dredging-associated effects to coral reefs in Apra Harbor, Guam – Part 2: Potential coral effects. *Journal of Environmental Management*, 168, 111–122. https://doi.org/10.1016/j.jenvman.2015.10.025

NOAA CRCP. (2018). Coral reef condition: A status report for the Northern Mariana Islands. NOAA Office of Coastal Management, Coral Reef Conservation Program. https://www.coris.noaa.gov/monitoring/status_report/docs/CNMI_status_report_forweb.pdf

NOAA IOCM. (2023). U.S. mapping coordination: A collaboration site for mapping data acquisition. https://www.seasketch.org/#projecthomepage/5272840f6ec5f42d210016e4

NOAA NCCOS. (2005). Shallow-water benthic habitats of American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. Shallow-Water Benthic Habitats of American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. NOAA Technical Memorandum NOS NCCOS 8.

NOAA OCM and USGS (2023). 2019 - 2020 USGS/NOAA topobathy lidar: CNMI (Aguijan, Rota, Saipan, Tinian) [Data set]. https://www.fisheries.noaa.gov/inport/item/66790

R Core Team. (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/

Raymundo, L. J., Burdick, D., Hoot, W. C., Miller, R. M., Brown, V., Reynolds, T., Gault, T., Idechong, J., Fifer, J., and Williams, A. (2019). Successive bleaching events cause mass coral mortality in Guam, Micronesia. *Coral Reefs*, 38, 677–700. https://doi.org/10.1007/s00338-019-01836-2

Reyes, A. J. U.S. Department of the Navy, Naval Facilities Engineering Systems Command (NAVFAC), Pacific Region. Personal communication. August 24, 2023

USACE. (2022a). The Commonwealth of the Northern Mariana Islands final post disaster watershed plan, July 2022. U.S. Army Corps of Engineers. https://www.poh.usace.army.mil/Portals/10/docs/Civil%20Works/CNMI%20Watershed/01%20CNMI_FinalReport_July2022.pdf

USACE. (2022b). The Commonwealth of the Northern Mariana Islands final watershed plan Appendix A stakeholder engagement summary July 2022. U.S. Army Corps of Engineers. https://www.poh.usace.army.mil/Portals/10/docs/Civil%20Works/CNMI%20Watershed/02%20FINAL_Appendix%20A_CNMI_InteragencyAlignment_WA_WithAttachments_July2022.pdf

Van Ee, N. NMI Division of Fish and Wildlife. Personal communication. August 23, 2023

Whitall, D., Mason, A. Johnson, S., Okano, R., and Iguel, J. (2016). Chemical contaminants in corals (Pocillopora damicornis) in Tinian, CNMI. NOAA Technical Memorandum NOS NCCOS 219. https://doi.org/10.7289/V5/TM-NOS-NCCOS-219

Williams, A. Guam Bureau of Statistics and Plans. Personal communication.September 4, 2023

Yeo, M-H. University of Guam, Water and Environmental Research Institute of the Western Pacific. Personal communication. April 6, 2023

Yeo, M.-H., Patil, U. D., Chang, A., and King, R. (2023). Changing Trends in Temperatures and Rainfalls in the Western Pacific: Guam. *Climate*, 11, 81. https://doi.org/10.3390/cli11040081

Appendices

Appendix A: Data Inventory Reference Table

Table A.1. Data inventory for Guam and the CNMI. Each web service within the data inventory shared with participants is listed below. Specific island coverage is also noted.

Category	Item Name	Guam	CNMI	Description	Map Service URL
Bathymetry	Multibeam Collected by NOAA Ship Rainier (Footprints, 2022)	X	X	Collection of footprints representing areas surrounding Guam and the Commonwealth of the Mariana Islands where multibeam bathymetric surveys were conducted by the NOAA Ship Rainier in 2022. Footprints were created from available online data sources: NOAA-NCEI Bathymetric Data Viewer	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Rainier_Guam_CNMI_2022/FeatureServer
	Guam and CNMI: Multibeam Collection (Footprints, 2000–2022)	X	X	Collection of footprints representing areas surrounding Guam and the Commonwealth of the Mariana Islands where multibeam bathymetric surveys have been conducted from 2000-2022. Footprints were created from available online data sources: NOAA-NCEI Bathymetric Data Viewer & Pacific Islands Benthic Habitat Mapping Center.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Guam_CNMI_Multibeam_final/FeatureServer/0; https://noaa.maps.arcgis.com/home/item.html?id=4c7d7fa94fda431f93b2f6a7e18a74ce&sublayer=0
	Saipan Lagoon: Satellite Derived Bathymetry (NOAA NCCOS, 2016)		X	Under NOAA NCCOS and NCCOS' Biogeography Branch, this dataset is a by-product of a year-long project to map the benthic habitat of the Saipan Lagoon. Multispectral satellite-derived imagery was used to produce an updated shallow-water (<30m) depth as a predictor for habitat types.	https://services.arcgis.com/qchgHH9IIeiivY5M/arcgis/rest/services/SPN_Lagoon_Bathymetry/FeatureServer
	Guam and CNMI: Composite Bathymetry from Various Sources (PIBHMC, 2001–2014)	X	X	Integrated products from multiple sources of bathymetric information. These products include bathymetry data collected by multibeam, LIDAR, and IKONOS satellite which have been integrated to create a single surface. Products developed by the Pacific Islands Benthic Habitat Mapping Center.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Integrated_Methods/FeatureServer https://noaa.maps.arcgis.com/home/item.html?id=81ca60d083544a5eb6ccf8d993b20506
Lidar/Aerial	Guam and CNMI: Topobathy Lidar (NOAA NGS, 2019–2020)	X	X	Bathymetric lidar data footprints for Guam & CNMI (2019-2020). Source: NOAA Digital Coast Data Access Viewer, NOAA Office for Coastal Management (NOAA/OCM). Source link: https://coast.noaa.gov/dataviewer/#/lidar/search/	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Guam_CNMI_LIDAR/FeatureServer https://noaa.maps.arcgis.com/home/item.html?id=3cca4e18714745088870b1908e13bf77
Habitat Maps	Saipan Habitat Map Boundary (in progress, 2023)		X	Boundary of habitat map effort conducted by NOAA's NCCOS from 2020 to 2023 in Saipan. Final habitat map expected to be completed by January 2024.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Saipan_Habitat_Map_2023_Boundary/FeatureServer https://noaa.maps.arcgis.com/home/item.html?id=dee0771abb454762bef85fd72f2ca19c
	Guam Habitat Map Boundary (in progress, 2023)	X		Boundary of habitat map effort conducted by NOAA's NCCOS from 2020 to 2023 in Guam. Final habitat map expected to be completed early 2024.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Guam_Habitat_Map_2023_Boundary/FeatureServer https://noaa.maps.arcgis.com/home/item.html?id=d598f082c4934aa8aff1525d97c27565
	Saipan Lagoon Benthic Habitat (2016)		X	This composite habitat map for the Saipan lagoon is based on both remote sensing of satellite imagery and extensive field data from 2016	https://tiles.arcgis.com/tiles/qchgHH9IIeiivY5M/arcgis/rest/services/Saipan_Lagoon_Habitat_2016/MapServer
	Saipan Lagoon Benthic Habitat (2008)		X	Benthic habitat map of the Saipan Lagoon. Published by Houk et. al (2008)	https://services.arcgis.com/qchgHH9IIeiivY5M/arcgis/rest/services/Saipan_Lagoon_Benthic_Habitat/FeatureServer/0
	Guam BioMapper–Structure (2005)		X	Fourteen distinct and non-overlapping geomorphological structure types were identified that could be mapped by visual interpretation of the IKONOS imagery. Habitats or features that cover areas smaller than the MMU were not considered.	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BenthicMapping_BenthicHabitats/MapServer/35
	Guam BioMapper–Zone (2005)	X		Thirteen mutually exclusive zones were identified from land to open water corresponding to typical insular shelf and coral reef geomorphology. Zone refers only to each benthic community's location and does not address substrate or cover types within.	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BenthicMapping_BenthicHabitats/MapServer/36
	Guam BioMapper–Biological Cover (2005)	X		Eighteen distinct and non-overlapping biological cover types were identified that could be mapped through visual interpretation of the IKONOS imagery. Cover type refers only to predominate biological component colonizing the surface of the feature and does not address location (e.g., on the shelf or in the lagoon).	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BenthicMapping_BenthicHabitats/MapServer/34
	CNMI BioMapper–Structure (2005)		X	Fourteen distinct and non-overlapping geomorphological structure types were identified that could be mapped by visual interpretation of the IKONOS imagery. Structure refers only to predominate physical structural composition of the feature and does not address location (e.g., on the shelf or in the lagoon).	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BenthicMapping_BenthicHabitats/MapServer/29
	CNMI BioMapper–Zone (2005)		X	Thirteen mutually exclusive zones were identified from land to open water corresponding to typical insular shelf and coral reef geomorphology. Zone refers only to each benthic community's location and does not address substrate or cover types within.	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BenthicMapping_BenthicHabitats/MapServer/30
	CNMI BioMapper–Biological Cover (2005)		X	Eighteen distinct and non-overlapping biological cover types were identified that could be mapped through visual interpretation of the IKONOS imagery.	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BenthicMapping_BenthicHabitats/MapServer/28

Table A.1. Data inventory for Guam and the CNMI continued.

Category	Item Name	Guam	CNMI	Description	Map Service URL
Boundaries	40-Meter Bathymetric Contour of Guam and CNMI	X	X	Fourty meter depth contour of Guam and Commonwealth of Northern Mariana Islands (CNMI) created using 2020 Lidar, 2007 Multibeam, and charted sounding data from NOAA's Office of Coast Survey (Farallon de Medinilla only).	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/40_Meter_Bathymetric_Contour_of_Guam_and_CNMI/FeatureServer\ https://noaa.maps.arcgis.com/home/item.html?id=405b1854d6974bc89706a9ff86456e6c
	NOAA's Marine Protected Areas Inventory	X	X	The NOAA MPA Inventory (v2023) is a comprehensive catalog that provides detailed information for existing marine protected areas in the United States. The inventory provides geospatial boundary information (in polygon format) and classification attributes that seek to define the conservation objectives, protection level, governance and related management criteria for all sites in the database.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/NOAA_MPA_Inventory_2023/FeatureServer/0
Points	RICHARD Coral Reef Assessment Dive Sites (2022)	X	X	Benthic survey sites from the RICHARD expedition.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/RICHARD_Benthic_Survey_Sites/FeatureServer/0
	Saipan Marine Sports Activity Locations		X	Map layers that decsribe various permitted marine sports activities in Saipan.	https://services.arcgis.com/qchgHH9IIeiivY5M/arcgis/rest/services/MarineSportsPermitting/FeatureServer
Other	CNMI Shallow Coral Mapping Prioritization Grid (2023)		X	Empty grid cell layer for the 2023 CNMI Coral Reef Mapping Prioritization. Each cell is 1 km in length per side (2.6 km^2 per grid cell).	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/CNMI_Prioritization_Grid/FeatureServer https://noaa.maps.arcgis.com/home/item.html?id=842bfa8a9a394115a7aaea2813c47c18
	Guam Shallow Coral Mapping Prioritization Grid (2023)	X		Empty grid cell layer for the 2023 Guam Coral Reef Mapping Prioritization. Each cell is 1 km in length per side (2.6 km^2 per grid cell).	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Guam_Prioritization_Grid/FeatureServer https://noaa.maps.arcgis.com/home/item.html?id=83f2d3d9c1ca4646831457f7b84a52fb
	Coral Recovery Geographic Data (Management, Threats, Geopolitical)			Within the map users can find data representing biogeographic , threats, geopolitical and existing management information regarding the targeted coral species. Data was sourced from a literature review and subject experts for incorporation into the project. Data has not been modified from its original source unless mentioned within the individual datasets metadata.	https://noaa.maps.arcgis.com/apps/webappviewer/index.html?id=556f4605cf474437a294310010eee2fb

Appendix B. Guam: Individual Maps for Each Management Use

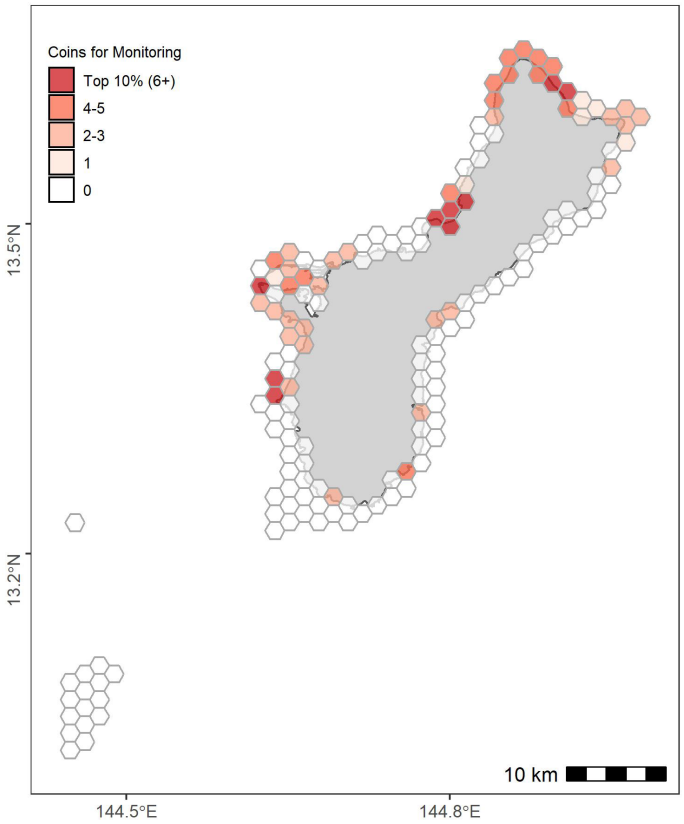


Figure B.1. Map of coins distributed for the Management Use *Monitoring*.

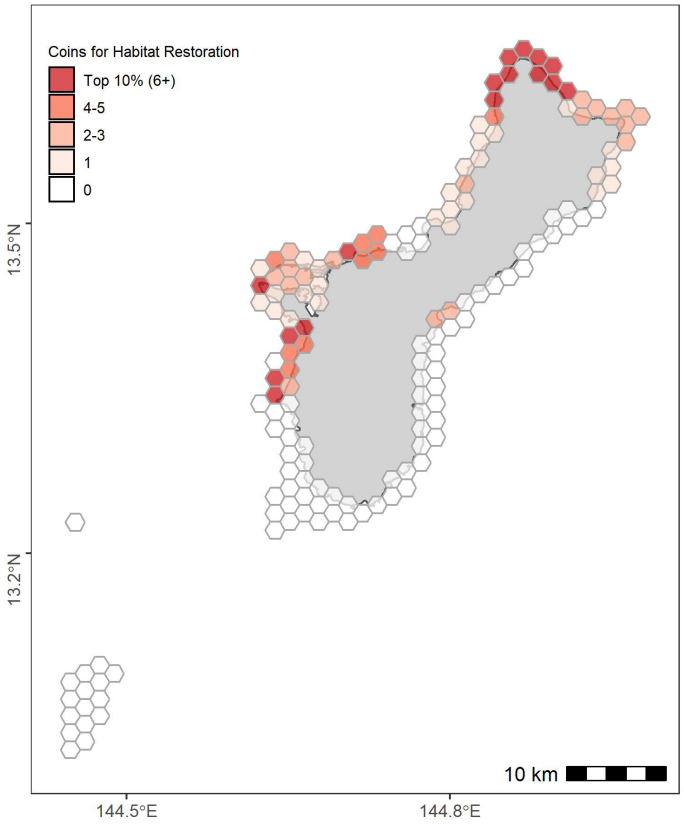


Figure B.2. Map of coins distributed for the Management Use *Habitat Restoration*.

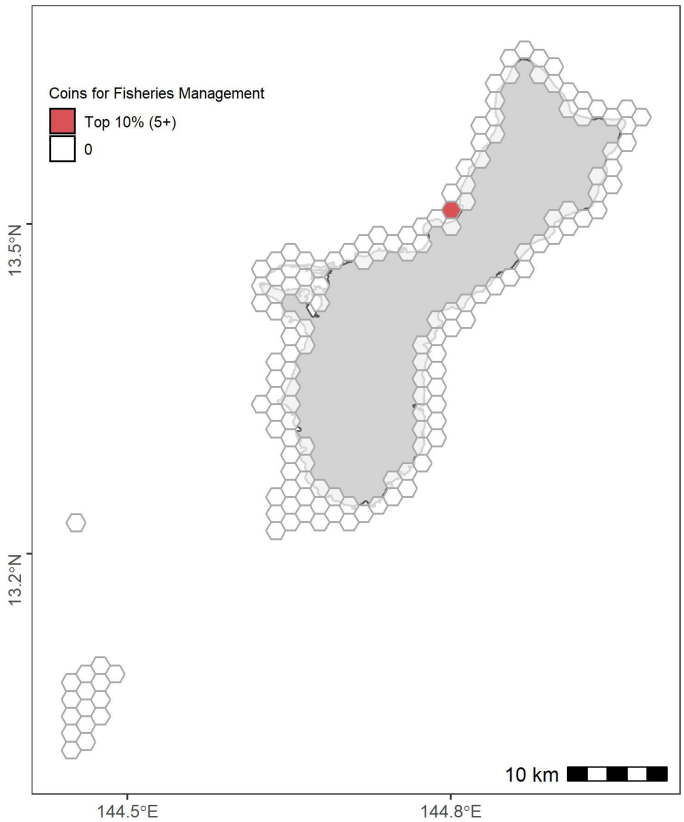


Figure B.3. Map of coins distributed for the Management Use *Fisheries Management*.

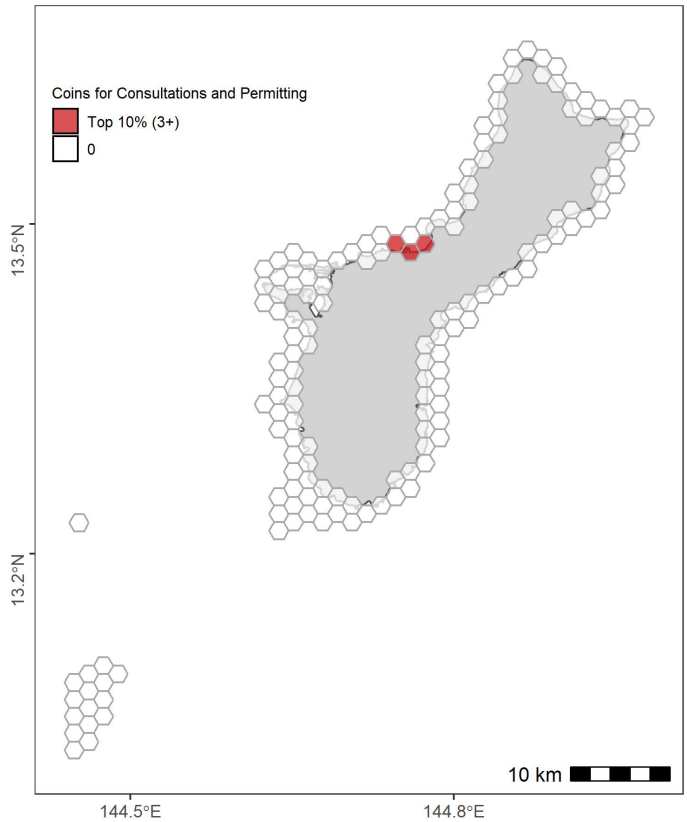


Figure B.4. Map of coins distributed for the Management Use *Consultations and Permitting*.

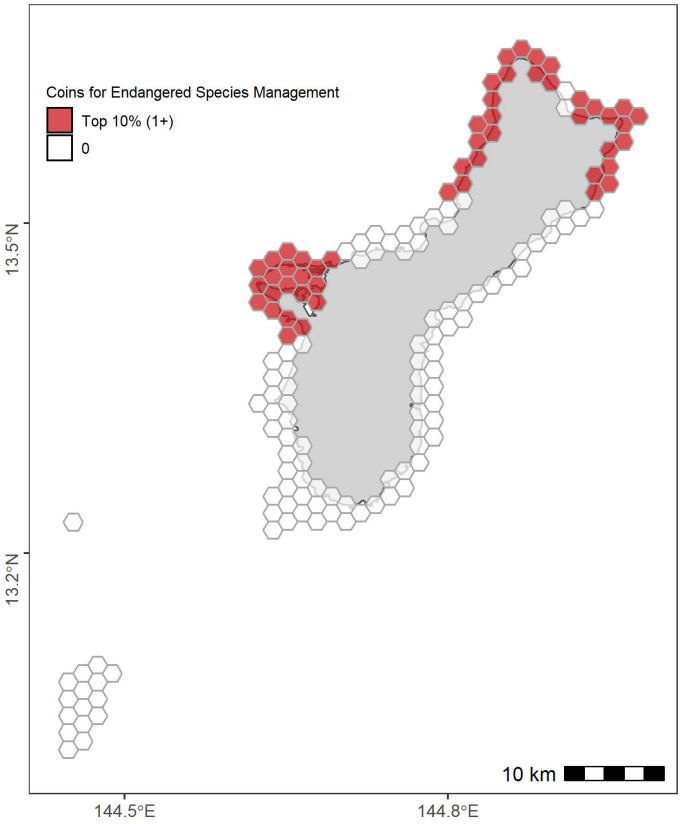


Figure B.5. Map of coins distributed for the Management Use *Endangered Species Management*.

Figure B.6. Map of coins distributed for the Management Use *Coastal Vulnerability and Planning*.

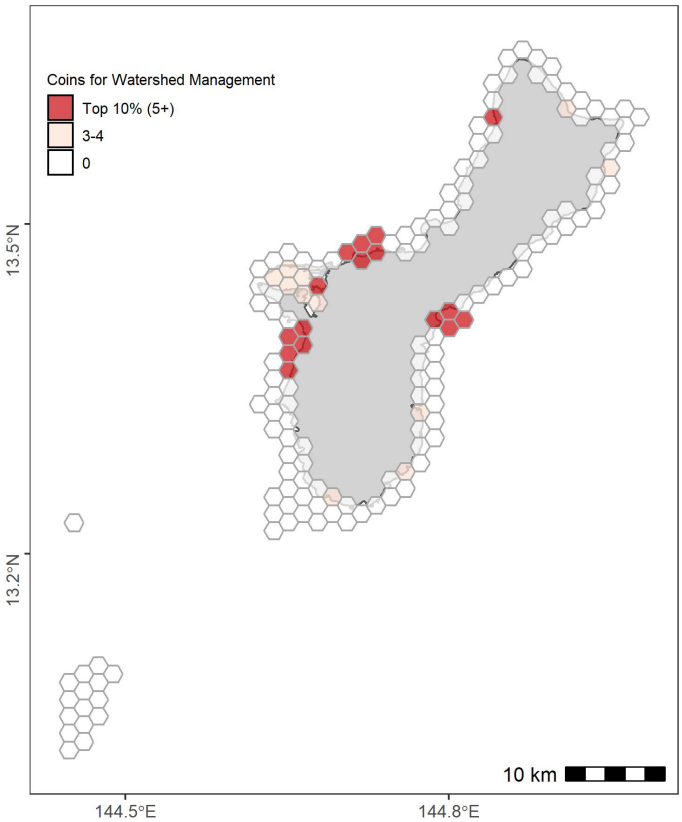


Figure B.7. Map of coins distributed for the Management Use *Watershed Management*.

Figure B.8. Map of coins distributed for the Management Use *Emergency Response*.

Appendix C. Guam: Individual Maps for Each Product Requirement

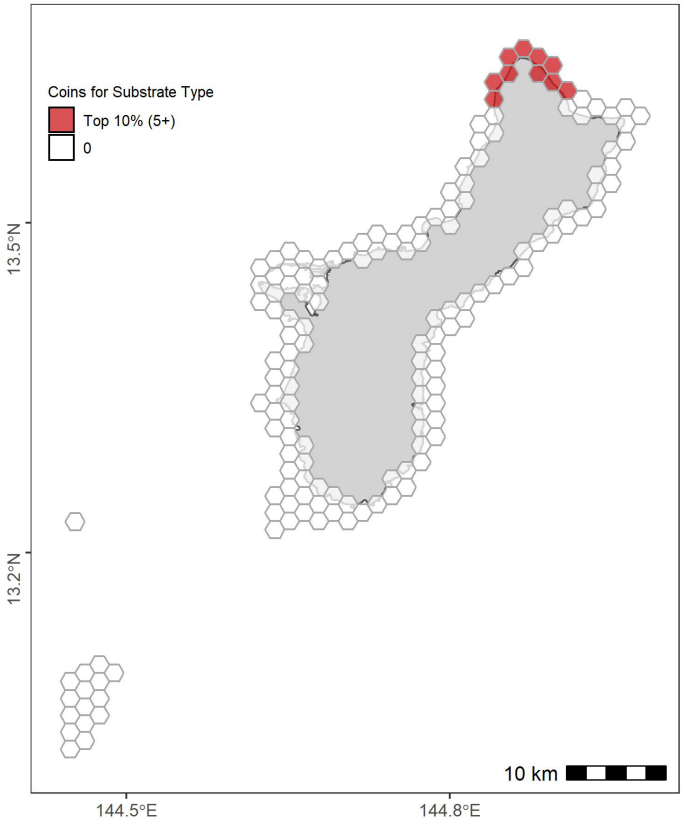


Figure C.1. Map of coins distributed for the Product Requirement *Substrate Types*.

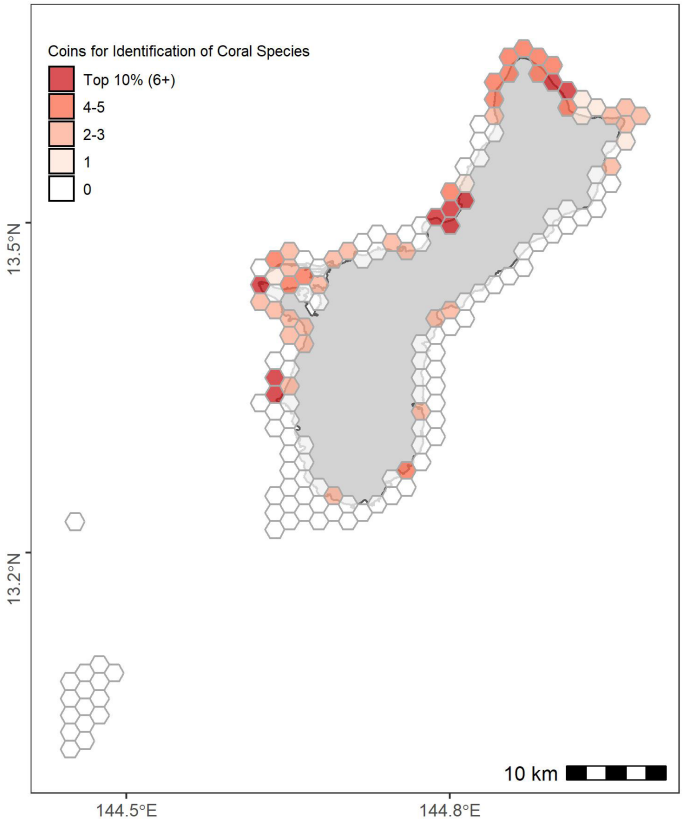


Figure C.2. Map of coins distributed for the Product Requirement *Identification of Coral Species*.

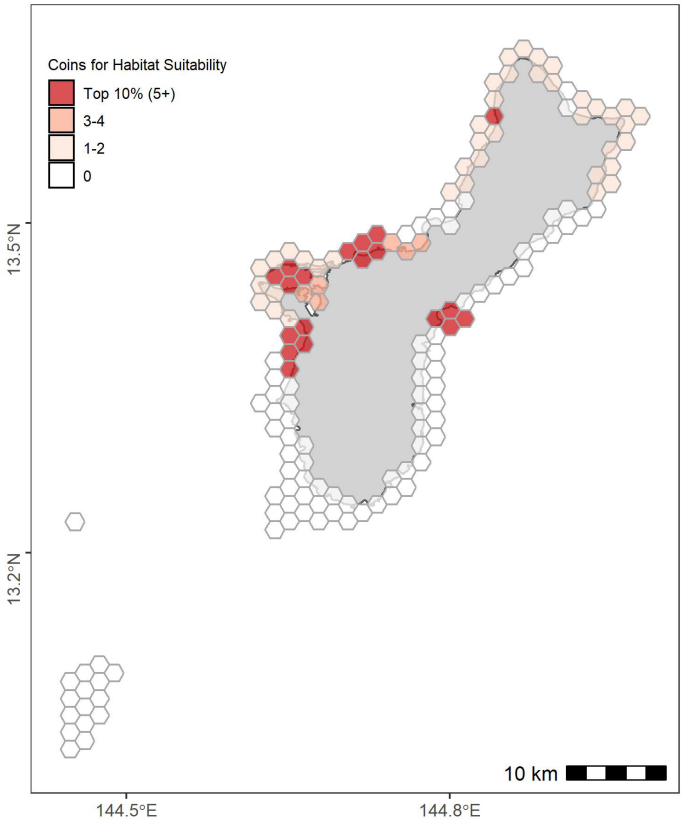


Figure C.3. Map of coins distributed for the Product Requirement *Habitat Suitability*.

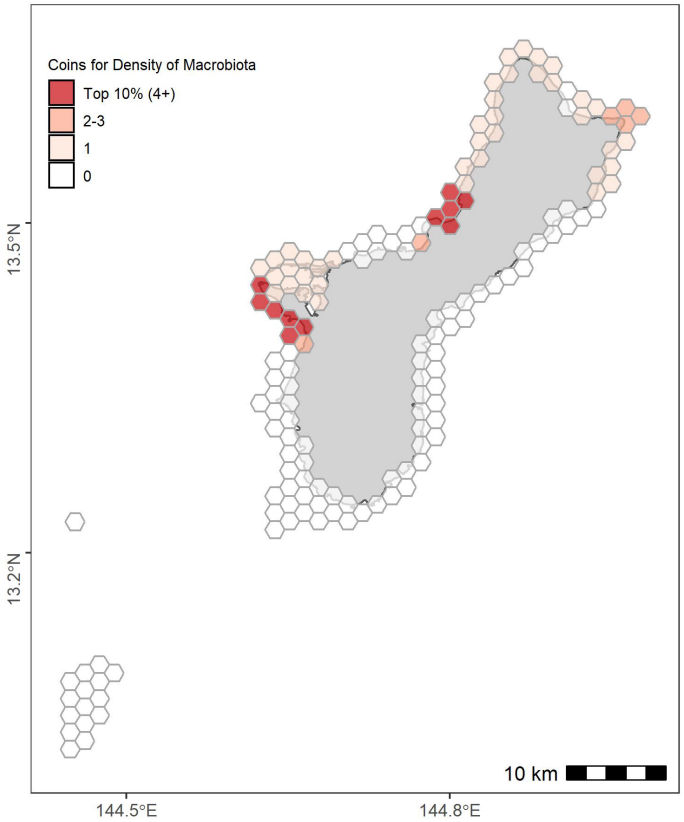


Figure C.4. Map of coins distributed for the Product Requirement *Density of Macrobiota*.

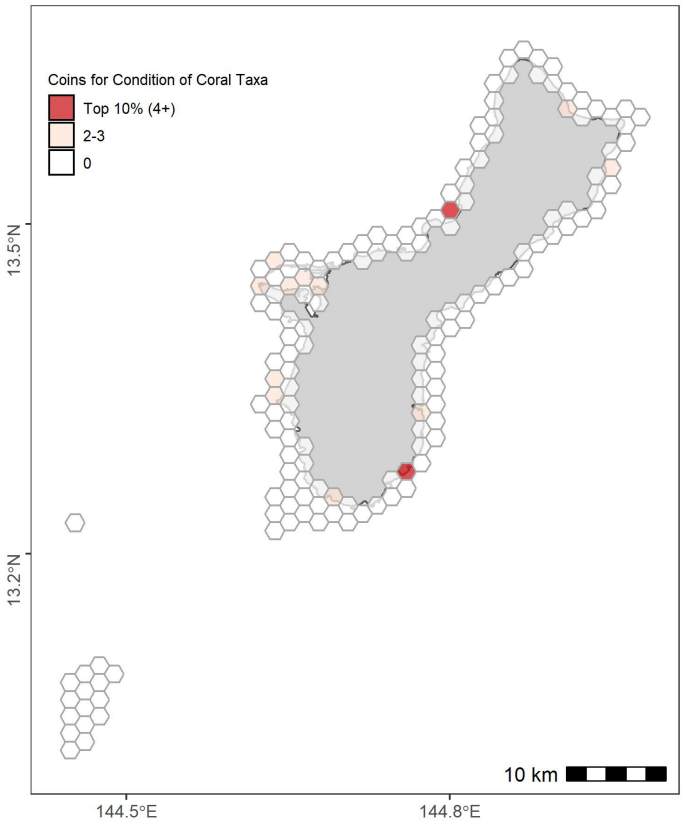


Figure C.5. Map of coins distributed for the Product Requirement *Condition of Coral Taxa*.

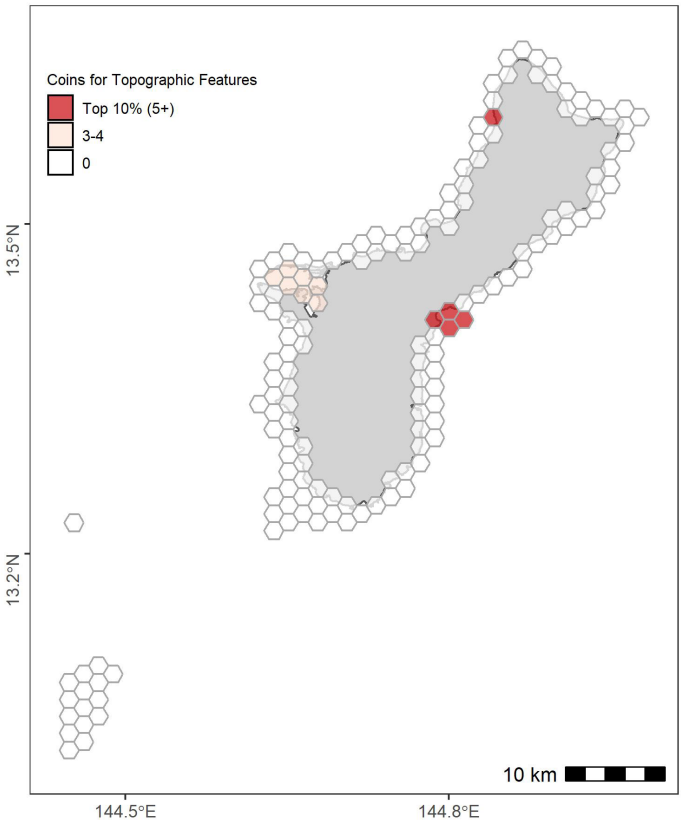


Figure C.6. Map of coins distributed for the Product Requirement *Topographic Features*.

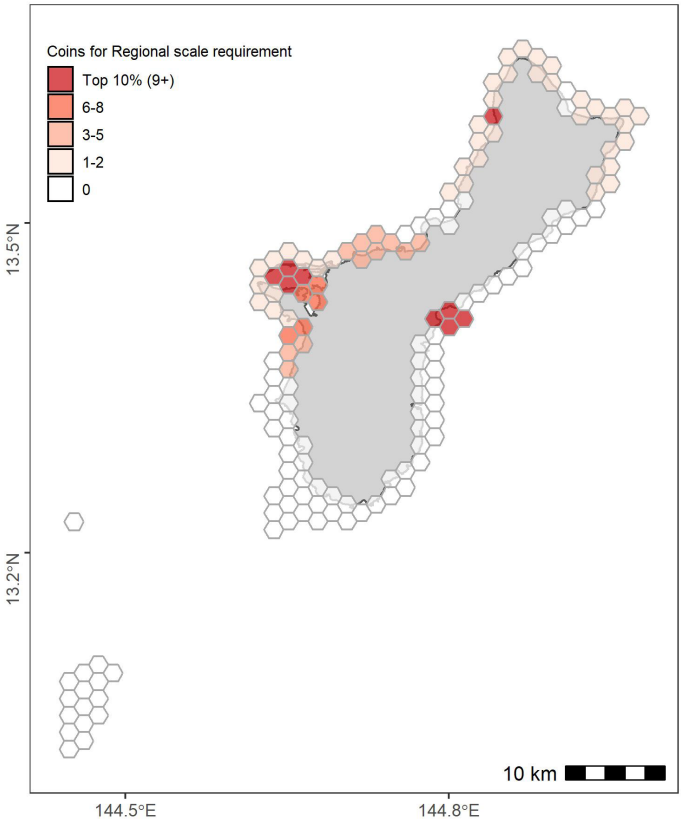


Figure C.7. Map of coins distributed for *Regional Scale* Product Requirements.

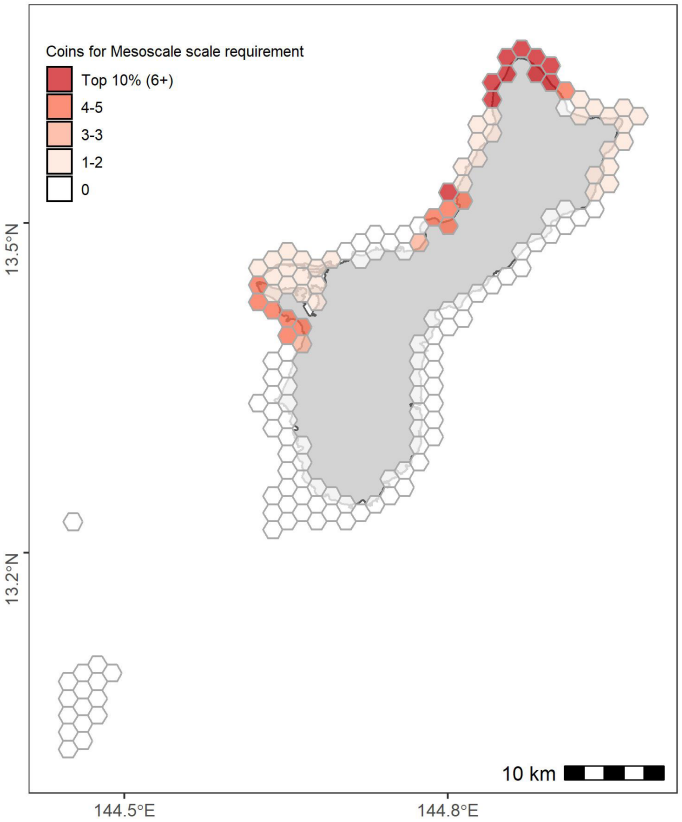


Figure C.8. Map of coins distributed for *Mesoscale* Product Requirements.

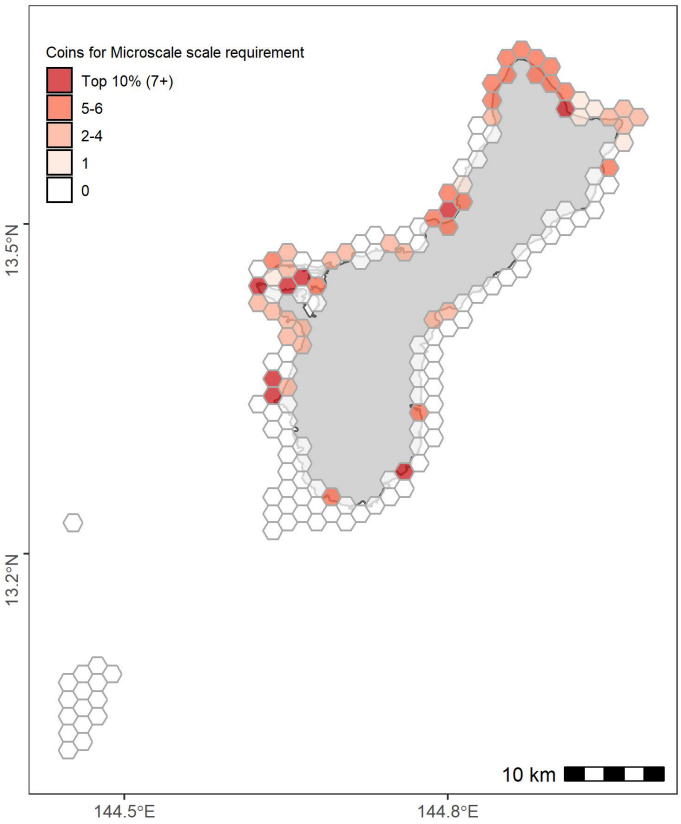


Figure C.9. Map of coins distributed for *Microscale* Product Requirements.

Appendix D. CNMI: Individual Maps for Each Management Use

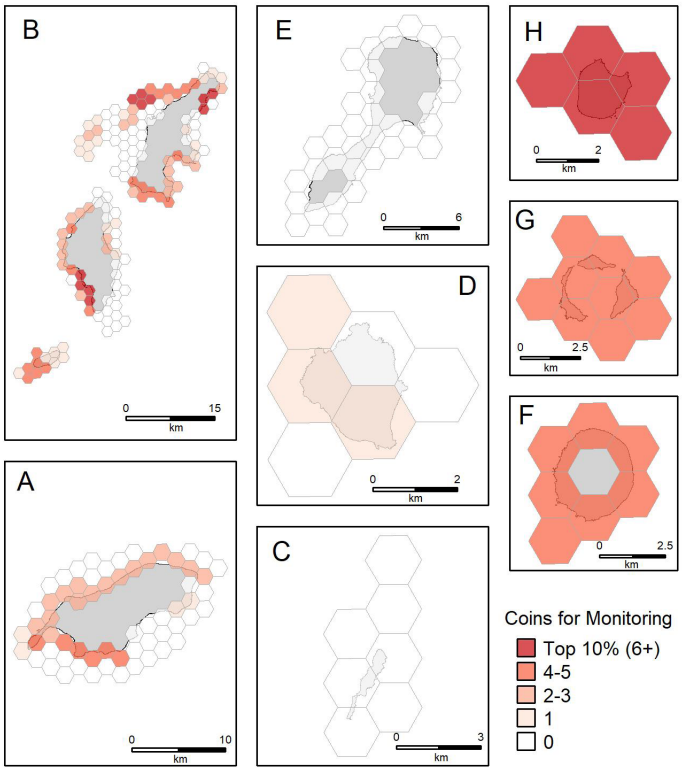


Figure D.1. Map of coins distributed for the Management Use *Monitoring*.

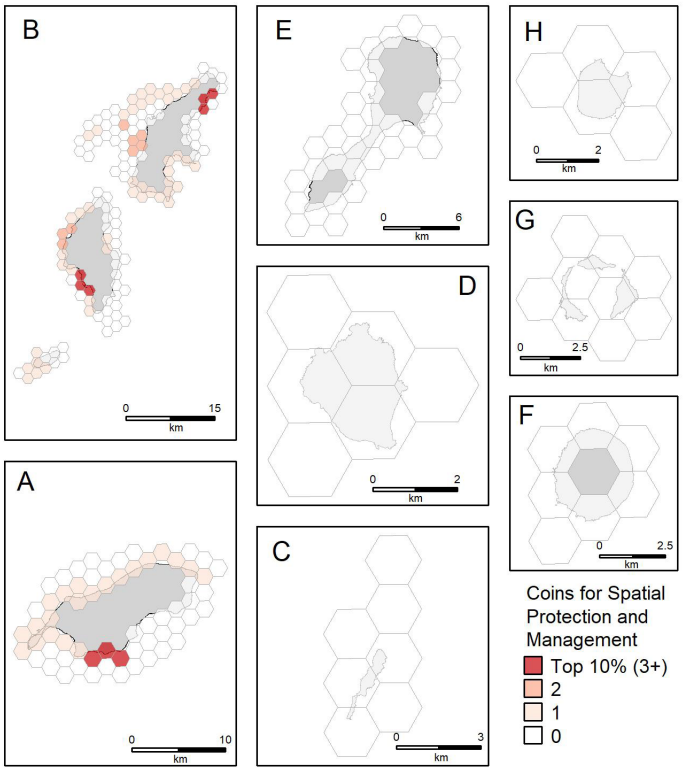


Figure D.2. Map of coins distributed for the Management Use *Spatial Protection and Management*.

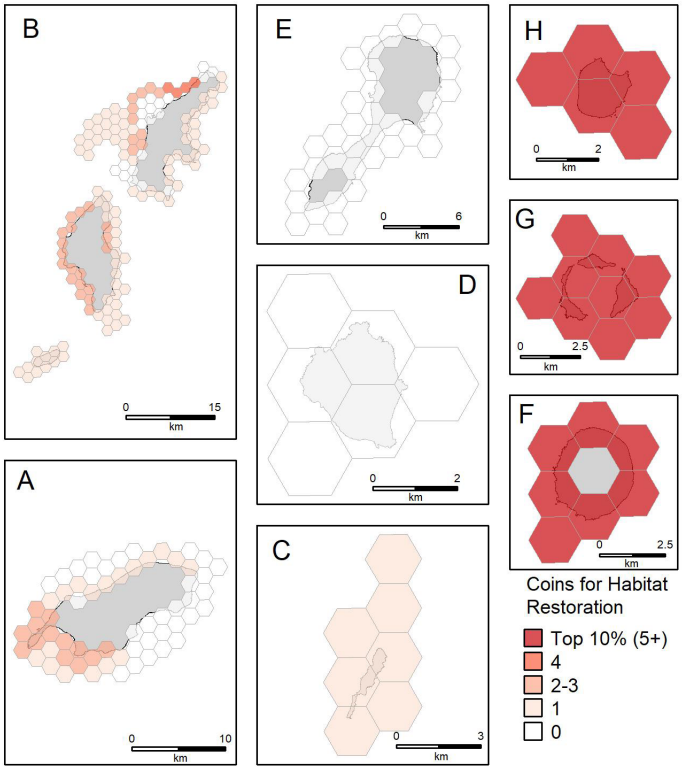


Figure D.3. Map of coins distributed for the Management Use *Habitat Restoration*.

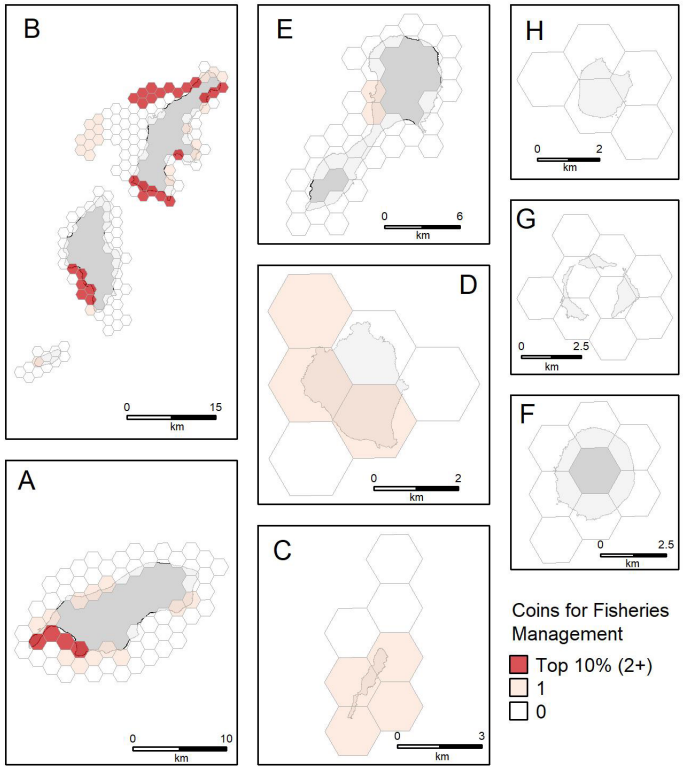


Figure D.4. Map of coins distributed for the Management Use *Fisheries Management*.

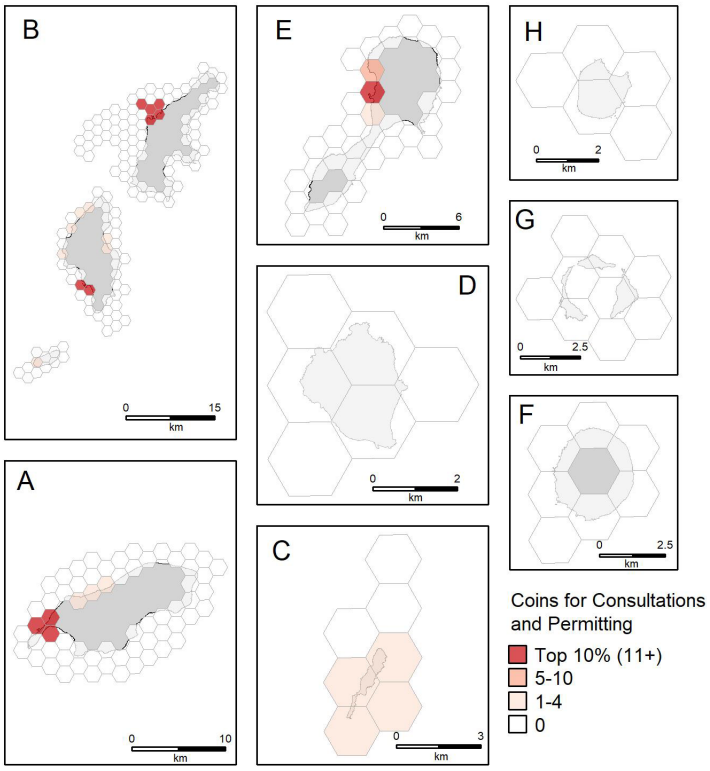


Figure D.5. Map of coins distributed for the Management Use *Consultations and Permitting*.

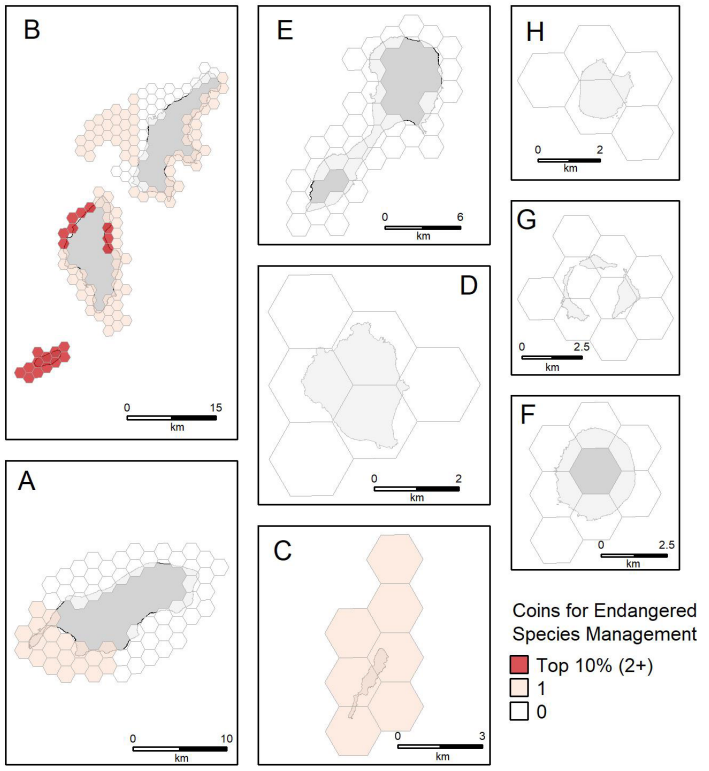


Figure D.6. Map of coins distributed for the Management Use *Endangered Species Management*.

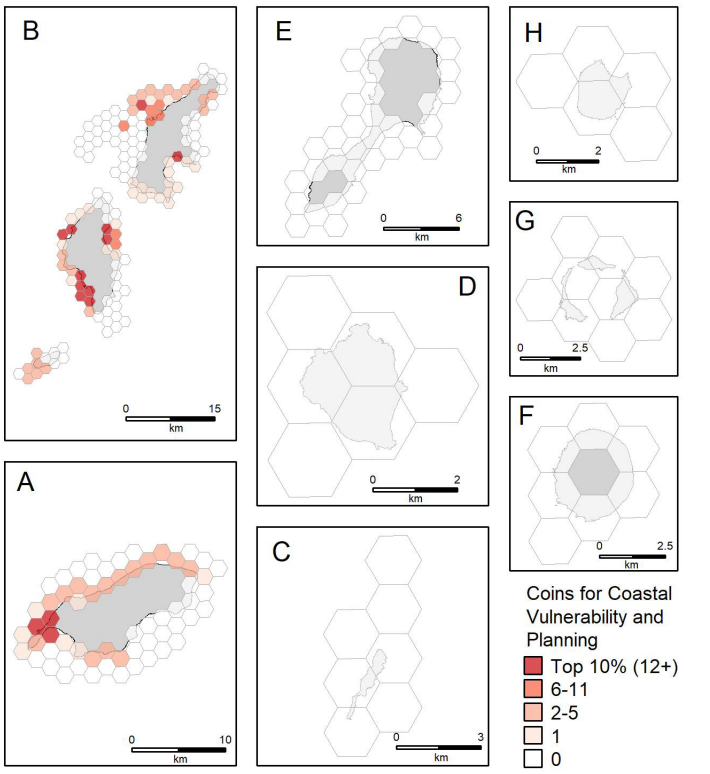


Figure D.7. Map of coins distributed for the Management Use *Coastal Vulnerability and Planning*.

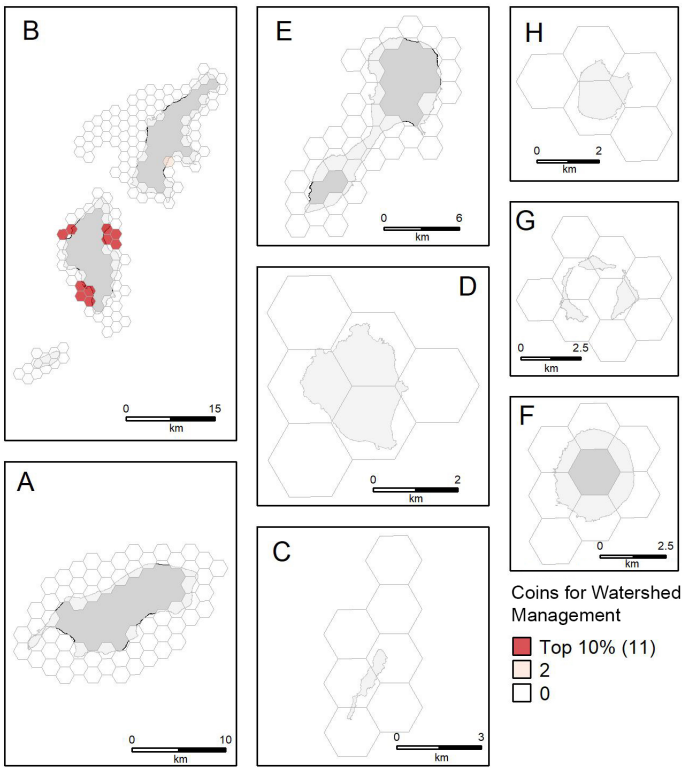


Figure D.8. Map of coins distributed for the Management Use *Watershed Management*.

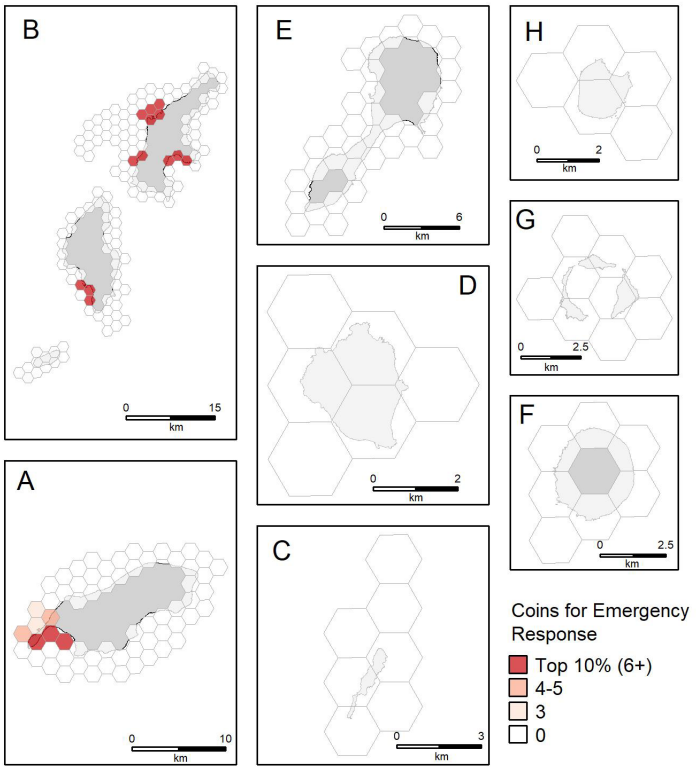


Figure D.9. Map of coins distributed for the Management Use *Emergency Response*.

Appendix E. CNMI: Individual Maps for Each Product Requirement

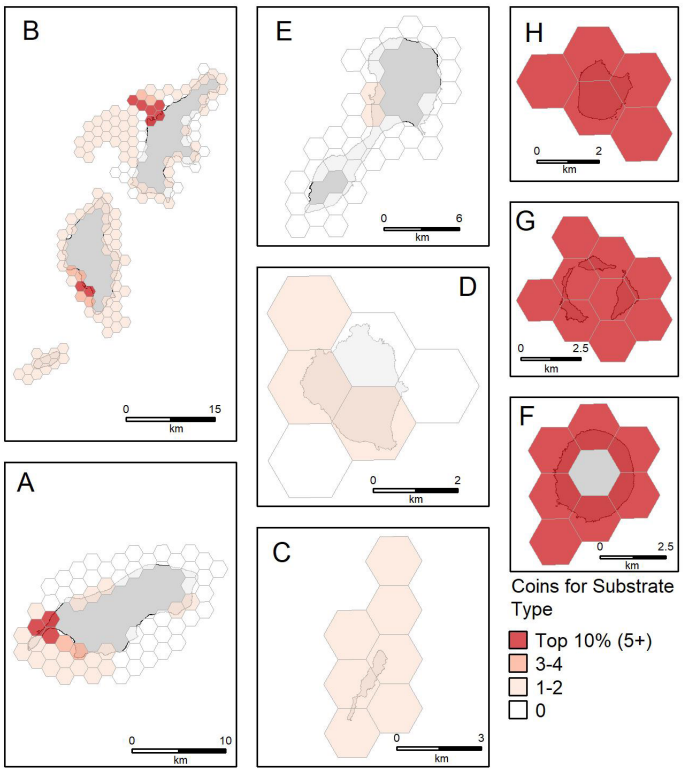


Figure E.1. Map of coins distributed for the Product Requirement *Substrate Types*.

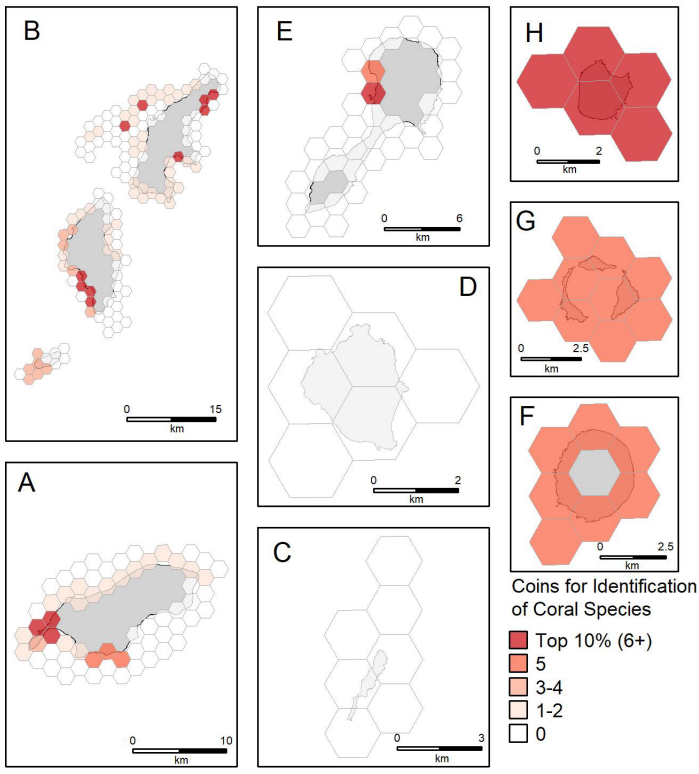


Figure E.2. Map of coins distributed for the Product Requirement *Identification of Coral Species*.

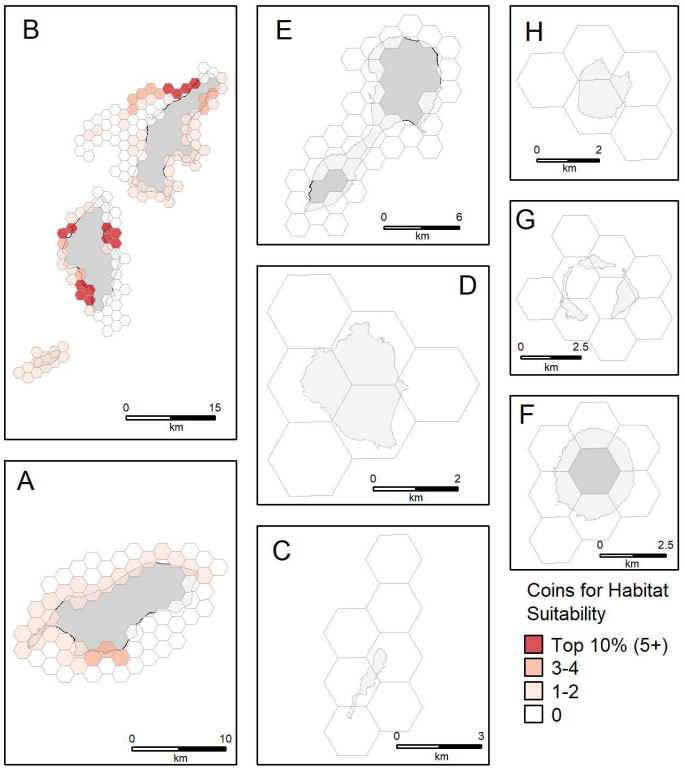


Figure E.3. Map of coins distributed for the Product Requirement *Habitat Suitability*.

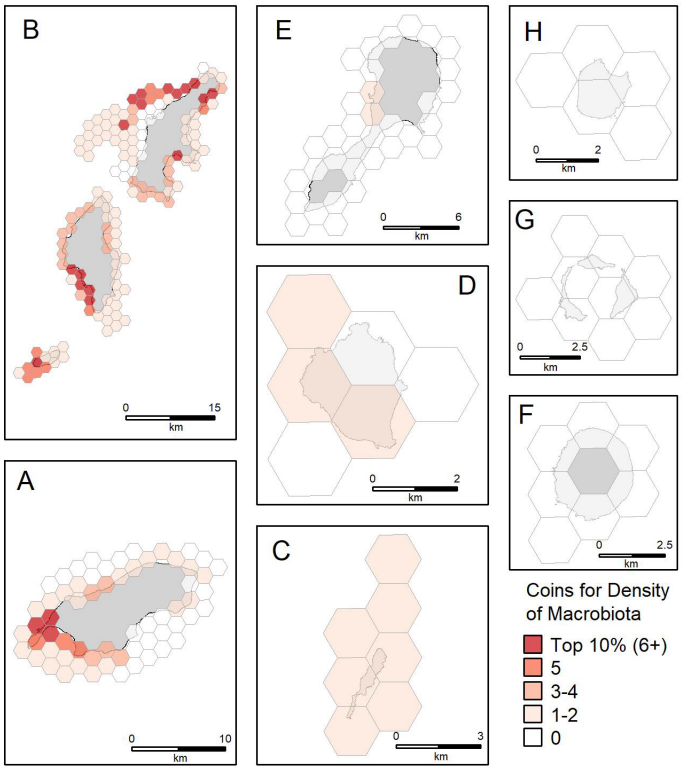


Figure E.4. Map of coins distributed for the Product Requirement *Density of Macrobiota*.

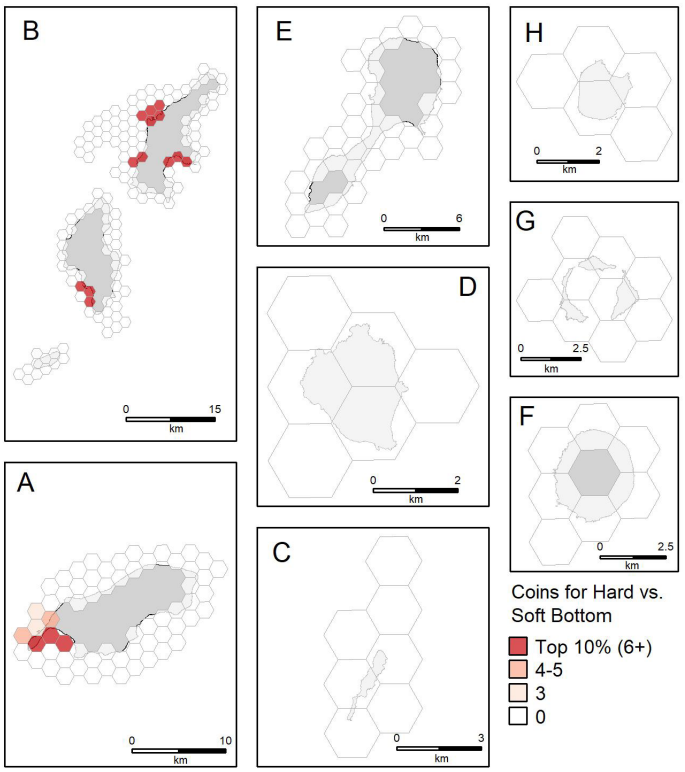


Figure E.5. Map of coins distributed for the Product Requirement *Hard vs. Soft Bottom*.

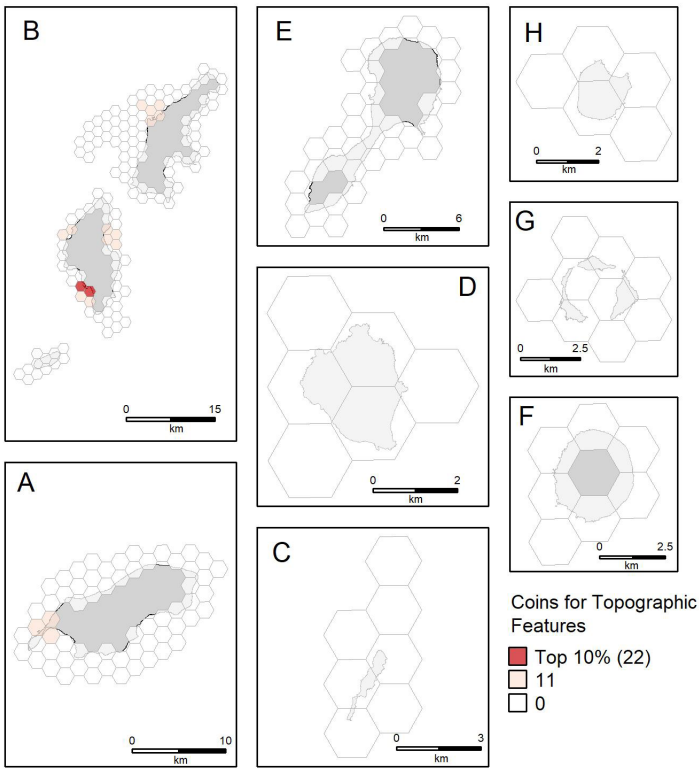


Figure E.6. Map of coins distributed for the Product Requirement *Topographic Features*.

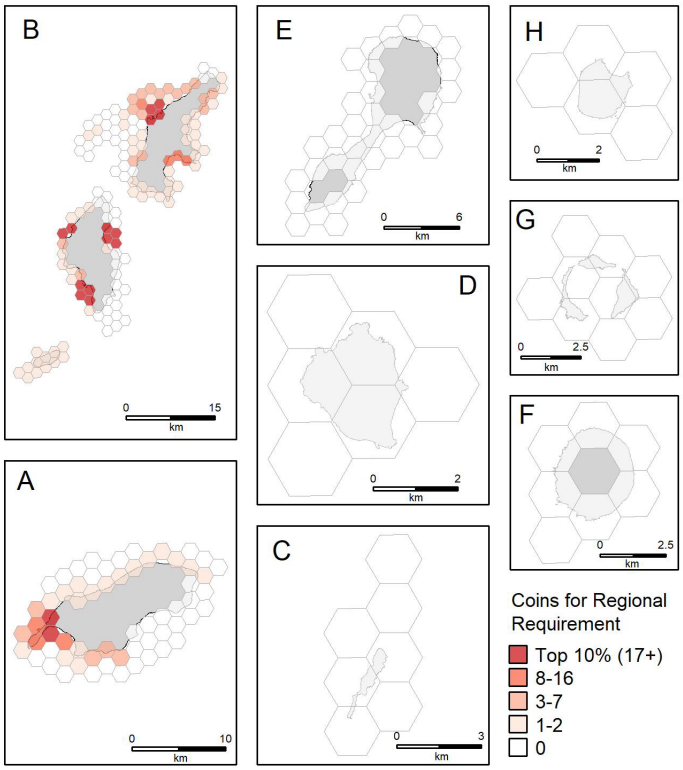


Figure E.7. Map of coins distributed for *Regional Scale* Product Requirements.

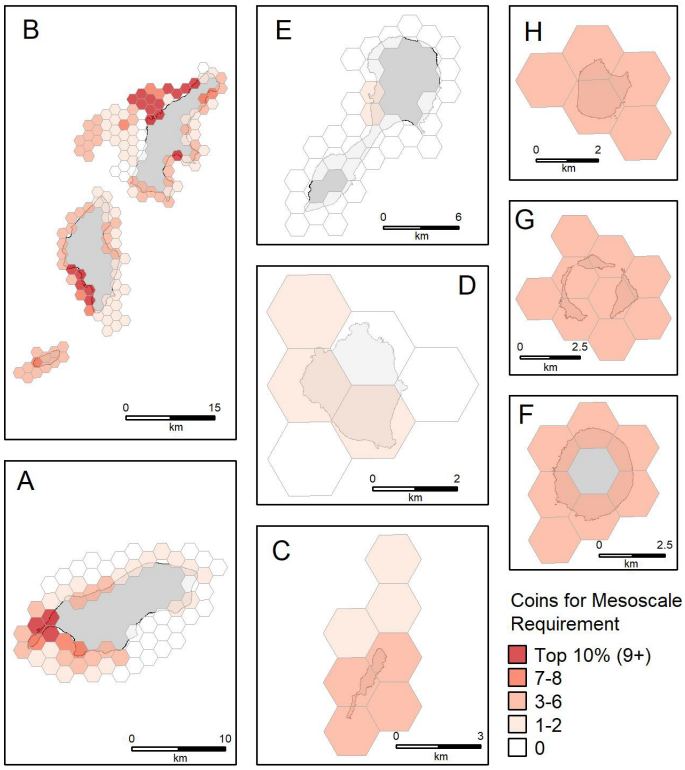


Figure E.8. Map of coins distributed for *Mesoscale* Product Requirements.

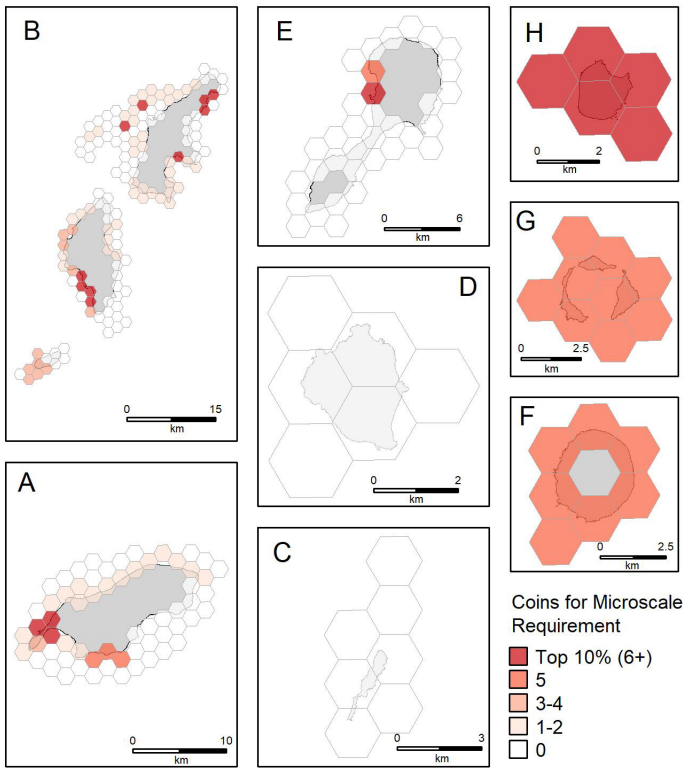


Figure E.9. Map of coins distributed for *Microscale* Product Requirements.

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

National Oceanic and Atmospheric Administration
Richard W. Spinrad, Ph.D., *Under Secretary for Oceans and Atmosphere*

National Ocean Service
Nicole LeBoeuf, *Assistant Administrator for National Ocean Service*

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