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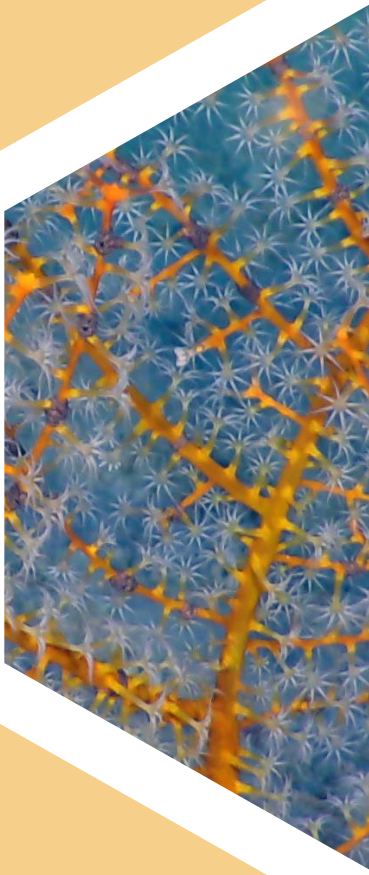
AGENCY PRIORITIES FOR MAPPING CORAL REEF ECOSYSTEMS IN PUERTO RICO AND THE U.S. VIRGIN ISLANDS



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For more information on this project, please visit:
https://us-shallow-coral-reef-mapping-priorities-noaa.hub.arcgis.com/

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Agency Priorities for Mapping Coral Reef Ecosystems in Puerto Rico and the U.S. Virgin Islands

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NOAA NOS NCCOS TECHNICAL MEMORANDUM 305

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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 identified the need for current priority locations based on emerging management requirements in coral reef areas up to 40 meters deep along the coasts of Puerto Rico and the U.S. Virgin Islands (USVI).

To meet this need, NOAA's National Centers for Coastal Ocean Science (NCCOS) developed a systematic, quantitative approach and online 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 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 requirements.

Participants input their mapping priorities for Puerto Rico (n=18) and the USVI (n=20) jurisdictions using an online tool. For both jurisdictions, participating groups included a range of partners such as fishery management councils, federal, state, territorial and municipal government agencies, nongovernmental organizations, and academia. The most commonly selected Management Use options in Puerto Rico were *Spatial Protection/Management* and *Monitoring*. In USVI, *Habitat Restoration* and *Spatial Protection/ Management* were the top choices. The top Map Product Requirement options revealed three main desired data types in both Puerto Rico and the USVI: *Substrate Types*, *Identification of Coral Species*, and *Habitat Suitability*. To further explore areas of high interest and need by participants, clusters of top ranking cells (based on total number of coins, number of participating groups, and number of unique Management Uses), or focal areas, were identified for each region. In Puerto Rico, four focal areas were identified: 1) Arecibo, 2) Ensenada and Guánica, 3) Humacao, and 4) northwest Sonda de Vieques. In the USVI, three focal areas were identified: 1) shelf off northwest of Saint Thomas (Cockroach Island and Dutchcap Pass), 2) northwest St. Croix, and 3) east St. Croix. These focal areas were of interest to participants for various reasons such as filling data gaps to support coral restoration efforts, and update existing data to help manage watersheds along a rapidly developing coastline. Overlapping participant interests highlight some of the best opportunities for collaboration, with the potential to satisfy a variety of coral management goals.

This report and interactive online maps provide a critical spatial framework for prioritizing mapping efforts in shallow coral reef ecosystems of Puerto Rico and the USVI. Results from the prioritization needs assessment are summarized and shared in this report. Summary results and an inventory of existing mapping data for Puerto Rico, USVI, and other completed jurisdictions are available at: https://us-shallow-coral-reef-mapping-priorities-noaa.hub.arcgis.com/.

Coral reef habitat in St. Croix, U.S. Virgin Islands (USVI). Credit: NOAA NCCOS

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 0–40 meters depth in all seven of the U.S. coral reef management jurisdictions (Figure 1). During Fiscal Year 2022, this activity was focused on shallow coral reef areas off the coast of Puerto Rico and the U.S. Virgin Islands (USVI).

Prioritization results directly support CRCP's four focus areas of their strategic plan: 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 identify locations of mutual interest, improve leveraging of mapping expertise and resources, and identify potential partnerships for future mapping efforts.

Coral in St. Croix, USVI. Credit: NOAA NCCOS

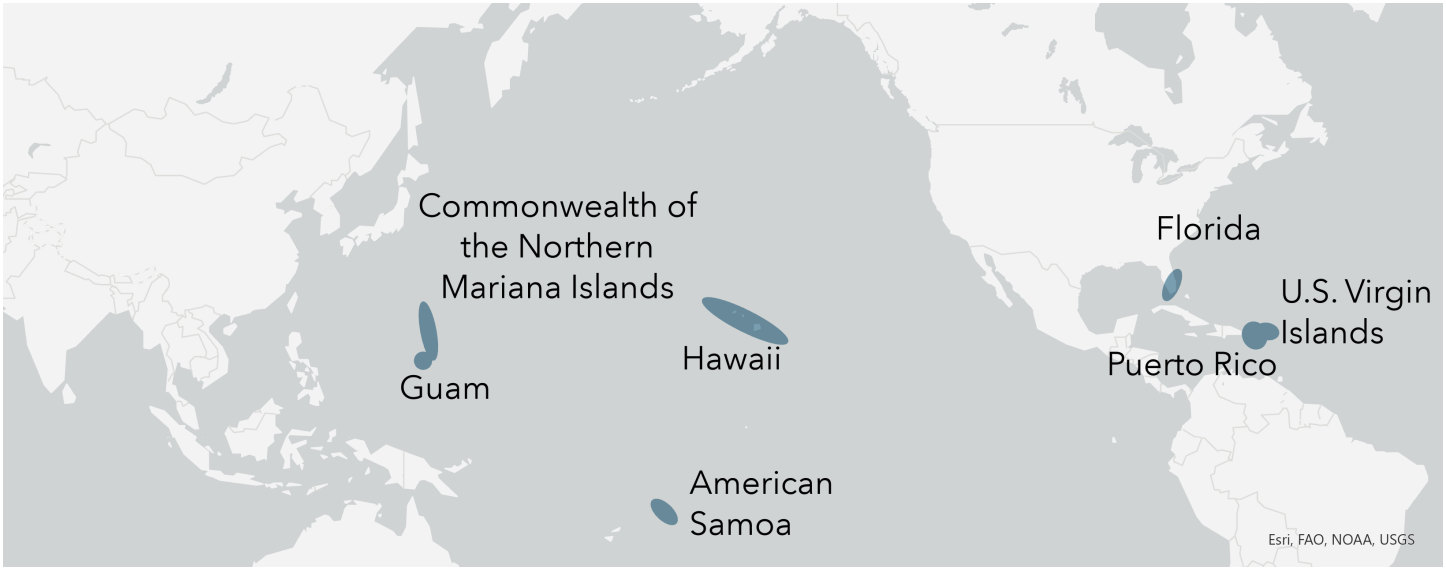


Figure 1. The seven U.S. coral reef jurisdictions that are the focal areas of this project.

Chapter 2 Methods

2.1 Advisory Team and Participating Groups

The technical advisory team (TAT) consisted of two representatives from CRCP, two Puerto Rico liaisons, and two USVI liaisons from local NOAA offices (National Marine Fisheries Service [NMFS] and CRCP). 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 potential participants was created and approved by the TAT. This list included contacts from federal, state, territorial, and municipal government agencies, nongovernmental organizations, and academia who use mapping data to inform coral reef management in Puerto Rico and/or the USVI.

Participating groups had various levels of expertise related to coral reef management including mapping, conservation, fisheries, and habitat classification (Table 1). Some participants were the sole expert and respondent for their group, whereas others consulted with colleagues to input a collaborative mapping need. Additionally, some participating groups had multiple experts with unique inputs and therefore were allowed to give separate responses (results were averaged for these groups).

Table 1. List of groups who were contacted to provide their coral reef mapping priorities. Each group was requested to provide a point of contact who would input their collective needs. Invited groups include federal, state, academic, and non-governmental organization (NGO). "X" indicates that group participated in coin allocation for that jurisdiction.

Participating Groups	*Acronym*	*Type*	*Puerto Rico*	*USVI*
Coastal Survey Solutions	CSS	NGO	X	
Environmental Protection Agency	EPA	Federal	X	X
National Park Service	NPS	Federal		X
NOAA National Centers for Coastal Ocean Science	NCCOS	Federal	X	X
NOAA National Coral Reef Monitoring Program	NCRMP	Federal	X	X
NOAA Caribbean Fisheries Management Council	CFMC	Federal	X	X
NOAA Restoration Center	RC	Federal	X	X
NOAA Southeast Fisheries Science Center	SEFSC	Federal	X	X
NOAA Southeast Regional Office	SERO	Federal	X	X
NOAA Office for Coastal Management	OCM	Federal		X
NOAA Office of Coast Survey	OCS	Federal	X	X
Pew Research Center	PEW	NGO	X	X
Puerto Rico Department of Environmental & Natural Resources	DNER	State	X	
The Nature Conservancy	TNC	NGO	X	X
U.S. Geological Survey	USGS	Federal	X	X
U.S. Army Corps of Engineers	USACE	Federal	X	X
U.S. Virgin Islands Department of Planning & Natural Resources – Division of Fish and Wildlife	DPNR-DFW	State		X
U.S. Virgin Islands Department of Planning & Natural Resources – Coastal Zone Management	DPNR-CZM	State		X
University of Puerto Rico	UPR	Academic	X	
University of Virgin Islands	UVI	Academic		X

The following groups or agencies were contacted but were unable to provide input: NOAA Atlantic Oceanographic and Meteorological Laboratory, Federal Emergency Management Agency (FEMA), HJR Reefscaping, Protectores de Cuencas, Ridge to Reefs, and Sociedad Ambiente Marino.

2.2 Develop Prioritization Framework and Online Application

2.2.1 Spatial Framework

The Puerto Rico project area (Figure 2) extended around the archipelago, including the Islands of Mona, Desecheo, Culebra, and Vieques. The USVI project area (Figure 3) included the islands of St. Croix, St. Thomas, and St. John. For both jurisdictions, the geographic area was 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 a manageable number of total cells to choose from. The hexagonal grid shape was chosen to conform more easily to the curved 40-m contour and coastline.

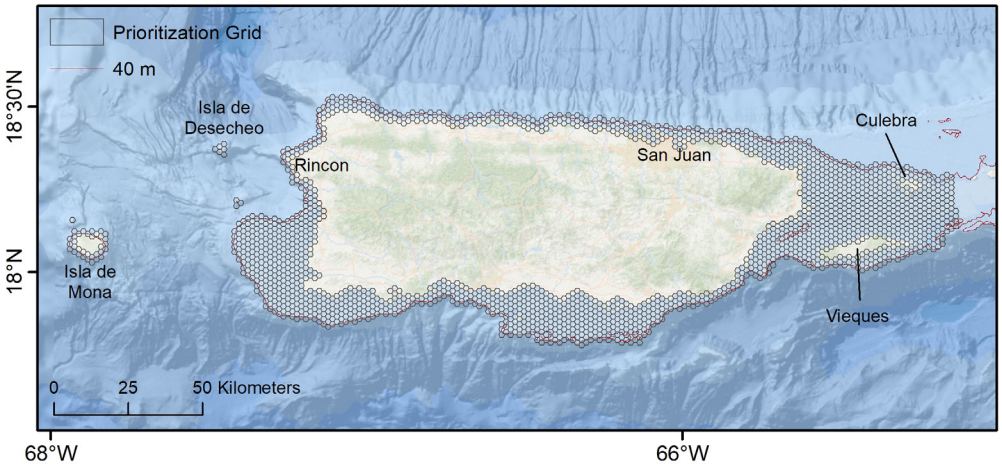


Figure 2. The hexagonal grid (1 km per side with total area of 1 mi^2 or 2.6 km^2) used for the Puerto Rico prioritization. The 40-m contour was used as the maximum depth for this prioritization effort.

2.2.2 Existing Data

Existing seafloor mapping data were compiled and provided as background data to help participants understand the extent of current information, locate data gaps, and identify areas to prioritize for future data collections. These data included various types of seafloor mapping data (e.g., multibeam, lidar) noting extent and resolution, results from a previous prioritization effort (Kraus et al., 2020), political and administrative boundaries (e.g., federal/state waters, marine protected areas), and benthic habitat maps. These datasets and web map services were published in a publicly available online web map and provided background data for the spatial prioritization application. See Appendix A for a reference list of map services included in the inventory.

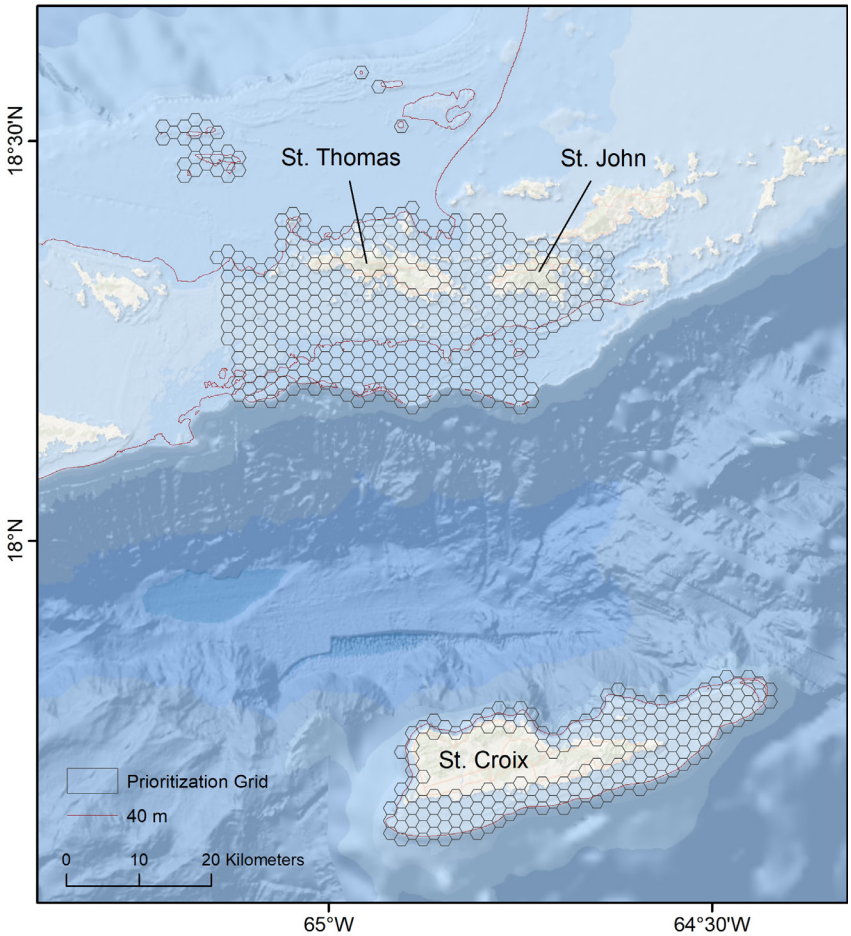


Figure 3. The hexagonal grid (1 km per side with total area of 1 mi^2 or 2.6 km^2) used for the U.S. Virgin Islands (USVI) prioritization. The 40-m contour was used as the maximum depth for this prioritization effort.

2.2.3 Spatial Prioritization Application

Participant needs 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 created using Esri's Web AppBuilder. The customized spatial prioritization widget is an online graphical user interface for participants to enter their priorities using 'virtual coins' and select from customized pull-down menus to record specific data needs. Development and use of the widget are detailed in Buja and Christensen (2019) and it has been utilized in a variety of regions including Florida's Coral Reef Ecosystems (Kraus et al., 2022a), U.S. Caribbean (Kraus et al., 2020), Thunder Bay National Marine Sanctuary (Kendall et al., 2020), West Coast U.S. (Costa et al., 2019), and Southeast U.S. (Buckel et al., 2021). This approach allows participants to assign, edit, and move their

coin placement as often as they like until the prioritization deadline. Each participant had password protected access to only their grids and coins, which prevented accidental overwrite or deletion by others.

Each participant was given a set number of virtual coins (600 in Puerto Rico, 200 in the USVI), to place in the prioritization grid to indicate the locations of their mapping interest. The number of coins per jurisdiction is 30% of the total number of grid cells (2,008 grid cells in Puerto Rico, 644 grid cells in USVI). The application also restricted the maximum number of coins a participant could input into a single cell. This equaled 10% of the total coins for that jurisdiction, so for example participants could not allocate more than 60 coins into a single cell for the Puerto Rico grid. These restrictions on coins were specifically designed to ensure that participants' needs were comparable (i.e., everyone "spent" the same number of coins) and encouraged a broad distribution of priorities, thus increasing the chance of overlap among participant needs.

The number of coins assigned to a cell translated to the priority of data collection. Specifically, cells with 8–10% of their coins indicated an immediate need for spatial data, cells with 4–7% of coins indicated a need in the next 2–4 years, 1–3% of coins indicated a need in the next 5–10 years, and 0 coins indicated data was not needed for more than 10 years.

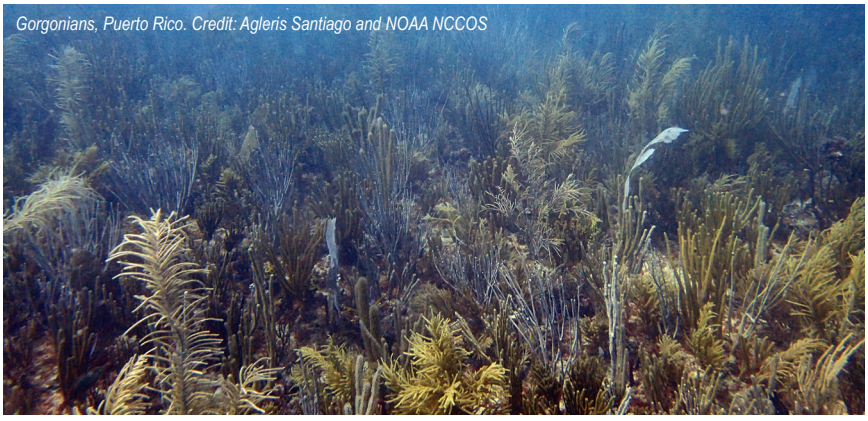
2.2.4 Management Use and Map Product Requirements

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 ten pre-defined Management Uses (Table 2), which were identified by the TAT and based on the coral management focus of the project. This selection indicated how participants plan to use the data to inform coral reef management. They could select up to two (primary and secondary) options for each cell using the pull-down menus in the prioritization widget.

Table 2. List of Management Uses that participants could select from when entering their priorities.

Management Use	*Definition*
1. *Endangered Species Management*	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 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 & 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 identify specific requirements for any new mapping data. These requirements 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 3). This category was used to help determine the spatial scale, product resolution, and suggested platform needed to meet data needs (Table 4).



Gorgonians, Puerto Rico. Credit: Agleris Santiago and NOAA NCCOS

Table 3. List of Map Product Requirements participants were asked to chose from to indicate what type of data they need.

Map Product Requirement	*Definition*
1. *Delineations of large topographic features (e.g., pinnacle)*	Includes escarpments, pinnacles, valleys, basins, and other large-scale bottom features detected
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)
3. *Models of habitat suitability for key taxa or communities*	Models of habitat suitability using course (>10m) resolution imagery
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.
5. *Models of presence/absence or density of corals*	Modeled percent cover and density of macrobiota
6. *Identification of coral species and their local environments*	Locate and identify species of corals and document their local environments (e.g. slope, rugosity)
7. *Documentation of individual specimen condition*	Identify the condition or health (e.g. injury, bleaching) of individual corals

Table 4. List of Map Product Requirements and their associated recommendations for resolution, scale, and platform.

Map Product Requirement	*Spatial Scale*	*Resolution/Product*	*Suggested Platform*
1. *Delineations of large topographic features (e.g., pinnacle)*	Regional	>10m resolution, coarse imagery	Ship/ROV
2. *Delineations of hard vs. soft bottom*	Regional	>10m resolution, coarse imagery	Ship/ROV
3. *Models of habitat suitability for key taxa or communities*	Regional	>10m resolution, coarse imagery	Ship/ROV
4. *Delineations of substrate types (e.g., sand, mud, coral, rock)*	Mesoscale	2–10m resolution DEM/photomosaics	Towed AUV/ROV
5. *Models of presence/absence or density of corals*	Mesoscale	2–10m resolution DEM/photomosaics	Towed AUV/ROV
6. *Identification of coral species and their local environments*	Microscale	<1m point clouds or DEM (high-res imaging)	AUV/ROV
7. *Documentation of individual specimen condition*	Microscale	<1m point clouds or DEM (high-res imaging)	AUV/ROV

Spatial scales were determined based on a set of pre-defined 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 (Table 4) and can be used to inform project planning and execution.

2.3 Priority Summaries and Spatial Analysis

As participants entered and edited their selections, their responses were continuously saved to an online data file that was unique to each participant. At the end of the data entry period, this information was downloaded, quality controlled, and analyzed to identify and summarize priorities within each coral reef 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 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. Once cells with coins passed this quality check, any Management Use and Map Product Requirement options assigned to cells with zero coins were removed. This situation commonly occurred when a participant assigned coins and other values to a cell then changed their mind and returned the coins to allocate elsewhere.

2.3.2 Data Analysis and Summary

To determine which Management Use and Mapping Product Requirement options were most commonly selected, the total number of coins were summed for each option at the primary, secondary, and overall levels across the entire project area. The number of coins for each Mapping Product Requirement scale (regional, mesoscale, microscale) were also summed to understand the spatial scale at which data is needed. To understand how coins were allocated spatially, the average number of coins from each participant group was calculated then summed in each grid cell. This prevented groups with multiple participants from outweighing those with only a

single participant. The total number of coins allocated towards each Management Use and Mapping Product Requirement from each participant group was also summed in each grid cell. Tallies were produced for each cell on the number of groups allocating at least one coin, the number of participants allocating at least one coin, and the number of different Management Use and Map Product Requirement options. The Top 10% of cells with coins were identified and used to highlight the highest priorities.

2.3.3 Summary Rank and Focal Areas

To understand areas of greater importance based on multiple data metrics, a composite rank analysis was conducted. First each cell was ranked by the following data metrics: total number of coins, number of participating groups, and number of unique Management Uses. Cells with the same value were given an average rank among the cells. The rank values for each of these data metrics were then summed to calculate an overall *summary rank*, indicating the importance of each grid cell across the number of coins, number of groups interested in the cell, and number of Management Uses supported if the cell were to be mapped.


Graysby (grouper) in coral reef habitat, USVI. Credit: NOAA NCCOS

Focal areas were selected by identifying clusters of cells that were comprised of more than five adjacent cells in the highest composite rank category (Top 10%). Five cells comprise an area of 13 km^2 which represents a manageable potential extent for mapping missions and improves efficiency of meeting multiple stakeholder needs with mission planning (e.g., minimized transit time, reduced days at sea). The focal areas selected were a subset of the identified clusters without existing high-quality data.

2.4 Project Timeline

Participating groups were contacted from October to November 2021 via email, were provided background information on the project, and requested to provide or verify the list of potential participants from their group. An introductory webinar was held on November 2, 2021 covering details on the project background, methods, outcomes, and web tool demonstration. The data inventory was finalized prior to coin allocation, and any datasets that were collected or published after this date were not included. Participants were requested to input their priorities anytime between November 3 to December 1, 2021, giving them approximately four weeks to complete their inputs. However, new background layers were discovered mid-December (listed in Appendix A as 'USVI Bathymetry Coverage by Resolution' and 'Puerto Rico Bathymetry Coverage by Resolution') and were considered highly important for participant decision-making, thus the deadline was extended to January 14, 2022. After the inputs were analyzed, participants were briefed on the preliminary results during a webinar on May 9, 2022, and were given the opportunity to make comments or suggestions.


High definition photo of a sea fan from a remotely operate vehicle, USVI. Credit NOAA NCCOS

Chapter 3 Puerto Rico Results

Overall, 26 groups from both Puerto Rico and USVI participated in this effort. Of those 26 participants, 16 provided input priorities for Puerto Rico.

3.1 Management Use

Nearly half (44%) of the total coins assigned were comprised of two Management Use options: *Monitoring* and *Spatial Protection/ Management* (Figure 4). *Habitat Restoration* was selected in 15% of coins overall, however it was selected almost exclusively as a secondary Management Use. All participating groups selected at least two different Management Uses (typically a primary and secondary), with one group (DNER) selecting seven different options (Figure 5). Maps of coin distributions for each Management Use selected for Puerto Rico can be found in Appendix B.

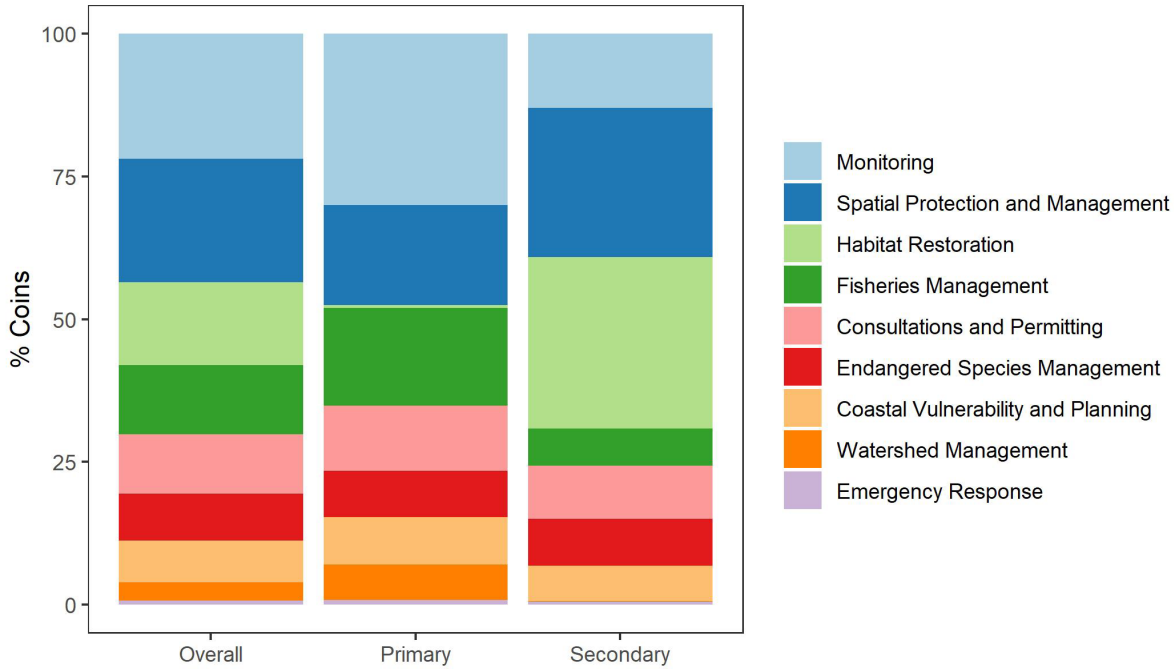


Figure 4. The percentage of coins for each Management Use selected at the overall, primary, and secondary levels in Puerto Rico.

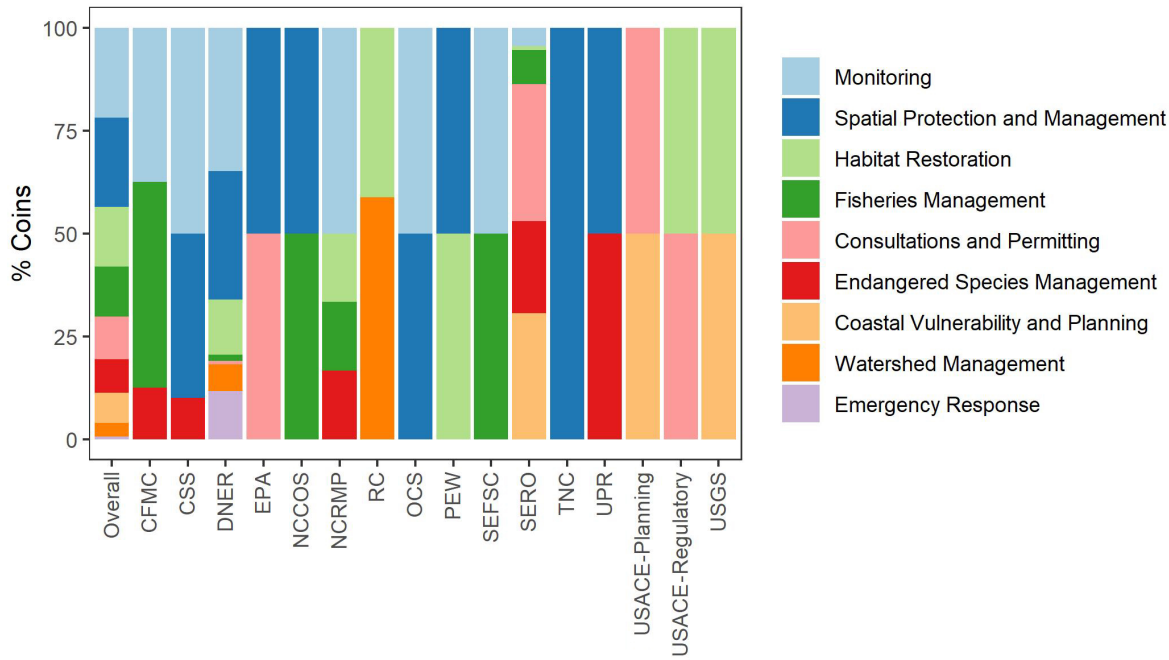


Figure 5. The percentage of coins for each Management Use selected per participant group in Puerto Rico.

3.2 Map Product Requirements

The proportion of coins that were assigned using the Map Product Requirement options at the primary and secondary levels revealed three top data requirements for coral management: *Substrate Types*, *Identification of Coral Species*, and *Habitat Suitability* (Figure 6). Of the seven options available, these three comprised nearly 71% of overall coins. Out of the 16 participating groups, 13 identified *Substrate Types* and/or *Identification of Coral Species* as a data requirement for future management actions (Figure 7). Maps of coin distribution for each Map Product Requirement can be found in Appendix C.

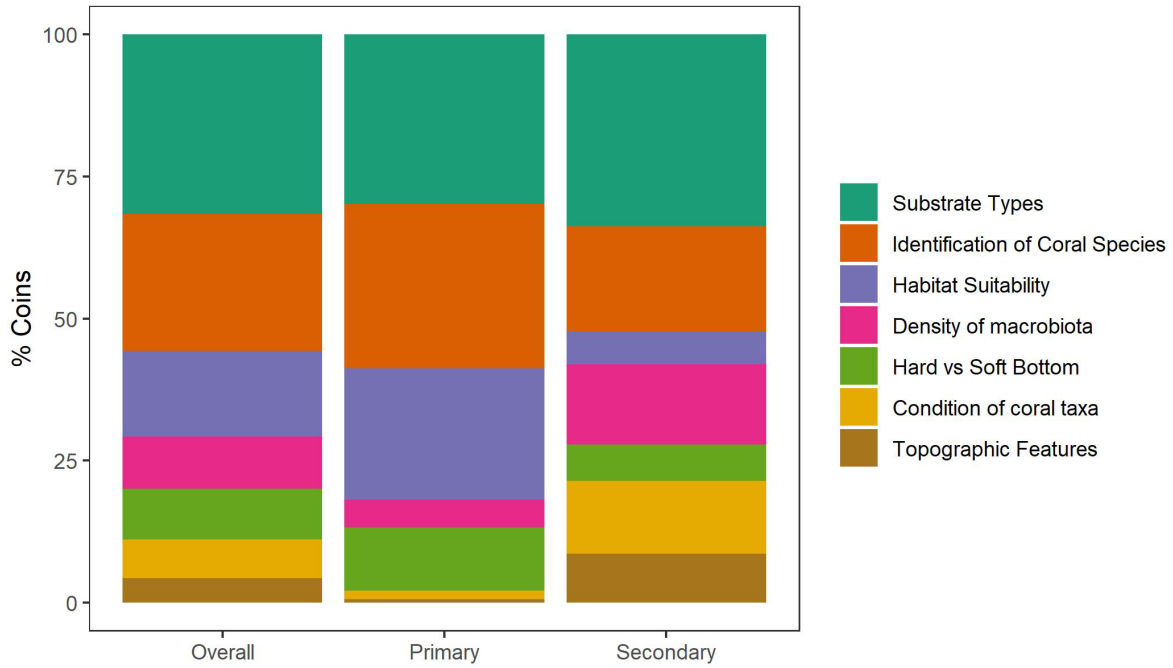


Figure 6. The percentage of coins for each Map Product Requirement selected at the overall, primary, and secondary levels in Puerto Rico.

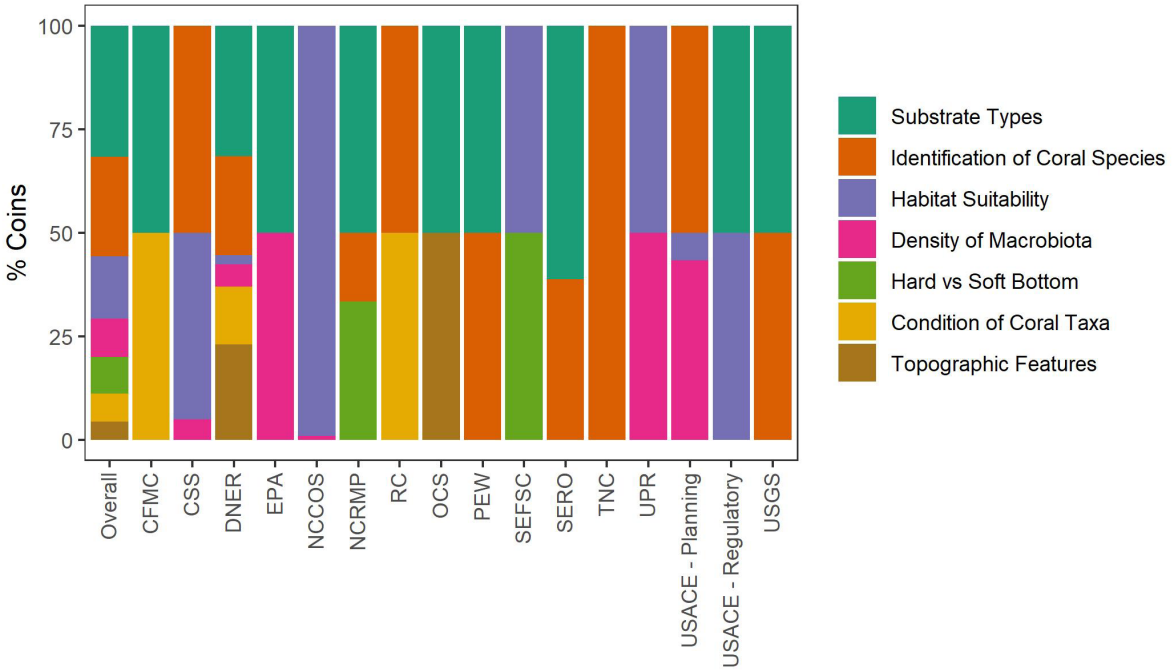


Figure 7. The percentage of coins for each Map Product Requirement selected per participant group in Puerto Rico.

Additionally, the proportion of coins that were assigned using the Mapping Product Requirement options were summarized by the spatial scale at which data is collected (i.e. regional, mesoscale, microscale, descriptions provided in Table 4). The proportion of coins overall revealed data at the mesoscale was most commonly selected (41%), followed by microscale (31%), and regional scale (28%) data (Figure 8). However, regional spatial scale was more commonly selected at the primary level, while mesoscale data was more commonly selected at the secondary level. Maps of coin distribution for each Map Product Requirement Spatial Scale can be found in Appendix C.

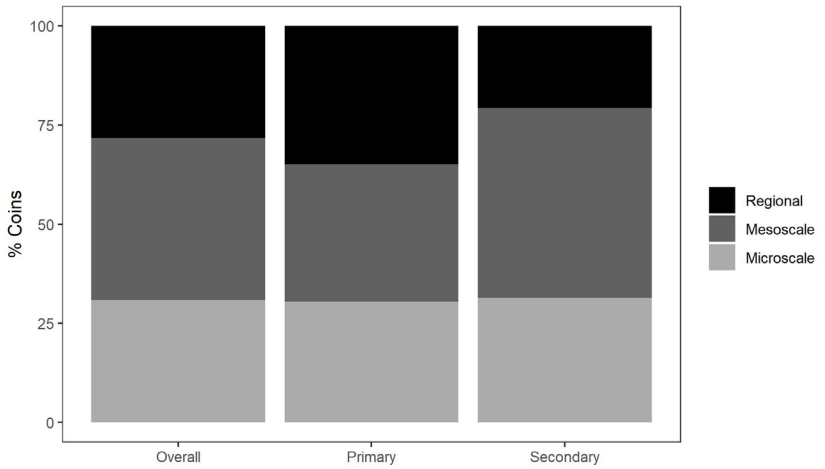


Figure 8. The percentage of coins for each Map Product Requirement spatial scale selected at the overall, primary, and secondary levels in Puerto Rico.

3.3 Total Coins and Summary Rank

Cells with the highest total number of coins (Top 10%) occurred in Desecheo Island, Rincón to Aguadilla Bay, Tourmaline Bank, East of Vieques Island, Culebra Island, along the bank edge between Buena Vista and Vieques Island, Rada Fajardo, Cayo Icacos, and San Juan (Figure 9). Cells containing the Top 10% of coins covered an area of 354 km^2.

A similar spatial pattern was found when considering the number of groups that allocated coins into each cell, which ranged from 1–6 groups per cell (Figure 10). The number of Management Uses, however, showed a different spatial pattern by highlighting several unique areas where a significant number of Management Uses (5+) were selected (Figure 11). For example, Sonda de Vieques (the bay west of Culebra Island) contains a particularly large area where over five different Management Uses were selected by participants. Coin distributions in this area suggest data are not needed immediately, however any new mapping data in this area would satisfy several different coral reef management uses.

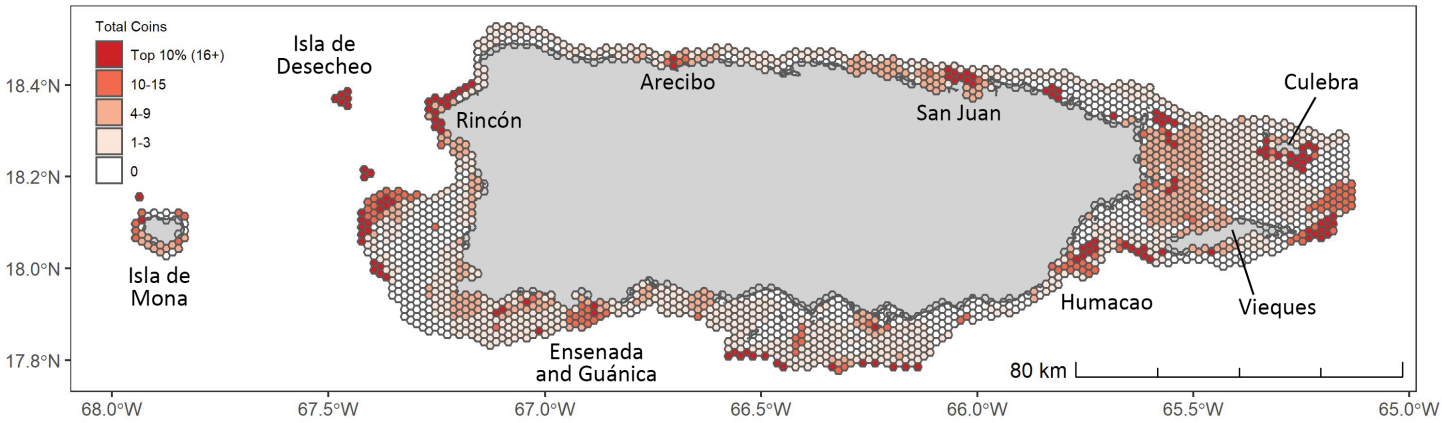


Figure 9. Map of total coins in Puerto Rico.

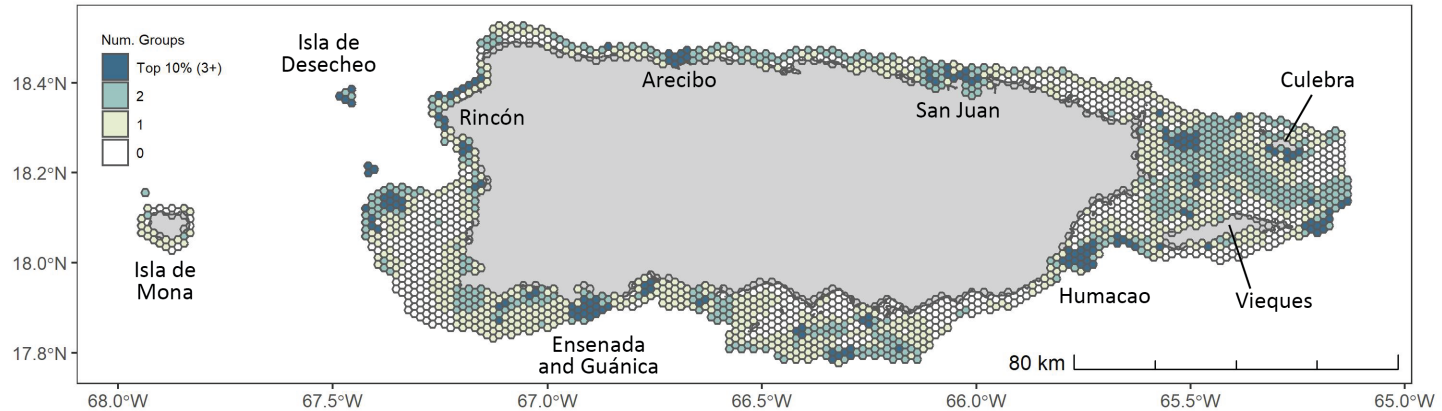


Figure 10. Number of groups who allocated at least one coin into each cell. A maximum of six participant groups input into a single cell in Puerto Rico.

By combining multiple aspects of cell importance into a single layer, this summary rank highlighted cells that were important when considering multiple data results in Puerto Rico (Figure 12). Highest ranked cells in the Top 10% were clustered in areas such as Ensenada Las Pardas (the bank east of Puerto Yabucoa), Puerto Arecibo, and the northern section of Sonda de Vieques.

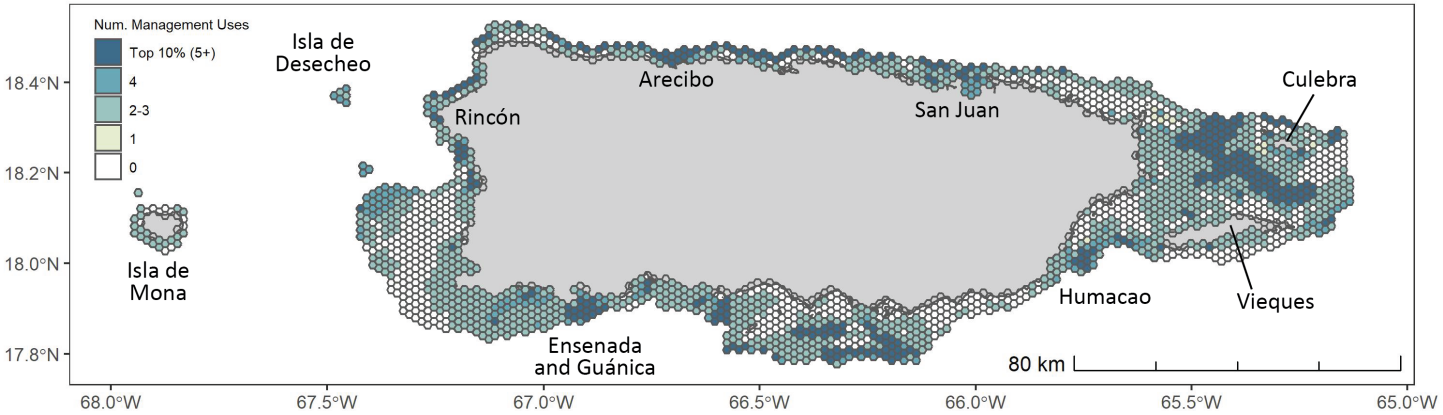


Figure 11. Number of Management Use options that were selected in each cell in Puerto Rico.

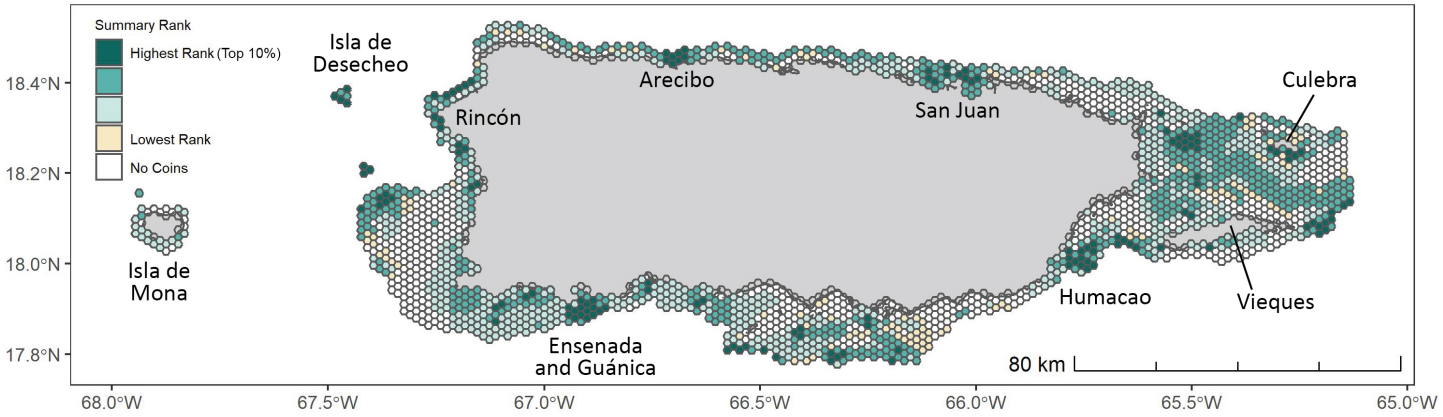


Figure 12. Sum of cell ranks based on total coins, number of participating groups, and diversity of Management Uses in each cell in Puerto Rico.

3.4 Focal Area Gap Analysis

There were four focal areas identified: 1) Arecibo, 2) Ensenada and Guánica, 3) Humacao, and 4) Northwest Sonda de Vieques (Figure 13). These four focal areas are discussed here because of they contained numerous adjacent cells within the highest summary rank category (Top 10%) and lacked existing or contemporary data.

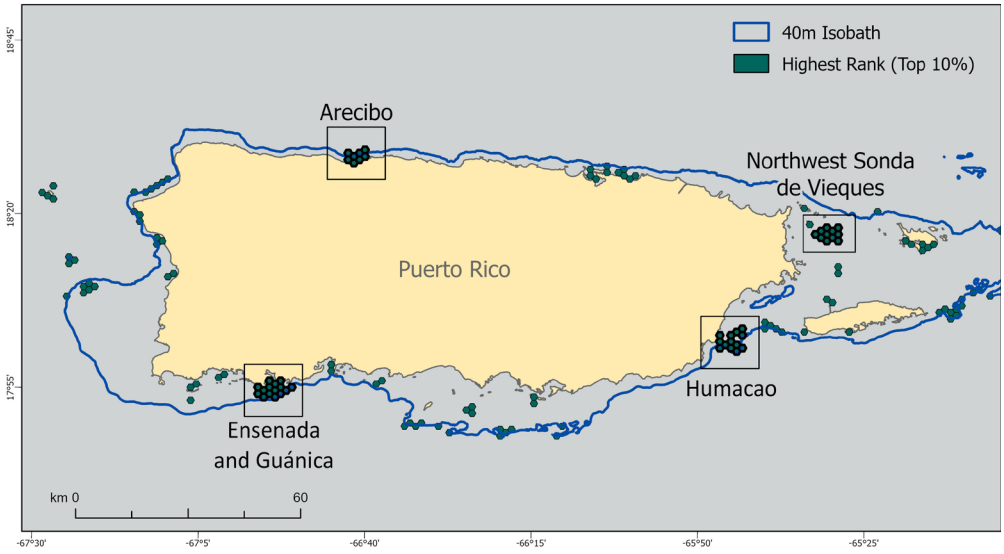


Figure 13. Focal areas in Puerto Rico identified using the highest summary rank (Top 10%).

3.4.1 Arecibo

Off the coast of Arecibo, eight hexagons (total area of 21 km^2) were identified as a top priority by four participating groups (Figure 14). Available lidar and multibeam data cover this region almost entirely, with some gaps in the eastern-most cells (Figure 15). Regional scale data needs were identified by most participants, indicating general habitat information is lacking in this area (Table 5). New information could be collected in the form of *Habitat Suitability* models, determining areas of *Hard vs. Soft Bottom*, which are the top two selected Map Product Requirements for this area. Data products that describe the general physical structures of the benthic environment, including detailed habitat maps, will help to inform management actions for several important coral communities along the coast including a few well developed *Acropora palmata* reefs (E. Weil, pers. comm.; I. Enochs, pers. comm.).

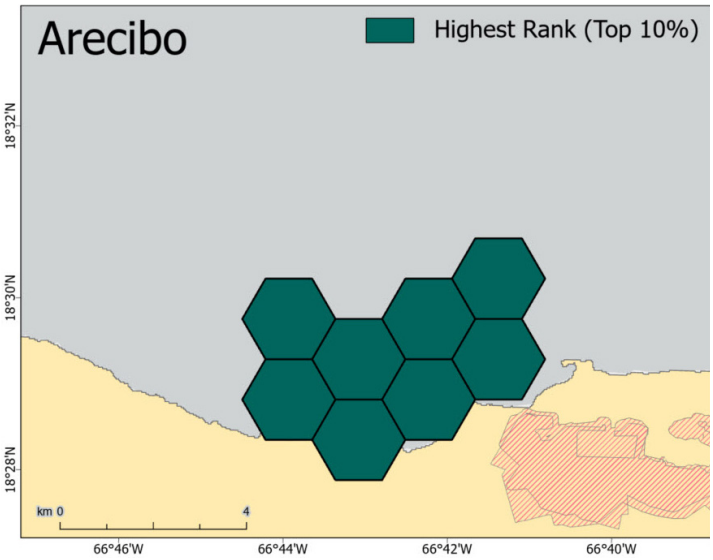
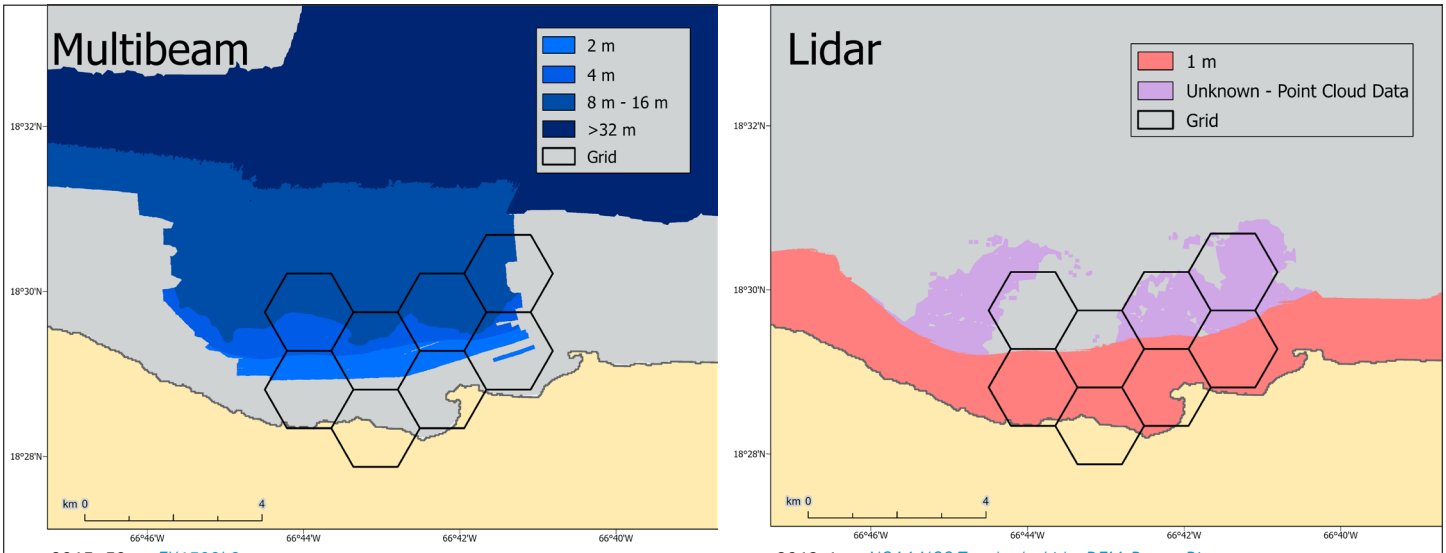


Figure 14. Highest ranking cells offshore of Arecibo.

Table 5. Data summary of participant input for the Arecibo focal area. Percent coins are calculated based on the Management Use, Map Product Requirement, and Spatial Scale coin totals within these eight 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% (8)	4
High (3)		
Medium (3)		
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Consultations & Permitting (47%)	Hard vs Soft Bottom (36%)	Regional (71%)
Coastal Vulnerability (45%)	Habitat Suitability (26%)	Mesoscale (24%)
Habitat Restoration (3%)	Substrate Types (24%)	Microscale (5%)
Spatial Protection/Mgmt. (2%)	Topographic Features (9%)	



2015: 50 m - EX1502L3
2013: 2 m, 4 m, 8 m, 16 m - W00297
2007: Unknown - NF-07-04-PMEL

2019: 1 m - NOAA NGS Topobathy Lidar DEM: Puerto Rico
2018: 1 m - M8571
2016: 1 m - M8462, M5154
2015: 1 m - M6211

Figure 15. Coverage of existing bathymetric data for multibeam (left) and lidar (right) in the Arecibo region. List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data. Point cloud data are discrete lidar points that can be used to derive data products (i.e., geotiffs).

3.4.2 Ensenada and Guánica Bay

In southern Puerto Rico, off the coast of Ensenada and Guánica, 15 hexagons (total area of 39 km^2) were identified by four participant groups as an area of need (Figure 16). A combination of lidar and multibeam data covers this region entirely (Figure 17), however multibeam data is only on the deeper edge. Both lidar and multibeam convey depth and substrate hardness, however lidar reflectance information (i.e. substrate hardness) are generally less detailed and may not meet high resolution requirements needed to evaluate detailed reef features (Costa et al., 2009).

Given the larger data spatial scales (Mesoscale and Regional) identified by participants (Table 6), it's possible the available lidar data, which covers a majority of the coral reef habitats outside Guánica Bay, could be used to fulfill the specified Map Product Requirements. Notably, the Guánica Bay watershed is a priority site for the U.S. Coral Reef Task Force, where significant investments have gone to the management of the watershed and associated coral reefs located downstream. Currently, several initiatives are evaluating the potential relationship between *Watershed Management* activities and changes in the condition of coral reefs in this area. Well-developed reefs such as Cayo Coral, an aggregated reef east of the Guánica Bay mouth, and Gilligan's Island contain extensive *Acropora palmata* colonies and thus are of high interest for *Spatial Protection* and *Habitat Restoration* efforts. Furthermore, Cayo Coral is a priority nursery for coral outplanting and disease intervention for NOAA's Restoration Center (E. Weil, pers. comm; N. Alvarado, pers. comm.).

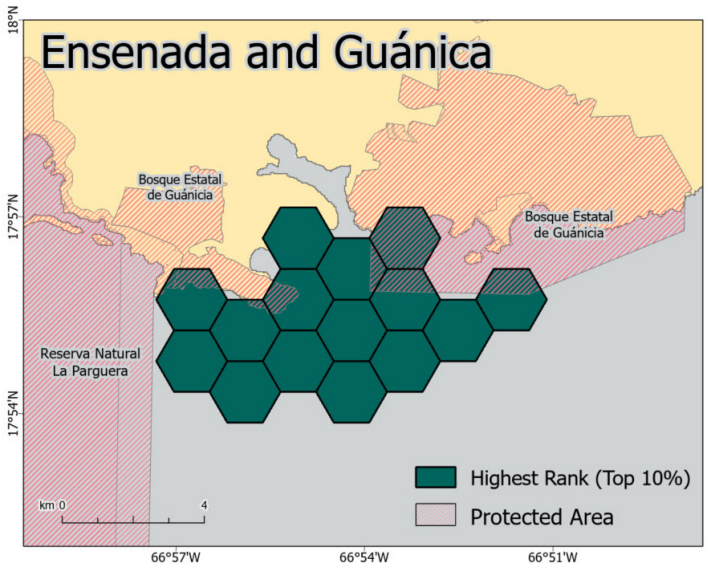


Figure 16. Highest ranking cells near Ensenada and Guánica in southern Puerto Rico.

Table 6. Data summary of participant input for the Ensenada and Guánica Bay focal area. Percent coins are calculated based on the Management Use, Product Requirement, and Spatial Scale coin totals within these 15 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)	Highest Top 10% (15)	4
High (13)		
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Spatial Protection/Mgmt (30%)	Substrate Types (37%)	Mesoscale (50%)
Habitat Restoration (20%)	Topographic Features (34%)	Regional (50%)
Monitoring (17%)	Habitat Suitability (16%)	Microscale (0%)
Watershed Mgmt (17%)	Density of Macrobiota (13%)	

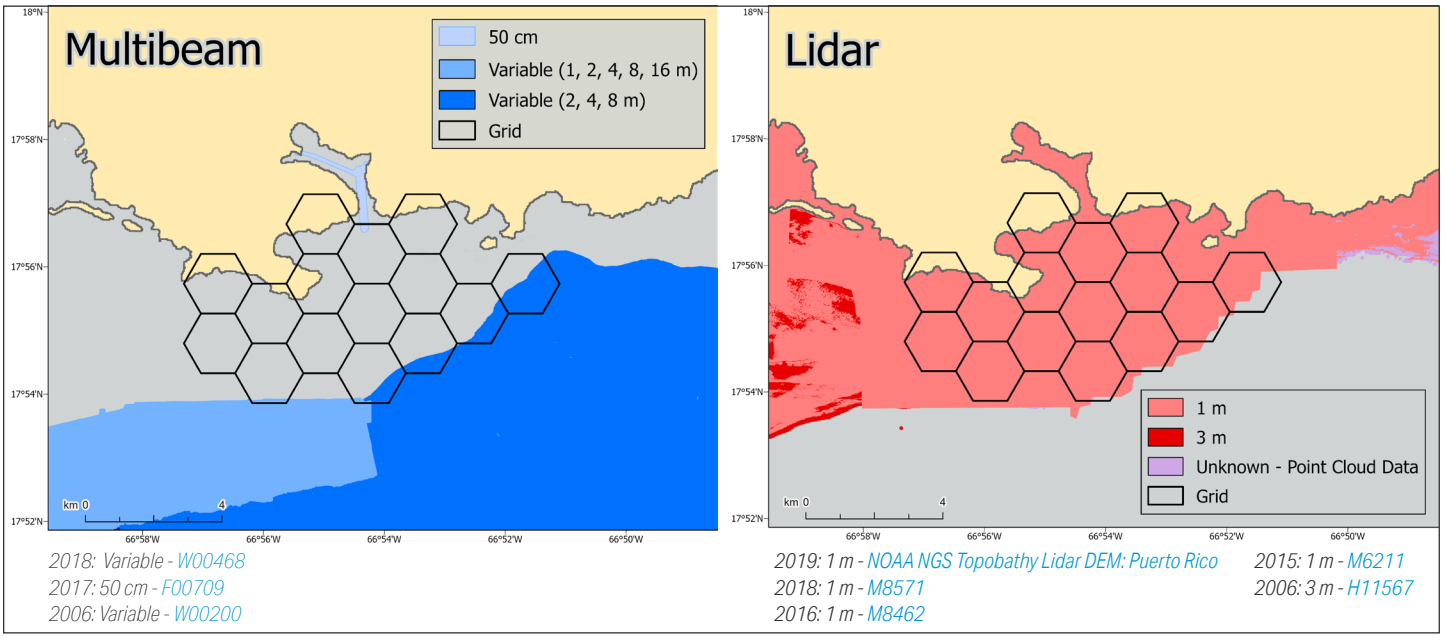


Figure 17. Coverage of existing bathymetric data for multibeam (left) and lidar (right) in the Ensenada and Guánica region. List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data. Point cloud data are discrete lidar points that can be used to derive data products (i.e., geotiffs).

3.4.3 Humacao

Off the coast of southeastern Puerto Rico, 13 hexagons (total area of 34 km^2) were identified by seven participant groups as an area of data needs (Figure 18). Multibeam data only covers a small portion of the outermost hexagons and lidar data cover only a small portion of only a few nearshore hexagons (Figure 19). This leaves a large data gap in much of this focal area.

This area also lacks any habitat information such as *Substrate Types* and *Aggregations of Coral Taxa*, which are the top two Map Product Requirements (Table 7). High-resolution bathymetry would support the characterization and restoration of poorly understood coral reef benthic communities in this area, particularly along the shelf-edge. This region is also near port infrastructure, additional data in the area would provide a better understanding of coral communities and would be valuable for port activity and impact assessments (N. Alvarado, pers. comm.).

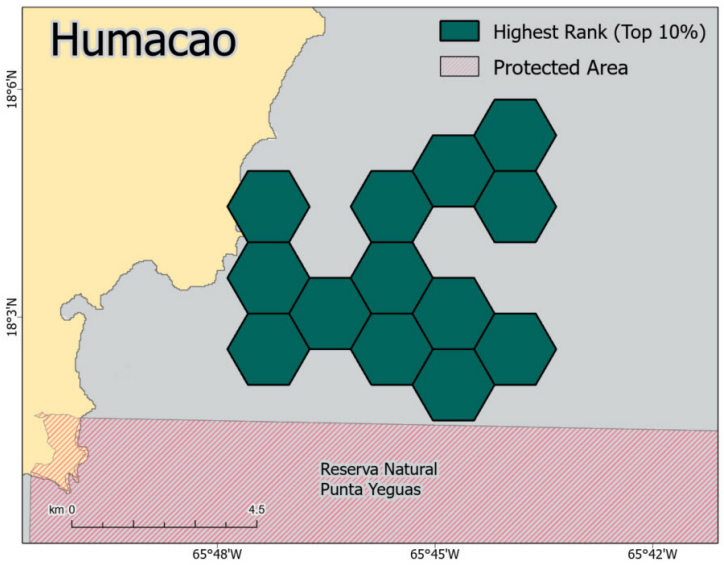
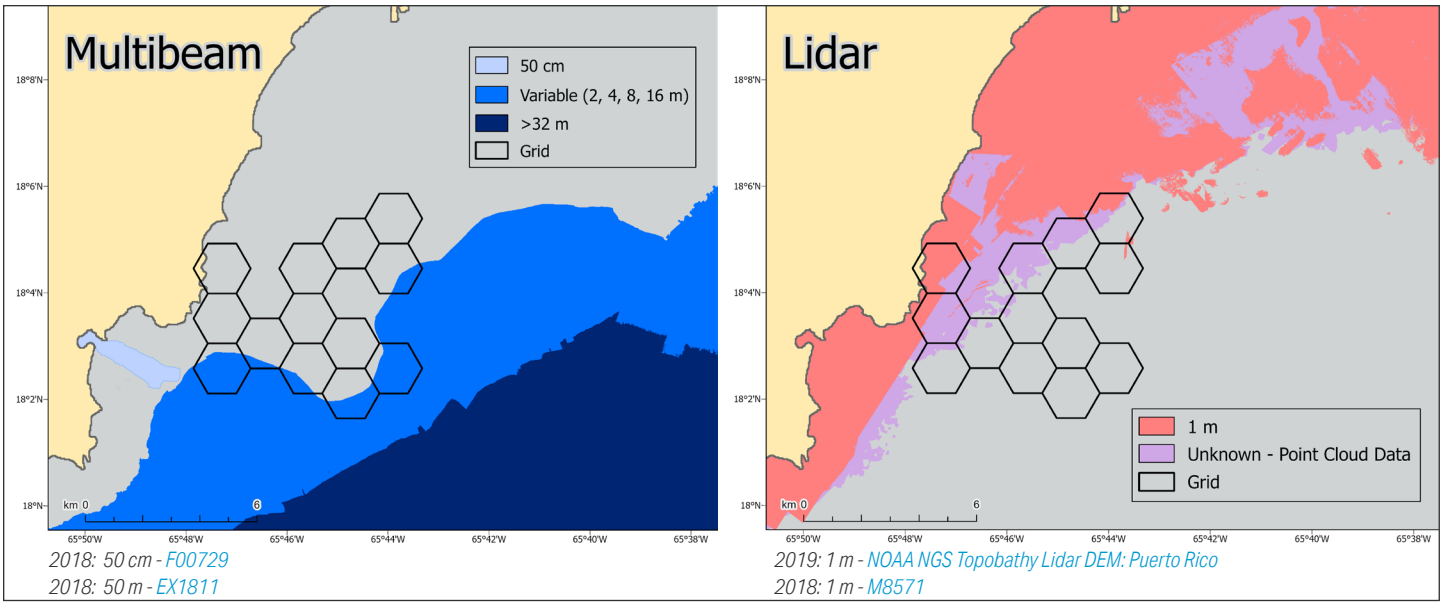


Figure 18. Highest ranking cells offshore of Humacao region in southeastern Puerto Rico.

Table 7. Data summary of participant input for the Humacao focal area. Percent coins are calculated based on the Management Use, Product Requirement, and Spatial Scale coin totals within these 13 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% (3)	Highest Top 10% (13)	4
High (10)		
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Spatial Protection/Mgmt (50%)	Substrate Types (41%)	Mesoscale (48%)
Monitoring (30%)	Agg. of Coral Taxa (33%)	Microscale (33%)
Consultations/Permitting (8%)	Topographic Features (13%)	Regional (19%)
Habitat Restoration (4%)	Density of Macrobiota (7%)	



2018: 50 cm - F00729
2018: 50 m - EX1811
2019: 1 m - NOAA NGS Topobathy Lidar DEM: Puerto Rico
2018: 1 m - M8571

Figure 19. Coverage of existing bathymetric data for multibeam (left) and lidar (right) in the Humacao region. List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data. Point cloud data are discrete lidar points that can be used to derive data products (i.e., geotiffs).

3.4.4 Northwest Sonda de Vieques

In the northwestern portion of Sonda de Vieques, a bay area located between Culebra and Vieques islands, 11 hexagons (total area of 29 km^2) were identified by four participant groups as an area of need (Figure 20). Lidar data coverage is sparse in this region, with no recent (2001 or later) multibeam data existing (Figure 21).

The top Management Uses identified in this area were *Monitoring* and *Fisheries Management* (Table 8), which would be difficult management objectives to accomplish without high quality benthic data. General requirements for mapping products for fisheries-independent surveys are sonar data with backscatter at a 1–2 m resolution in shallow (0–50 m) depths. This allows for characterization of substrate complexity and hardness (i.e. hard vs. soft). Mapping this area, specifically with multibeam sonar technology, would provide vital information that can be used to improve surveys of marine stock assessments and management conducted by various federal and territorial government agencies, in conjunction with academic partners (S. Smith, pers. comm.). Additionally, new mapping data will further support the bathymetric characterization of benthic habitats around the entire Puerto Rico Northeast Marine Corridor (N. Alvarado, pers. comm.).

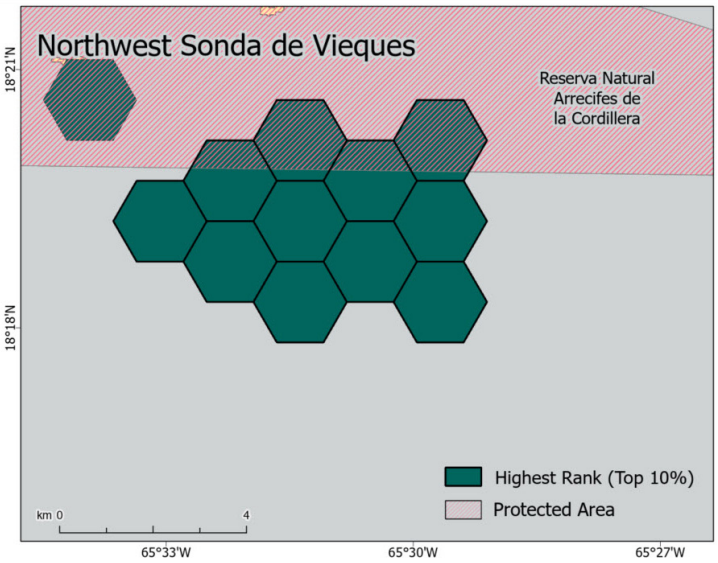
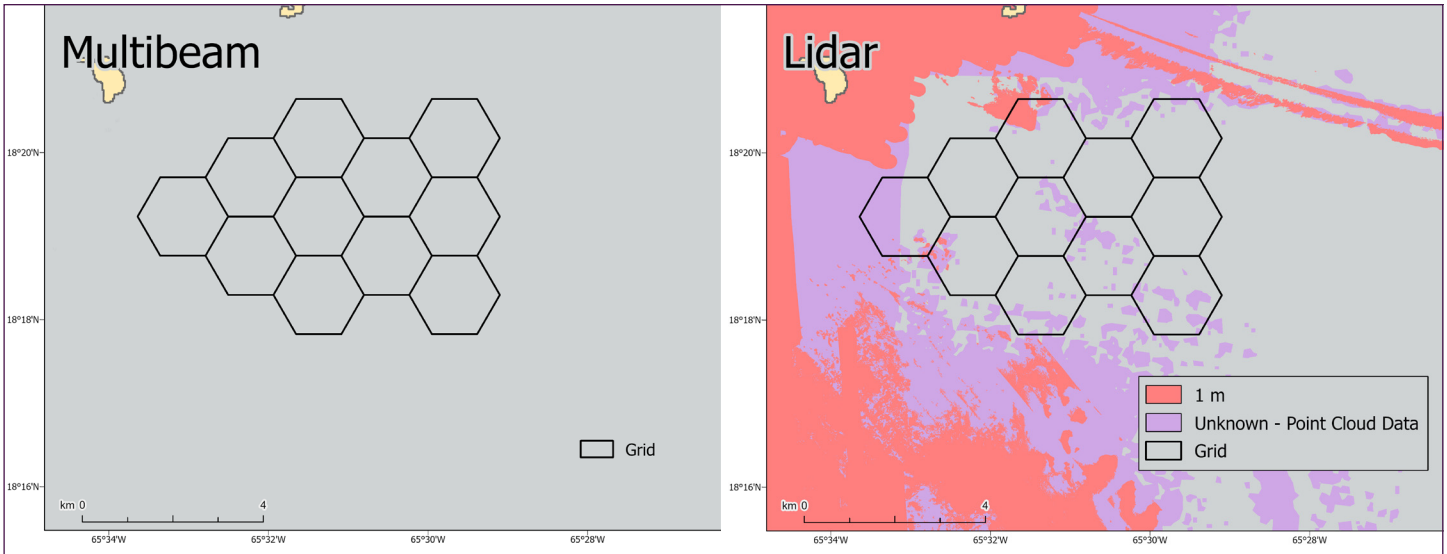


Figure 20. Highest ranking cells in the northwest portion of Sonda de Vieques off the east coast of Puerto Rico.

Table 8. Data summary of participant input for the northwest Sonda de Vieques focal area. Percent coins are calculated based on the Management Use, Product Requirement, and Spatial Scale coin totals within these 11 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% (3)	Highest Top 10% (13)	4
High (10)		
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Spatial Protection/Mgmt (50%)	Substrate Types (41%)	Mesoscale (48%)
Monitoring (30%)	Agg. of Coral Taxa (33%)	Microscale (33%)
Consultations/Permitting (8%)	Topographic Features (13%)	Regional (19%)
Habitat Restoration (4%)	Density of Macrobiota (7%)	



No multibeam data coverage exists from 2001 or later.

2019: 1 m - NOAA NGS Topobathy Lidar DEM: Puerto Rico
2018: 1 m - M8571
2016: 1 m - M8462, M5154
2015: 1 m - M6211

Figure 21. Coverage of existing bathymetric data for multibeam (left) and lidar (right) the northwest portion of Sonda de Vieques region. List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data. Point cloud data are discrete lidar points that can be used to derive data products (i.e., geotiffs).

Chapter 4 U.S. Virgin Islands Results

Overall, 26 groups from both Puerto Rico and USVI participated in this effort. Of those 26 participants, 18 provided input priorities for the USVI.

4.1 Management Use

Coins assigned using the Management Use options *Habitat Restoration* and *Spatial Protection and Management* were selected for a total of 40% of coins allocated (Figure 22). *Fisheries Management* and *Monitoring* were each selected for 16% of coins, and were selected most often as the primary option. *Endangered Species Management* was also selected for 16% of allocated coins, however mainly as a secondary option. Each participating group selected at least two different Management Uses (typically a primary and secondary), with one group (National Park Service) selecting six different options (Figure 23). Maps of coin distributions for each Management Use can be found in Appendix D.

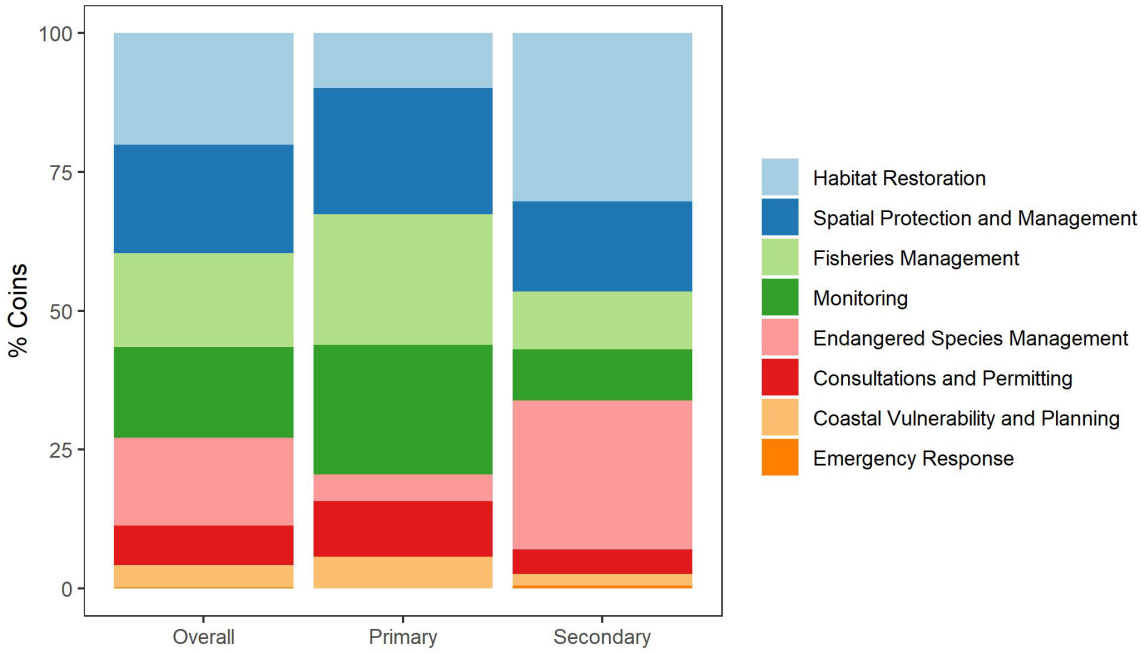


Figure 22. The percentage of coins for each Management Use selected overall, and at the primary and secondary levels in the USVI.

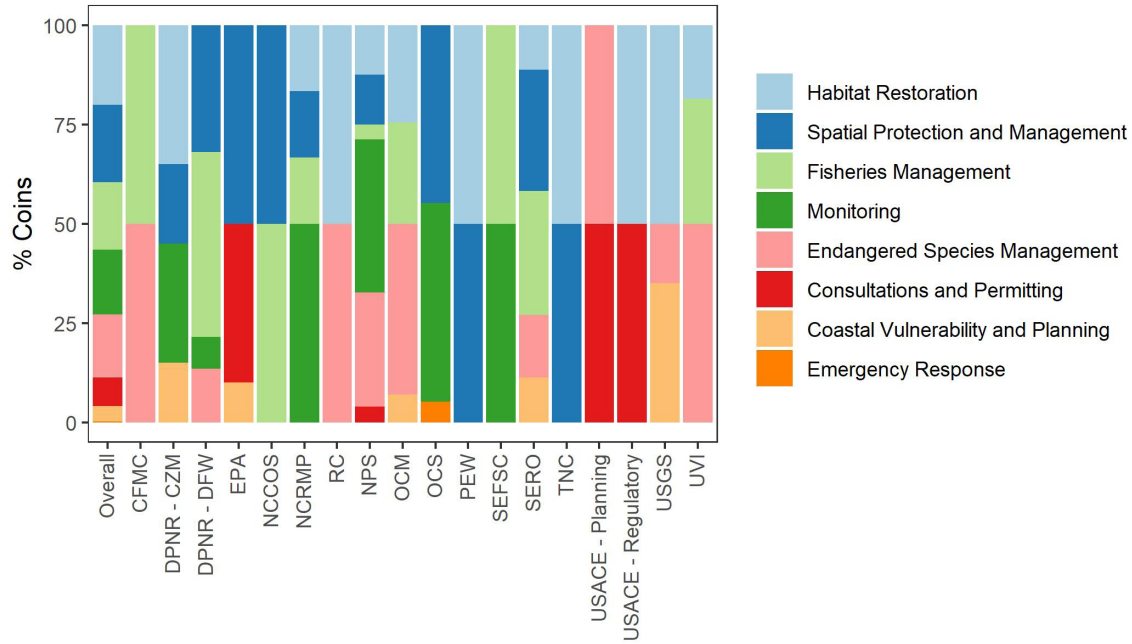


Figure 23. The percentage of coins for each Management Use selected per participant group in the USVI.

4.2 Map Product Requirements

The proportion of coins that were assigned using the Map Product Requirement options at the primary and secondary levels revealed the most commonly selected requirement for coral management was *Substrate Types*, comprising 34% of total coins. The next three most commonly selected Map Product Requirements were *Identification of Coral Species*, *Habitat Suitability*, and *Density of Microbiota*, which totaled another 45% of total coins allocated. Of the 18 participating groups, 13 identified *Substrate Types* as a data requirement for future management actions (Figure 25). Maps of coin distribution for each Map Product Requirement can be found in Appendix E.

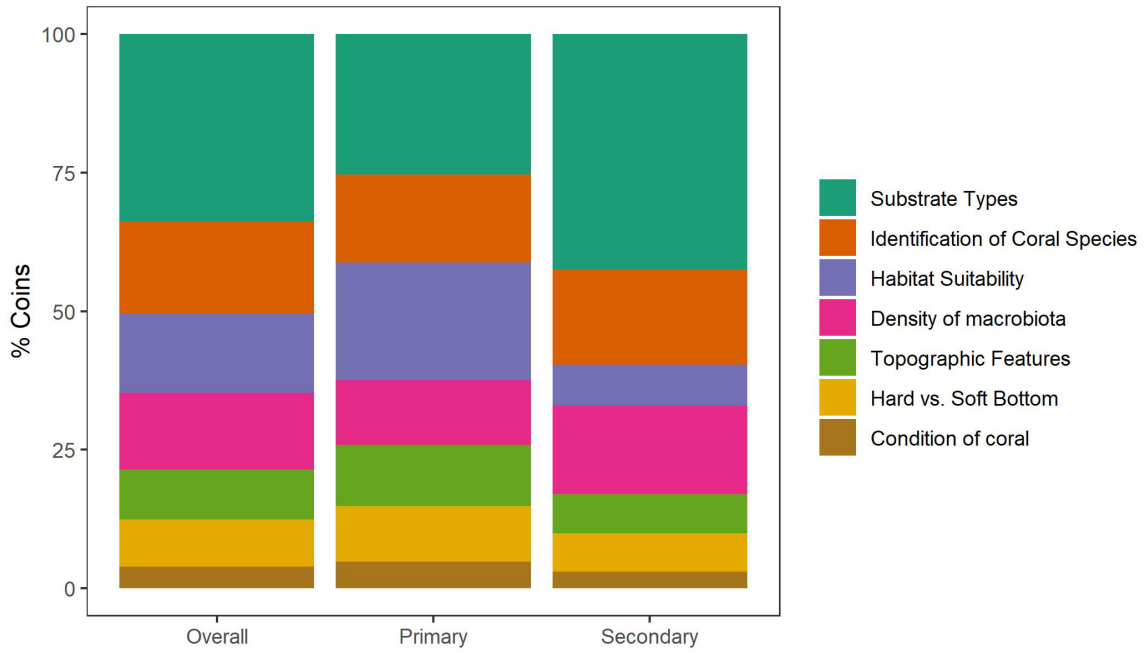


Figure 24. The percentage of coins for each Map Product Requirement selected at the overall, primary, and secondary levels in the USVI.

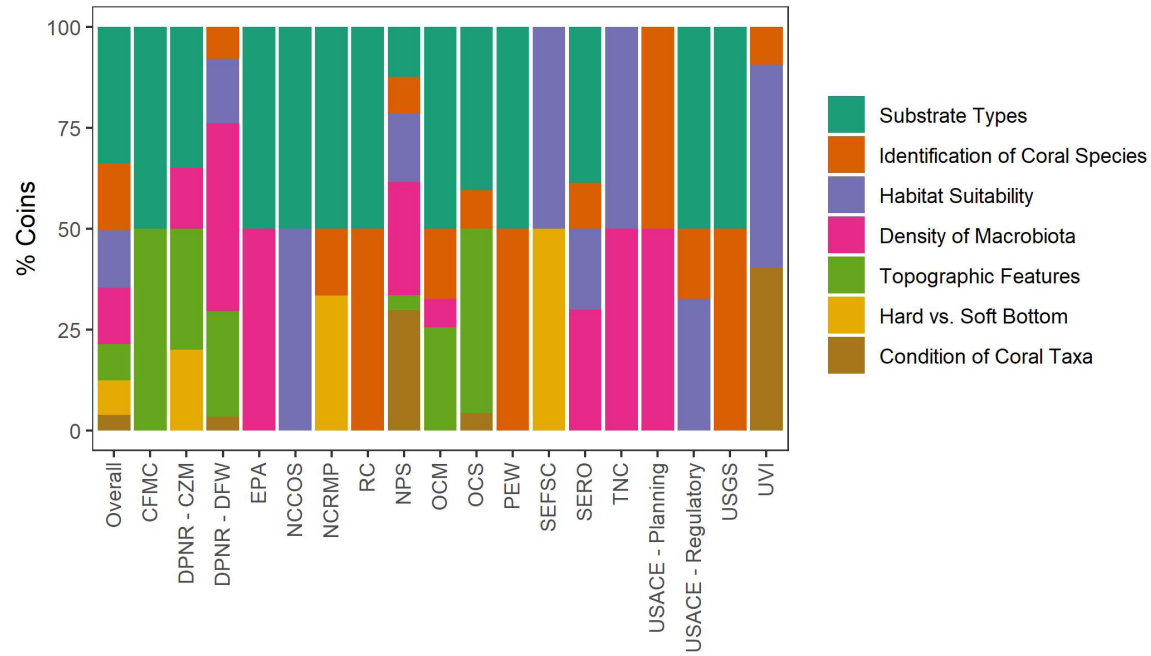


Figure 25. The percentage of coins for each Map Product Requirement selected per participant group in the USVI.

Additionally, the proportion of coins that were assigned using the Mapping Product Requirement options were summarized by the spatial scale at which data is collected (i.e., regional, mesoscale, microscale, descriptions provided in Table 4). The proportion of coins overall revealed data at the mesoscale was most commonly selected (48%), followed by regional (32%), and microscale (20%) data (Figure 26). However, data at the regional spatial scale was more commonly selected at the primary level, while mesoscale data was more commonly selected at the secondary level. Maps of coin distributions for each Map Product Requirement *Spatial Scale* can be found in Appendix E.

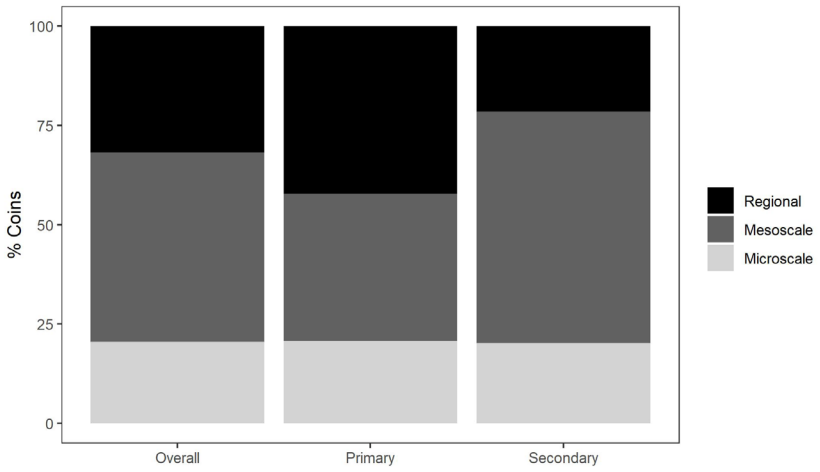


Figure 26. The percentage of coins for each Map Product Requirement spatial scale selected at the overall, primary, and secondary levels in the USVI.

4.3 Total Coins and Summary Rank

Cells with the highest total number of coins (Top 10%) occurred in several locations in waters surrounding the USVI. Areas with a high concentration of coins in the Top 10% were concentrated along the coastlines of St. Croix and St. Thomas (Figure 27). There are several smaller clusters of cells within the Top 10% located along a bank southeast of St. Croix, Lang Bank, and the offshore reef northwest of St. Thomas. There are also several small clusters of Top 10% coins along the reef edge south of St. Thomas.

The number of groups that allocated coins into each cell ranged from one to seven participant groups per cell (Figure 28). Between four and seven (Top 10%) participant groups showed interest along the north shore of St. Croix and Lang Bank. Additionally, four different groups selected a cluster of cells around Cockroach Island and Dutchcap Passage just northwest of St. Thomas. These are just some examples of areas where many different participant groups identified seafloor mapping needs for coral management, and thus would be an opportunity for collaboration.

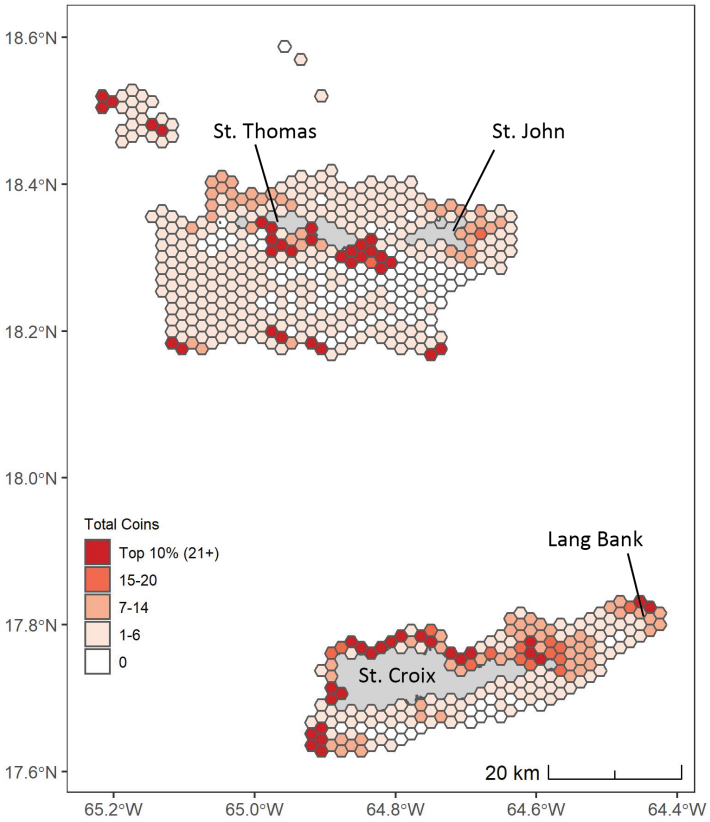


Figure 27. Map of total coins in the USVI region.

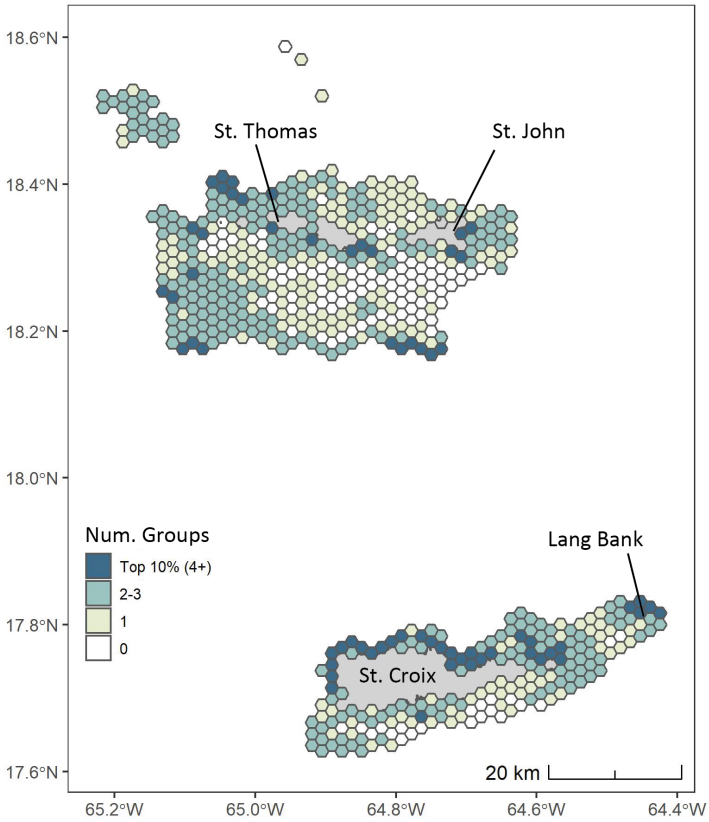


Figure 28. Number of groups who allocated at least one coin into each cell in the USVI. A maximum of seven participant groups input into a single cell.

The number of Management Uses highlighted several unique areas where a variety of mandates and management actions would be met by collecting the required data (Figure 29). There were several large clusters of cells that contained five to seven different Management Uses selected by participants including the northern coastline of St. Croix, Coral Bay in eastern St. John, and several large clusters of cells around St. Thomas. The St. Croix ridge, off the eastern coast of the island, contains a particularly large area where five different Management Uses were selected by participants, however the total coins and summary rank were in the medium categories. This suggests that although it's not a high priority to most agencies, any new mapping data in this area will likely satisfy several data uses to inform coral reef management. Alternatively, the large cluster of Top 10% cells for Management Use selections around Cockroach Island and Dutchcap Passage were also in the Top 10% for summary rank, indicating a higher priority for participants.

By combining multiple aspects of cell importance into a single layer, we were able to highlight cells that were of greater importance surrounding the USVI (Figure 30). Several large clusters of highest ranked cells (dark green) worth noting include a stretch of cells along the western and northern coast of St. Croix, along the eastern tip of St. Thomas, and surrounding Cockroach Island and Dutchcap Passage.

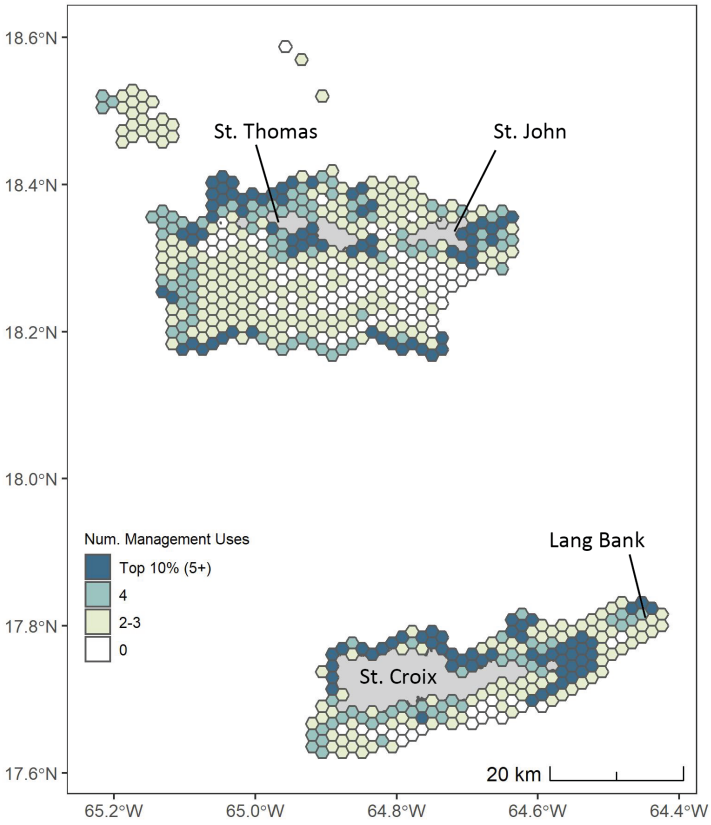


Figure 29. Number of Management Use options that were selected in each cell in the USVI.

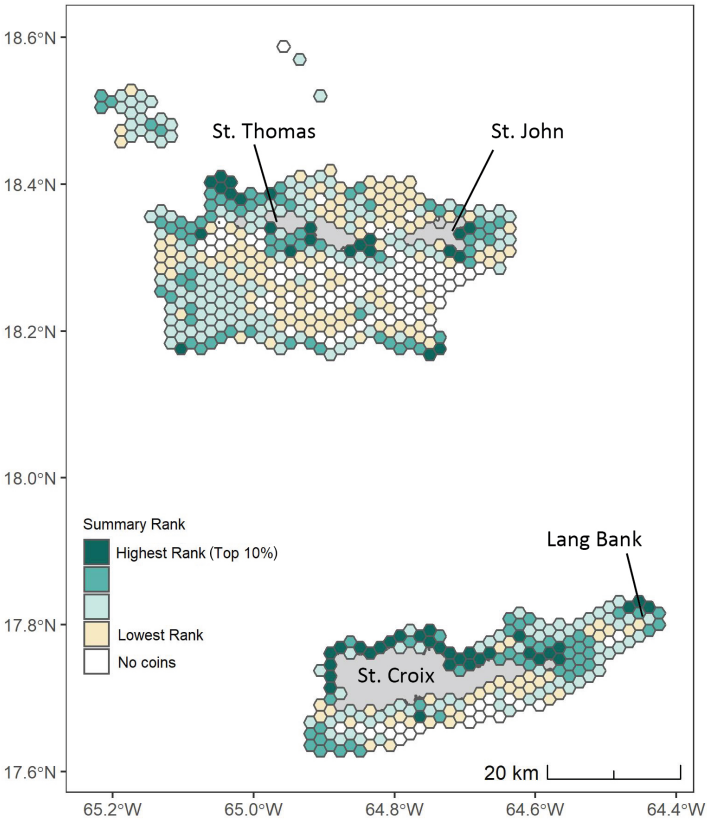
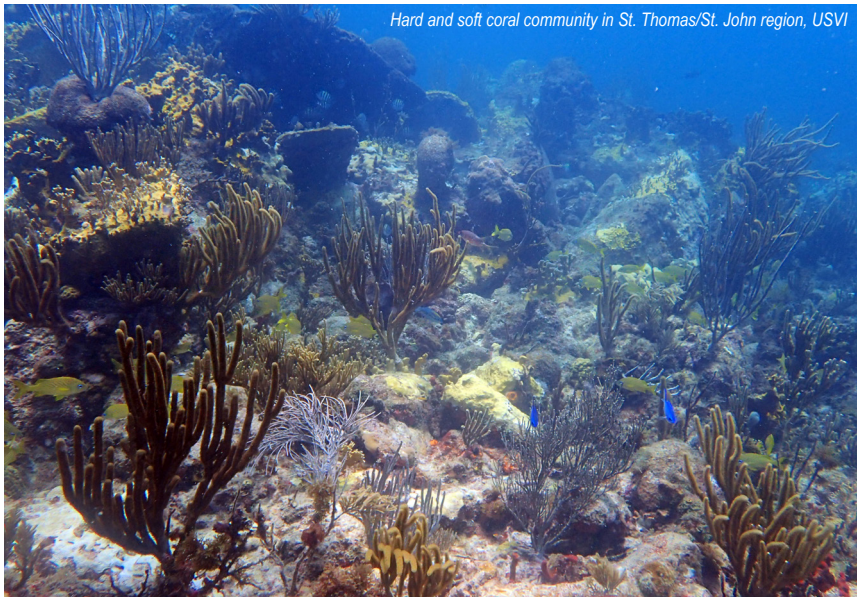


Figure 30. Sum of cell ranks based on total coins, number of participant groups, and diversity of Management Uses in each cell in the USVI.

4.4 Focal Area Gap Analysis

Three areas in the USVI were identified as high priority based on this prioritization effort: 1) shelf off northwest of St. Thomas (Cockroach Island and Dutchcap Pass), 2) northwest St. Croix, and 3) east St. Croix (Figure 31). These three focal areas are discussed here because they contained numerous adjacent cells within the highest summary rank category (Top 10%) and lacked existing or contemporary data.


Hard and soft coral community in St. Thomas/St. John region, USVI

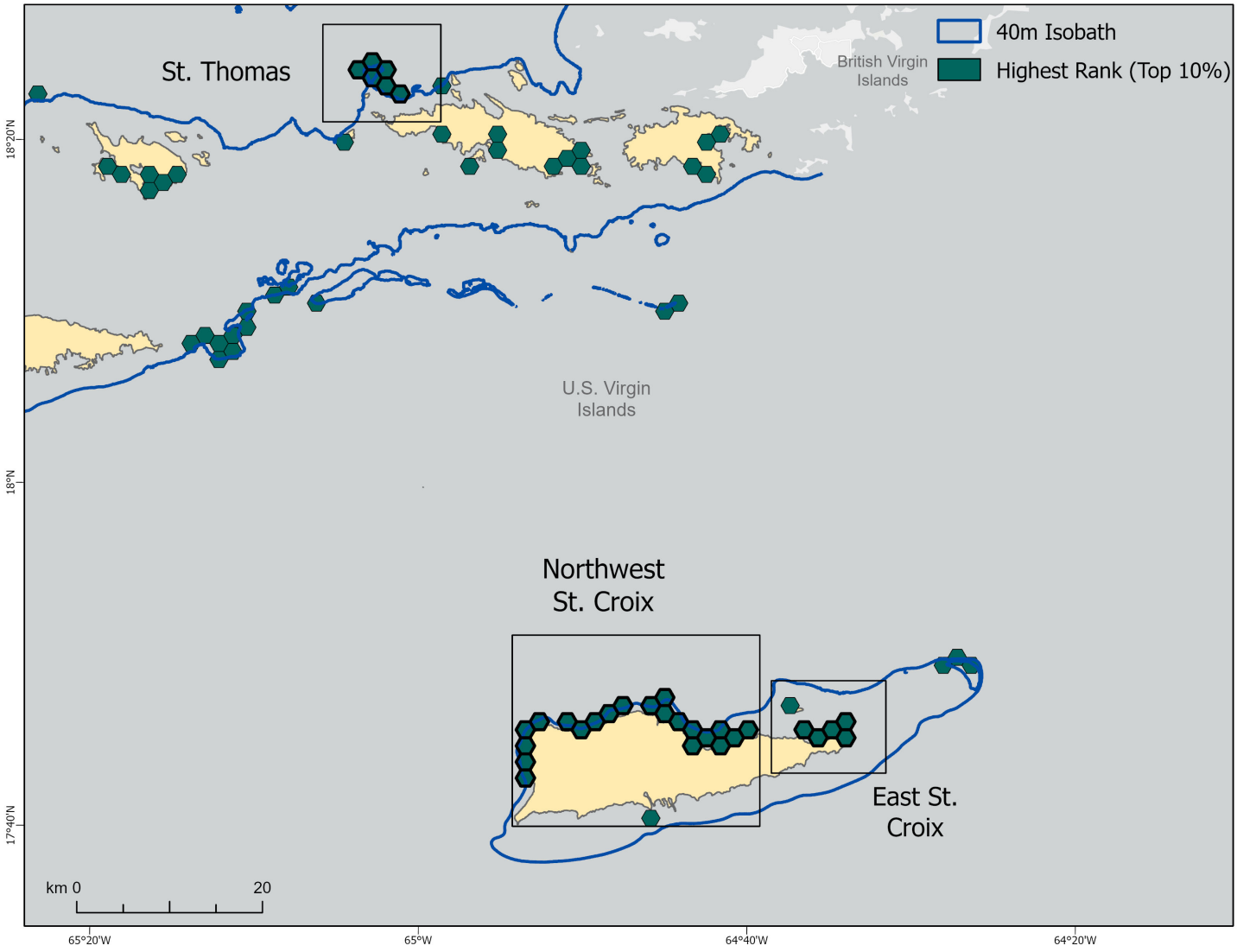


Figure 31. High priority areas identified in the USVI using the highest summary rank (Top 10%).

4.4.1 St. Thomas

Off the northwestern coast of St. Thomas, six hexagons (total area of 15.6 km^2) were identified by six participant groups (Figure 32). Lidar data covers sparse areas of this region, and recent (2001 or later) multibeam data coverage was not found within this area (Figure 33). Habitat characterization maps published in 2002 (NCCOS BIOmapper; Kendall et al., 2001) extend throughout this area, however updating is warranted given the severity of storms, expansion of Stony Coral Tissue Loss Disease (SCTLD), and various global and local stressors associated with climate change. Further, these habitat maps were derived using data collected over 20 years ago using older technology with coarser resolution than today's higher resolution technology.

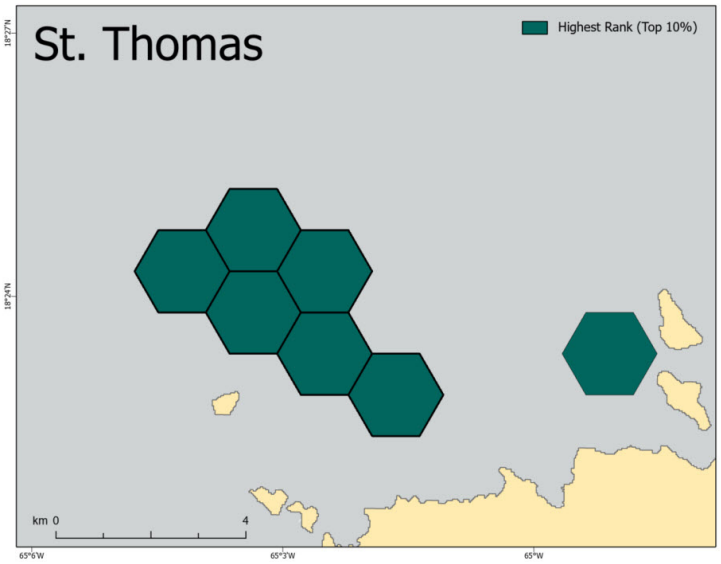
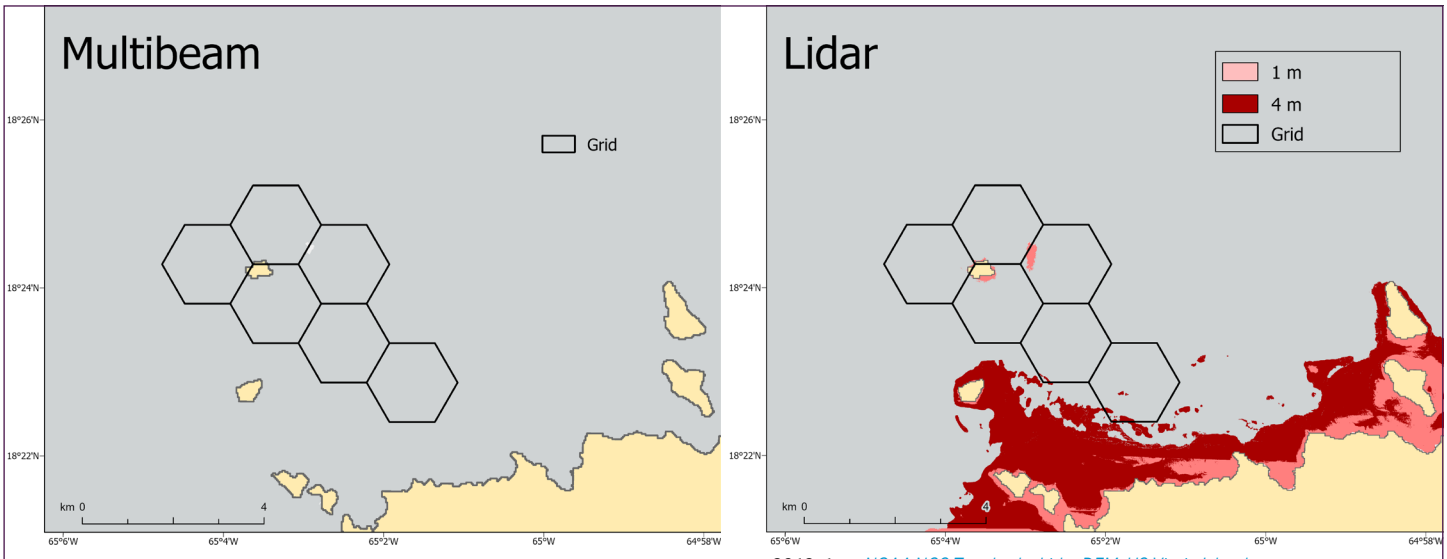


Figure 32. Highest ranking cells off the northwest coast of St. Thomas.

This focal area covers several offshore cays (Cockroach, Sula, and Cricket) which are locally managed by USVI Department of Natural Resources' (DPNR) Coastal Zone Management (CZM), and Division of Fish and Wildlife (DFW). These local government agencies are interested in these areas to support *Endangered Species Management*, *Fisheries Management* (Table 9), and general indexing for identifying areas of opportunity for species reintroduction, conservation, and restoration. The top two Map Product Requirements in this region, *Density of Macrobiota* and *Substrate Types*, would not be able to be characterized using the sparse existing lidar data. Additional surveys to collect underwater photos and videos would be crucial in confirming habitat characteristics to support the top Management Uses (*Spatial Protection* and *Fisheries Management*) and long-term *Monitoring* (S. Habtes, pers. comm.).

Table 9. Data summary of participant input for the northwest St. Thomas focal area. Percent coins are calculated based on the Management Use, Map 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:**
Medium (6)	Highest Top 10% (6)	4
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Spatial Protection/Mgmt (40%)	Density of Macrobiota (35%)	Mesoscale (68%)
Fisheries Mgmt (21%)	Substrate Types (34%)	Regional (27%)
Endangered Species Mgmt (17%)	Topographic Features (16%)	Microscale (5%)
Monitoring (4%)	Hard vs. Soft Bottom (11%)	



No multibeam data coverage exists from 2001 or later.

2019: 1 m - NOAA NGS Topobathy Lidar DEM: US Virgin Islands
2011: 4 m - H12271

Figure 33. Coverage of existing bathymetric data for multibeam (left) and lidar (right) in the northwest St. Thomas region. List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data.

4.4.2 Northwest St. Croix

Off the northwestern coast of St. Croix, 21 hexagons (total area of 54.6 km^2) were identified as an area of data need by ten participant groups (Figure 34). A combination of lidar and multibeam data covers this region entirely (Figure 35) but may not be at the appropriate scale or have the necessary data products supporting primary management uses (Table 10, mesoscale and microscale). The top Management Use selected was *Habitat Restoration*, with the top Map Product Requirements *Substrate Types* and *Coral Species Identification* (Table 10).

This region of shoreline along the northern and western section of St. Croix is densely populated and contains extensive reef habitat. Recent development and ecological activities have been proposed in this area such as marinas, piers, road projects, coral nurseries, etc., and require special considerations to ensure compliance with Section 7 of the Endangered Species Act (ESA) and Section 404(b)(1) of the Clean Water Act (K. Urelius, pers. comm.). Updated data within this area would improve permit evaluations.

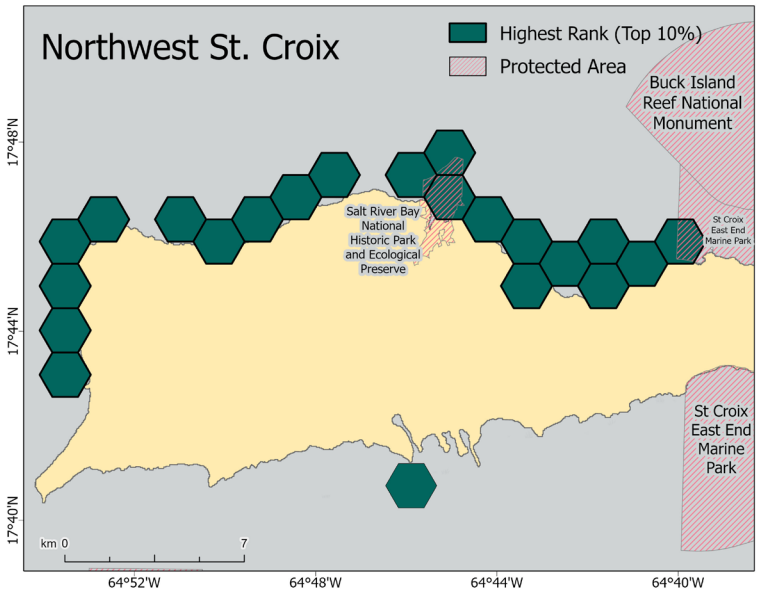


Figure 34. Highest ranking cells along the northwest coast of St. Croix.

Table 10. Data summary of participant input for the northwest St. Croix focal area. Percent coins are calculated based on the Management Use, Map Product Requirement, and Spatial Scale coin totals within these 21 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% (11)	Highest Top 10% (21)	10
High (5), Medium (5)		
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Habitat Restoration (37%)	Substrate Types (28%)	Mesoscale (44%)
Monitoring (19%)	Coral Species ID (22%)	Microscale (30%)
Coastal Vulnerability (15%)	Density of Macrobiota (17%)	Regional (26%)
Endangered Species Mgmt (12%)	Habitat Suitability (16%)	

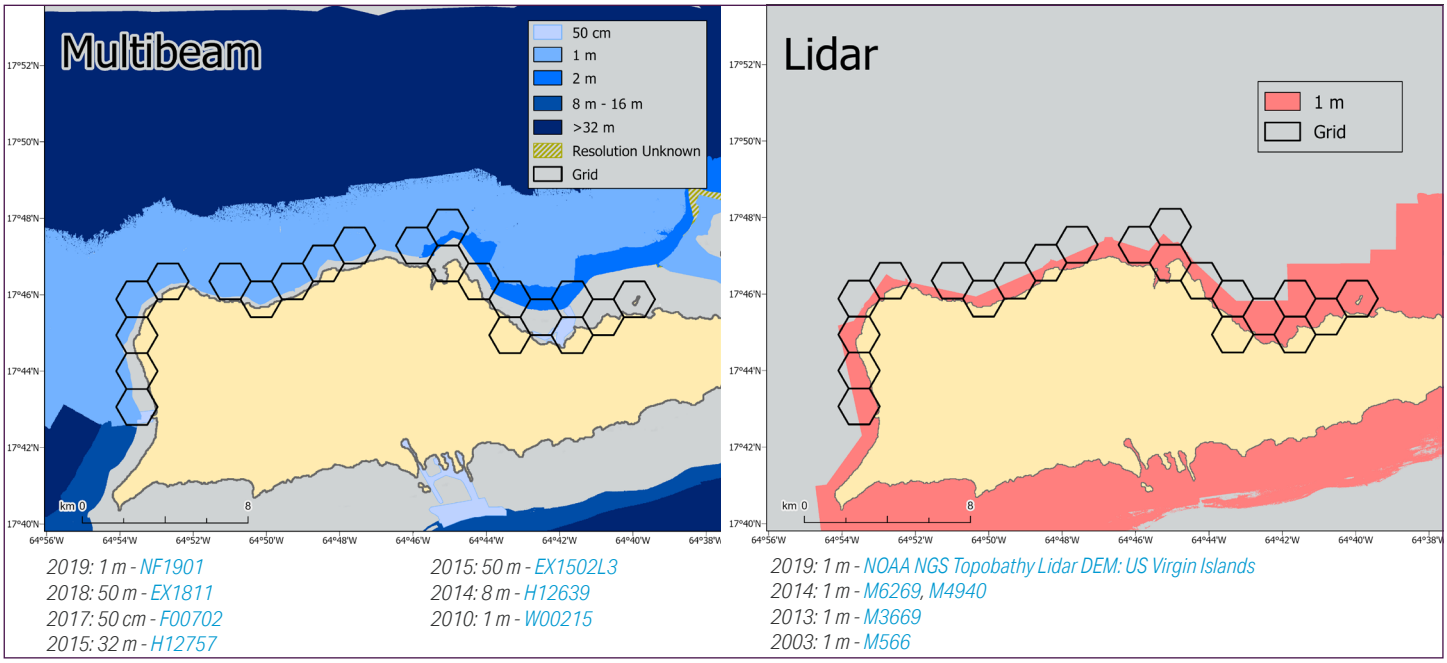


Figure 35. Coverage of existing bathymetric data for multibeam (left) and lidar (right) in northwest St. Croix region. List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data.

4.4.3 East St. Croix

Off the eastern coast of St. Croix, five hexagons (total area of 13 km^2) were identified as an area of need by five participant groups (Figure 36). These cells are well covered by lidar with very little multibeam coverage, leaving some data gaps in the two easternmost cells (Figure 37). This entire focal area is within the St. Croix East End Marine Park.

The top Management Uses identified in this area were *Habitat Restoration* and *Spatial Protection and Management* (Table 11). General requirements for mapping products for fisheries-independent surveys are sonar data with backscatter at a 1–2 m resolution in shallow depths (0–50 m). This allows for characterization of substrate complexity and hardness (i.e., hard vs. soft). Mapping this area with multibeam sonar technology would provide vital information that can be used to improve stock assessments and management by federal and territorial government agencies, in conjunction with academic partners (S. Smith, pers. comm.).

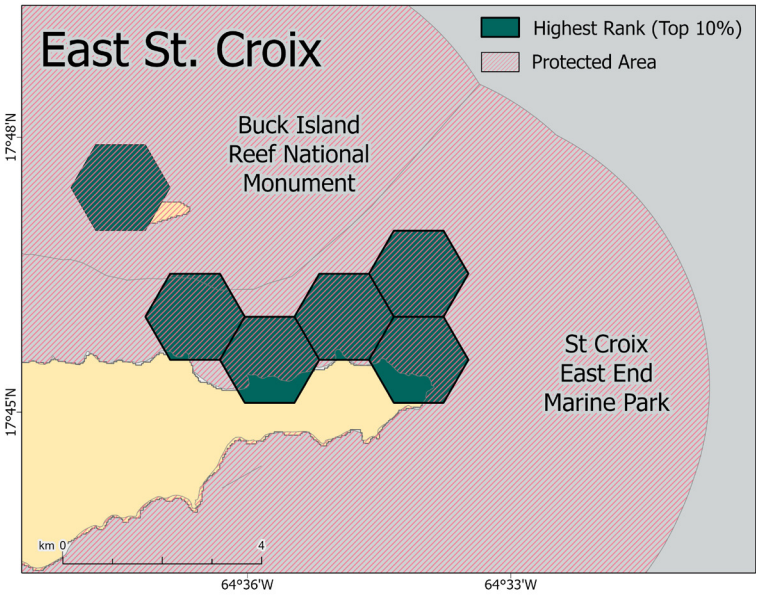
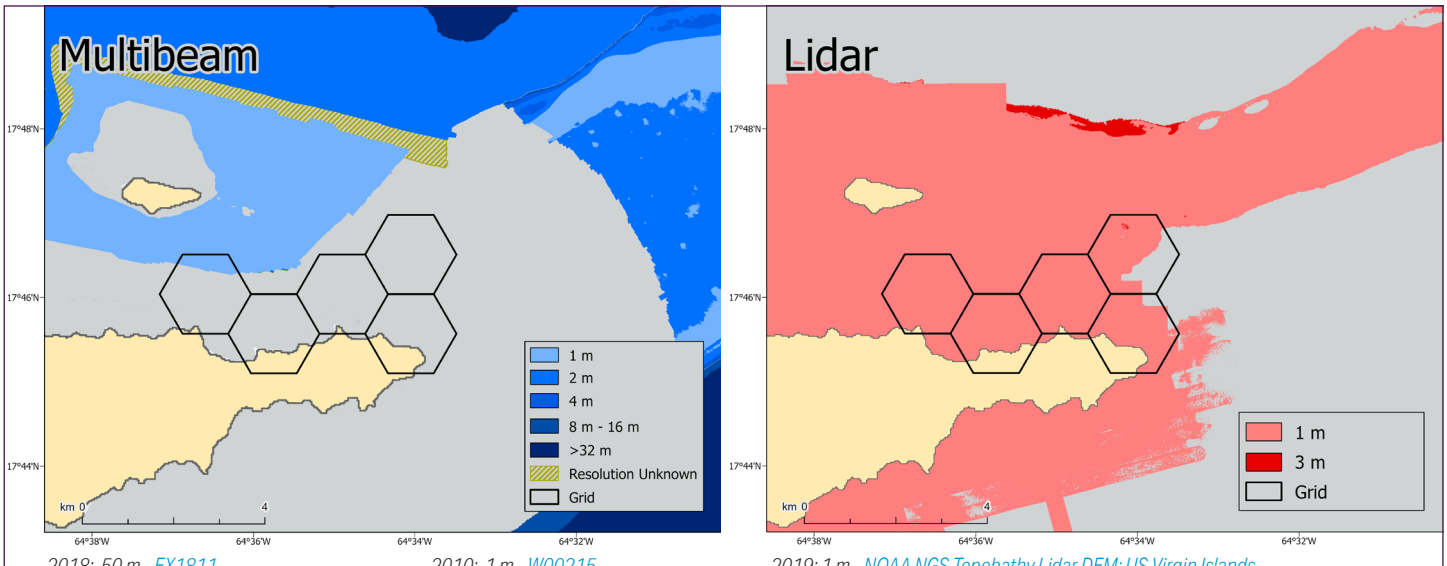


Figure 36. Highest ranking cells off the east coast of St. Croix.

Table 11. Data summary of participant input for the east St. Croix focal area. Percent coins are calculated based on the Management Use, Map Product Requirement, and Spatial Scale coin totals within these nine 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)	Highest Top 10% (5)	5
High (3)		
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Habitat Restoration (36%)	Habitat Suitability (38%)	Regional (50%)
Spatial Protection/Mgmt (29%)	Density of Macrobiota (27%)	Mesoscale (39%)
Monitoring (17%)	Hard vs. Soft Bottom (13%)	Microscale (10%)
Fisheries Mgmt (12%)	Substrate Types (12%)	



2018: 50 m - EX1811
2015: 32 m - H12757
2014: 1, 2, 4, 8 m - H12639
2010: 1 m - W00215
2006: 2 m - W00199
2006: 150 m - RB0604
2019: 1 m - NOAA NGS Topobathy Lidar DEM: US Virgin Islands
2014: 1 m - M6269, M4940
2011: 1 m - M1394
2003: 1 m - M566

Figure 37. Coverage of existing bathymetric data for multibeam (left) and lidar (right) in the east St. Croix region. List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data.

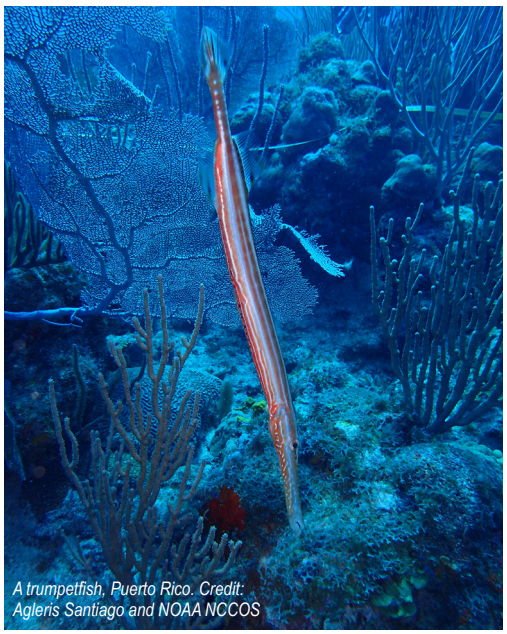
Chapter 5 Conclusion


A hamlet species in hard bottom habitat, Puerto Rico. Credit: Agleris Santiago and NOAA NCCOS

We used an online application to gather data needs from local experts in Puerto Rico and the USVI regarding their priorities for benthic mapping to support coral reef management. This system allowed participants to indicate where mapping data are needed, the urgency of the need, what coral management actions will be addressed with this data, and what type of objectives will be met. There are many areas that were of high interest for future mapping. These areas were within the Top 10% of ranked cells having the highest combined overall coin totals, number of participant groups who allocated coins into those cells, and diversity of Management Uses. In Puerto Rico, clusters of highest ranking cells (Top 10%) were located off the coasts of Guánica Bay, Arecibo, and Humacao. Another top ranked area was in the northwest portion of Sonda de Vieques, a large bay area located between Culebra and Vieques islands. Several smaller groups of high ranking cells were located off the west coast of Puerto Rico, in areas such as coastal Rincón and around Desecheo Island. Results around the USVI highlighted several more areas of high interest to local participants, including along the entire northern shoreline of St. Croix, and around several offshore cays off the northwest coast of St. Thomas. There were data needs identified by participants around St. John Island, with one high priority cell in Coral Bay. However, these cells around St. John were not ranked high overall due to fewer total coins and small number of participants.

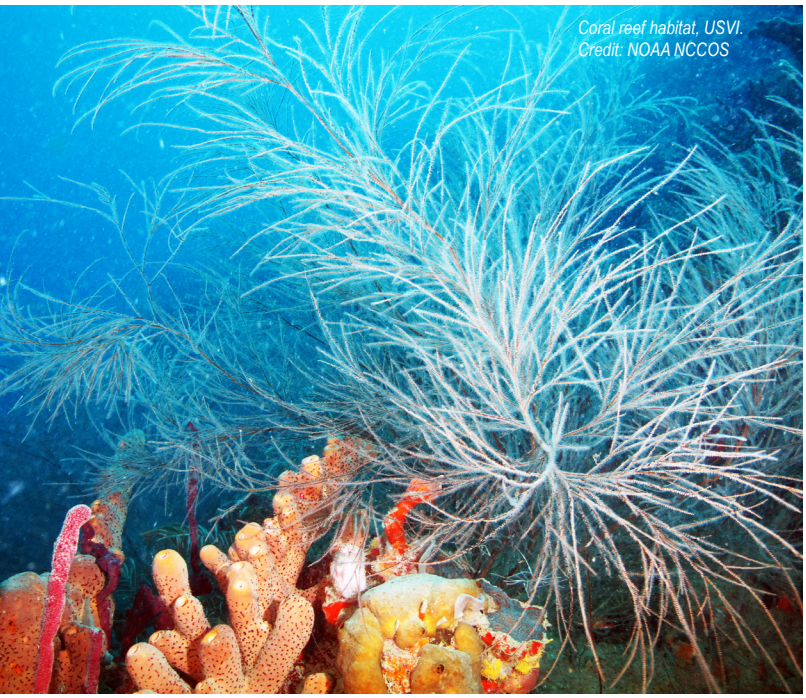
These highest ranking cell clusters highlight some of the best opportunities for collaboration, with the potential to meet a variety of coral reef management goals. As an example, a large group of cells outside Guánica Bay in south Puerto Rico highlights several initiatives and mandates aimed at managing the watershed and associated downstream coral reefs. Additionally, this area contains several high interest coral aggregations containing ESA-listed coral species and areas of interest for for coral nurseries, outplanting, and disease intervention. Another example within the USVI is a group of cells off the northwestern coast of St. Thomas, an area that covers several offshore cays locally managed by the government of Virgin Islands, DPNR, and DFW. These local government agencies are interested in identifying areas of opportunity for species reintroduction, conservation, and restoration surrounding these small islands which currently lack high-quality mapping data.

It is also important to recognize that some places were identified as high priority, but for only one or two participating groups. For example, cells off the east coast of Culebra Island had values in the Top 10% for overall coins, however several of these cells only had input from one participant group. There were, however, several cells in this area that were high ranking and of interest to four different groups. Thus, any mapping data collection would be valuable to multiple groups and provides an opportunity for collaboration with other participants to expand data collection to adjacent areas of interest. The distribution and diversity of Management Use selection can also highlight important areas where a variety of goals can be met. For example, the entire Sonda de Vieques region had five or more different Management Uses selected by participating groups. However, these cells did not receive a significant amount of coins and thus were not deemed a high priority in terms of urgency. Similarly, several areas around St. Croix and Culebra Island showed a high need for the Map Product Requirement *Condition of Coral Taxa*, however were only selected by three participant groups. These examples illustrate the diversity of goals across participating groups and, in some cases, the uniqueness of participant group needs.


A trumpetfish, Puerto Rico. Credit: Agleris Santiago and NOAA NCCOS

Also noteworthy are areas of urgent data need by a participant group, or groups. Cells receiving 8–10% of a participant's coins indicated data were needed within a year. Often these areas were not within the Top 10% of total coins or highest summary rank category when all data were combined but are discussed here due to the urgency of need. Within the USVI, an area off the southwest corner of St. Croix's Sandy Point received coins by multiple organizations, with one assigning the maximum (20) coins. This area is a mutton snapper spawning aggregation area, and updated data would improve information for stock assessment and coral reef and fish management. The eastern end of St. Thomas, including the St. Thomas East End Reserve and the St. James Marine Reserve and Wildlife Sanctuary, was also identified as an area of urgent data need by three organizations. The cells receiving 8–10% of coins did not overlap between these three organizations but were adjacent to one another, suggesting an urgent need within this entire area. This area of the coastline is rapidly developing and includes busy ferry traffic transiting through these reserves multiple times per day. Within Puerto Rico, two organizations identified urgent data needs on the south and east ends of Culebra. Portions of San Juan, Arrecifes de la Cordillera Natural Reserve, Desecheo, and Punta Ganiquilla also contained areas of urgent data needs for participant groups. These areas of Puerto Rico align with coastal development and/or managed areas.

For future mapping planning efforts, targeting cells within the highest summary rank categories will ensure that data collection will fulfill a variety of coral reef management purposes, address a need for several participating groups, and satisfy an immediate need for updated information. However, refining the area based on survey optimization and finer scale considerations is necessary to address specific needs and mandates. For example, the tools and effort needed to map various grid cells differs depending on depth and water clarity. Benthic sonar and lidar mapping technologies are typically focused on gathering data over large geographic areas and features. On the other hand, 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), however the needed processed products (e.g., habitat maps or models) may not exist or there may be missing information (e.g., data may be outdated, too coarse resolution, poor quality, or lack ancillary data such as backscatter) that make the data unusable for the needed management requirement. Future surveys may exclude these areas that have already been mapped, however whether these existing data meet the needs of local agencies should be considered.



Coral reef habitat, USVI. Credit: NOAA NCCOS

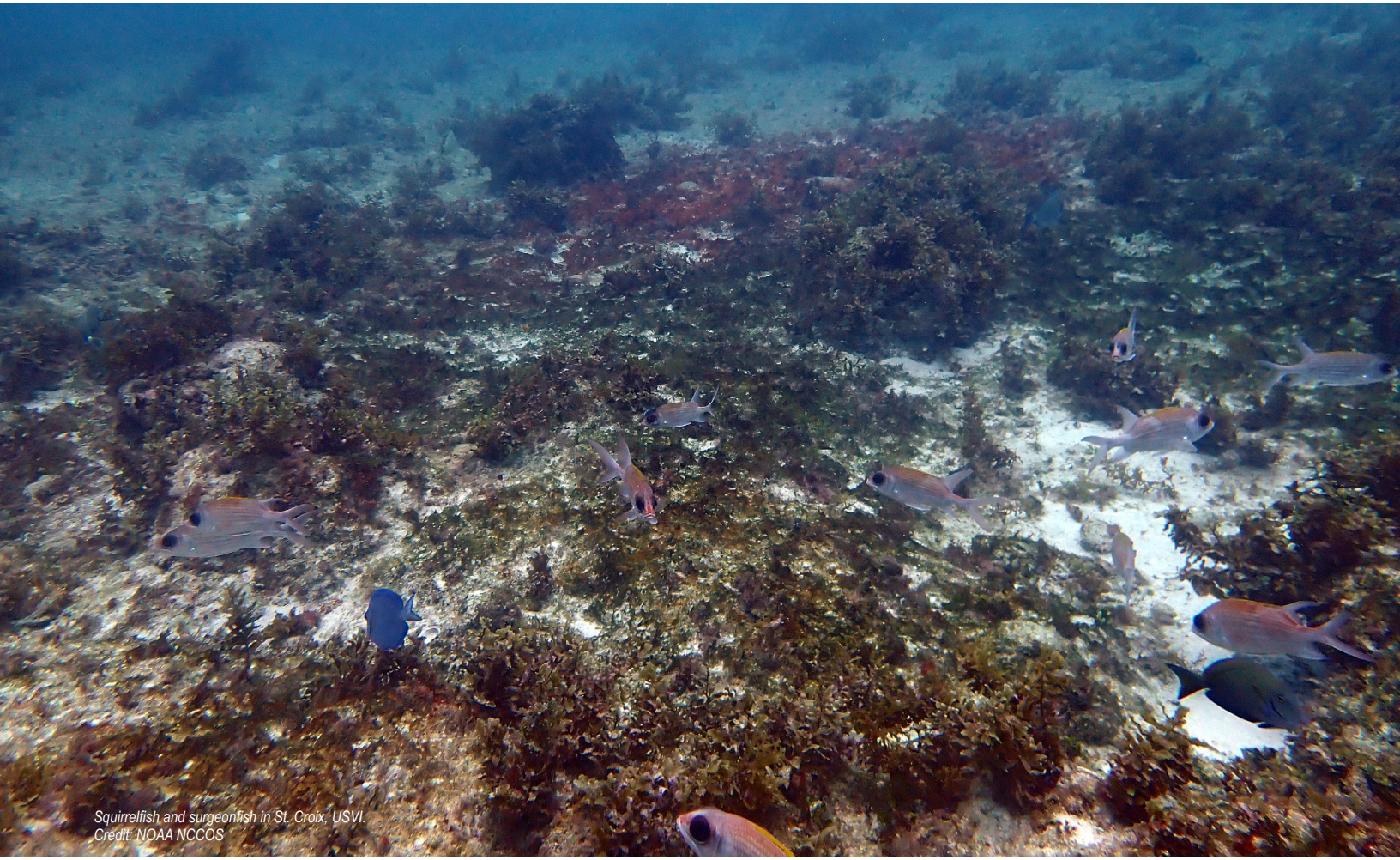
Hard bottom habitat with gorgonian sponge, USVI. Credit: NOAA NCCOS

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 submitted to Zenodo, an online data repository approved by NOAA, for long-term preservation and public access. Finally, these web mapping services were ingested by and published in NOAA's Integrated Ocean and Coastal Mapping (IOCM) U.S. Mapping Coordination website (NOAA IOCM, 2021). See links below for access to reports, data viewers, and downloads.

Datasets, Data Web Services, and Metadata:

- 2022: Priority areas recommended for shallow coral reef management in Puerto Rico and the U.S. Virgin Islands, 2021-11-03 to 2022-01-14
  - Zenodo Accession (Kraus et al. 2022)
- 2022: Dashboard - Puerto Rico and US Virgin Islands Coral Reef Mapping Prioritization Results
- 2021: Project Website - Coral Reef Prioritization | A Roadmap for Future Mapping
- 2021: NCCOS Website - Defining Future Seafloor Mapping Priorities to Inform Shallow Coral Reef Management



Squirrelfish and surgeonfish in St. Croix, USVI.
Credit: NOAA NCCOS

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Appendices

Appendix A: Data Inventory Reference Table

Table A.1. Puerto Rico and the USVI mapping inventory data table. Each webservice within the data inventory shared with participants is listed below. Whether the data cover an archipelago area is also noted (PR = Puerto Rico, STTJ = St. Thomas and St. John, STX = St. Croix). Map service URLs accessed on June 20, 2022.

Category	Item Name (name of web service)	PR	STTJ	STX	Description	Map Service URL
Multibeam	Bathymetric Attributed Grid (BAG) Image Services with Survey Polygons	x	x	x	Various resolutions. A compilation of bathymetric data sources housed by NOAA NCEI.	https://noaa.maps.arcgis.com/home/item.html?id=26ee4c6159b842219cb9729b9ef1b881
	Nancy Foster 2019 MBES (USVI)			x	(1m, 2m, 4m, 8m, 16m, 32m) mosaiced to 32m. Multibeam bathymetry from the Nancy Foster 2019 mission off the northwest coast of STX.	https://noaa.maps.arcgis.com/home/item.html?id=13d47a3bb08949118e3bf93f1fff1c68
	Multibeam Footprints (2001–2018)	x	x	x	Various Resolutions. An inventory of existing seafloor mapping surveys including coverage extent footprints of currently available digital, contemporary swath acoustic sonar for the US Caribbean. Data source is the NOAA NCEI Bathymetric Data Viewer. Data collected between 2001–2018.	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BiogeographicAssessments_USCaribbeanPrioritization/MapServer/21
Lidar	2019 Puerto Rico and US Virgin Islands NGS Topobathy Lidar (1m)	x	x	x	1m resolution. A tiled collection of lidar from the coast of PR and the USVI, collected in 2019	https://noaa.maps.arcgis.com/home/item.html?id=74f727b75394456da24db47653e6c33b
	Puerto Rico LiDAR (USACE and NGS, 2016, 2018)	x			1m resolution. A tiled collection of lidar from the coast of PR, collected in 2016 and 2018	https://noaa.maps.arcgis.com/home/item.html?id=b4ed1b56a65a47fdb514c69469e9567d
	Lidar Footprints (2000–2018)	x	x	x	Various Resolutions. An inventory of existing seafloor mapping surveys from 2000–2018, including coverage extent footprints of currently available digital, contemporary Lidar for the US Caribbean. Data source is the NOAA NCEI Bathymetric Data Viewer.	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BiogeographicAssessments_USCaribbeanPrioritization/MapServer/21
Habitat Maps	Puerto Rico Coral Habitat (2016)	x			This tiled layer displays coral habitat data from 2016 in PR. Only the habitats used in the hurricane coral reef assessment and triage effort in PR in 2018 are shown.	https://noaa.maps.arcgis.com/home/item.html?id=b9b34be4a767489ab0e69b48eb667bfc
	Northeast Reserve, PR (2015) - Zoom to view	x			This habitat map from 2015, displays benthic data used to support the hurricane coral reef assessment and triage effort in PR in 2018. Specifically off the east coast of PR.	https://noaa.maps.arcgis.com/home/item.html?id=6c62152a98874dabb7e00c1c87854f2d
	Northeast Reserve Coral Cover - Zoom to view	x			This tiled layer displays coral habitat data related to the Northeast Reserve in PR. Only the habitats used in the hurricane coral reef assessment and triage effort in PR in 2018 are shown.	https://noaa.maps.arcgis.com/home/item.html?id=d8964cf16c4e44da9cccb6913a5bacca
	Various Habitat Maps (NOS Biogeo Biomapper)	x	x	x	These data provide a detailed, contemporary evaluation on the status, abundance, and distribution of marine benthic habitats for PR and the USVI. NE Marine Corridor 2014, southwest PR 2012, Jobos Bay 2010, Vieques 2010, STTJ 2013, PR 2002, Buck Island 2011, STJ 2009 shallow, STJ 2009 moderate, USVI 2002	https://idpgis.ncep.noaa.gov/arcgis/rest/services/NOS_Biogeo_Biomapper
Boundaries Points	2019 US Caribbean Prioritization Results	x	x	x	This data identifies priorities for seafloor mapping and visual surveys in the US Caribbean territories of PR and USVI. This analysis was conducted in 2019.	https://www.fisheries.noaa.gov/inport/item/65526
	Puerto Rico NCRMP Grid (50m)	x			The 50m sampling grid used by the National Coral Reef Monitoring Program (NCRMP) in PR	https://noaa.maps.arcgis.com/home/item.html?id=55a6df4be15a433f853befba022da59b
	St. Thomas, St. John, St. Croix NCRMP Grid (50m)		x	x	The 50m sampling grid used by NCRMP in the USVI	https://noaa.maps.arcgis.com/home/item.html?id=e553b6d5ad9b449c98c6a1d9d3c3a0d4
	Depth Contour (40m)	x	x	x	The 40m depth contour around Puerto Rico and the USVI derived from NOAA's NCEI Digital Elevation Models Global Mosaic.	https://noaa.maps.arcgis.com/home/item.html?id=7727ae56f8db4b5e960db210ead0cebc
	US National Park Service Lands		x	x	Areas of land and ocean managed by the National Parks Service in the US Caribbean.	https://noaa.maps.arcgis.com/home/item.html?id=5ebb85755b864aefa150c012c82f6624
	Protected Areas	x	x	x	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. Last updated in 2016	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BiogeographicAssessments_USCaribbeanPrioritization/MapServer/7
	Maritime Limits	x	x	x	Maritime limits and boundaries for the U.S. are measured from the official U.S. baseline, recognized as the low-water line along the coast as marked on the NOAA nautical charts in accordance with the articles of the Law of the Sea.	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BiogeographicAssessments_USCaribbeanPrioritization/MapServer/3
	Secondary Sensors (split beam, sidescan, etc.)	x	x	x	Various Resolutions. An inventory of existing seafloor mapping surveys including coverage extent footprints of currently available digital, contemporary split beam, side scan, and sounding survey data. Data source is the NOAA NCEI Bathymetric Data Viewer.	https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BiogeographicAssessments_USCaribbeanPrioritization/MapServer/22
	USVI Bathymetry Coverage by Resolution		x	x	This polygon layer shows footprints of bathymetric coverage split out by resolution (2m, 3m, 4m, 10m) for the USVI.	https://noaa.maps.arcgis.com/home/item.html?id=7b48324fe60c4861b858c7d22ef9acf8
	Puerto Rico Bathymetry Coverage by Resolution	x			This polygon layer shows footprints of bathymetric coverage split out by resolution (2m, 3m, 4m, 10m) for PR.	https://noaa.maps.arcgis.com/home/item.html?id=c54c42295fe0455a8c29b812d405ff0c
	Puerto Rico Bathymetry Coverage by Resolution	x			This polygon layer shows footprints of bathymetric coverage split out by resolution (2m, 3m, 4m, 10m) for PR.	https://noaa.maps.arcgis.com/home/item.html?id=c54c42295fe0455a8c29b812d405ff0c
Points	Coral Health Survey Basic Mapping (SCTLD)(2019–2021)	x	x	x	This point file shows various areas in the US Caribbean water where SCTLD has been identified.	https://services8.arcgis.com/C2yYpahRgrVlBqfg/ArcGIS/rest/services/Coral_Health_Survey_Basic_mapping/FeatureServer/0
	SCTLD (rover surveys 2018–2021)	x	x	x	This point file shows all of the roving diver surveys conducted by the US Virgin Islands Coral Disease Advisory Committee between 2018–2021	https://noaa.maps.arcgis.com/home/item.html?id=1d9d72216be84b35b46aefc26ec9c43e

Appendix B: Puerto Rico Individual Maps for Each Management Use

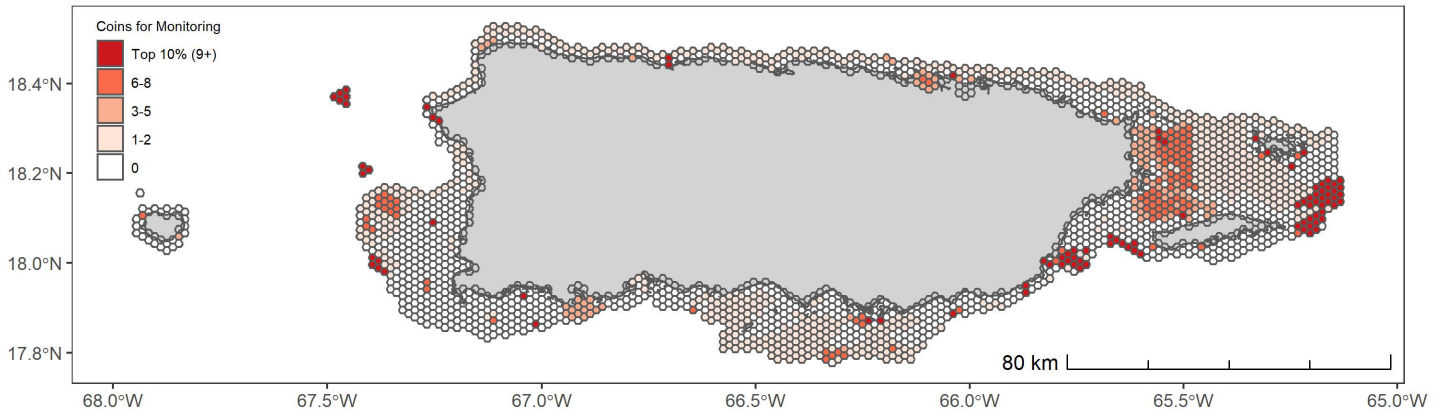

Figure B.1. Map of coins distributed for the Management Use *Monitoring*

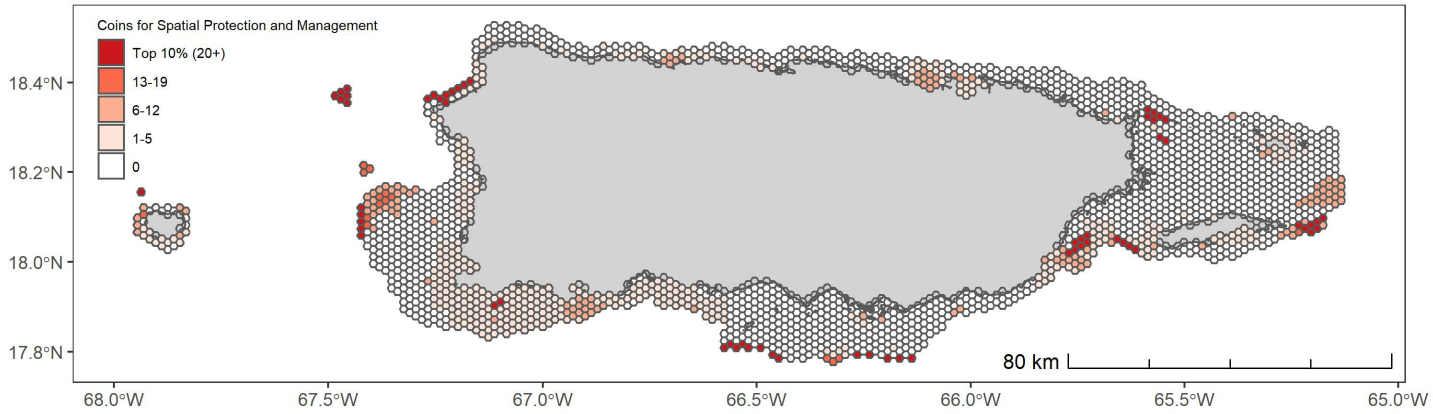

Figure B.2. Map of coins distributed for the Management Use *Spatial Protection & Management*

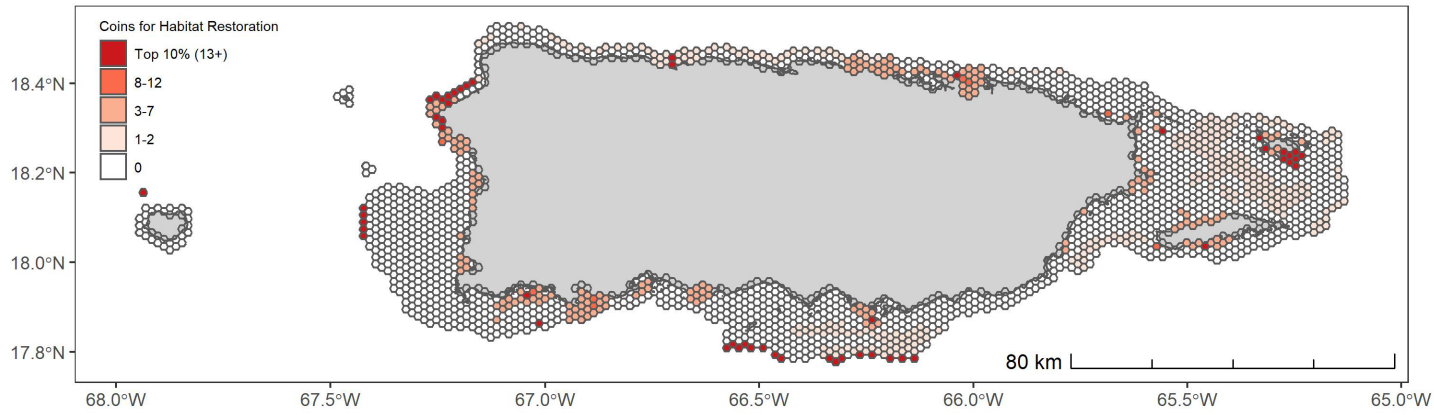

Figure B.3. Map of coins distributed for the Management Use *Habitat Restoration.*

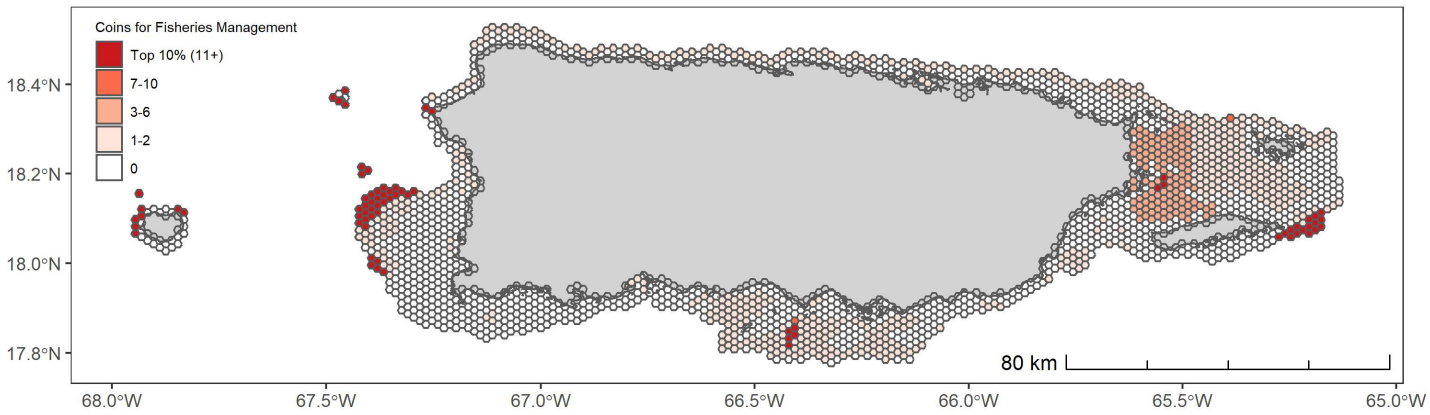

Figure B.4. Map of coins distributed for the Management Use *Fisheries Management.*

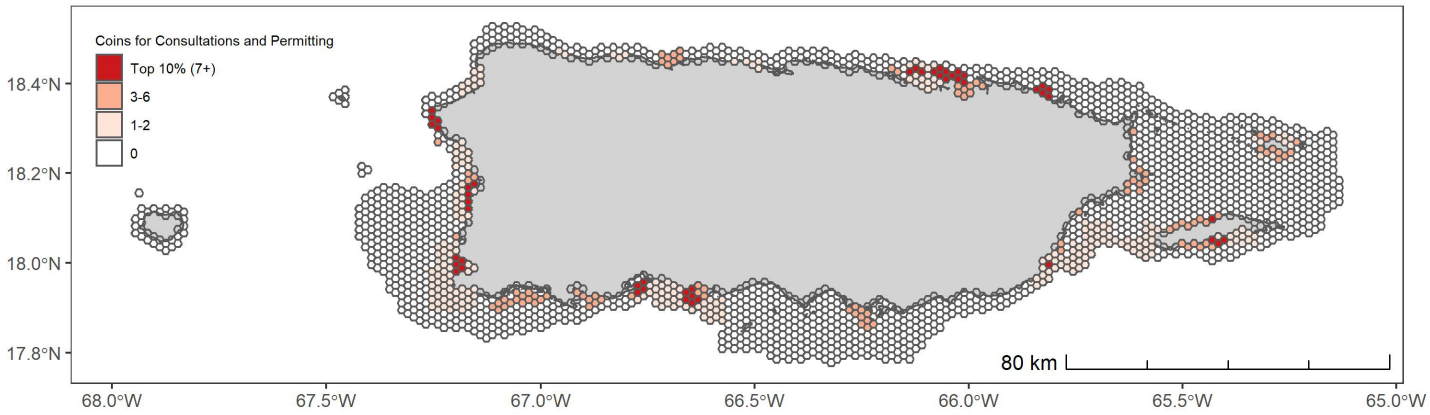

Figure B.5. Map of coins distributed for the Management Use *Consultations and Permitting.*

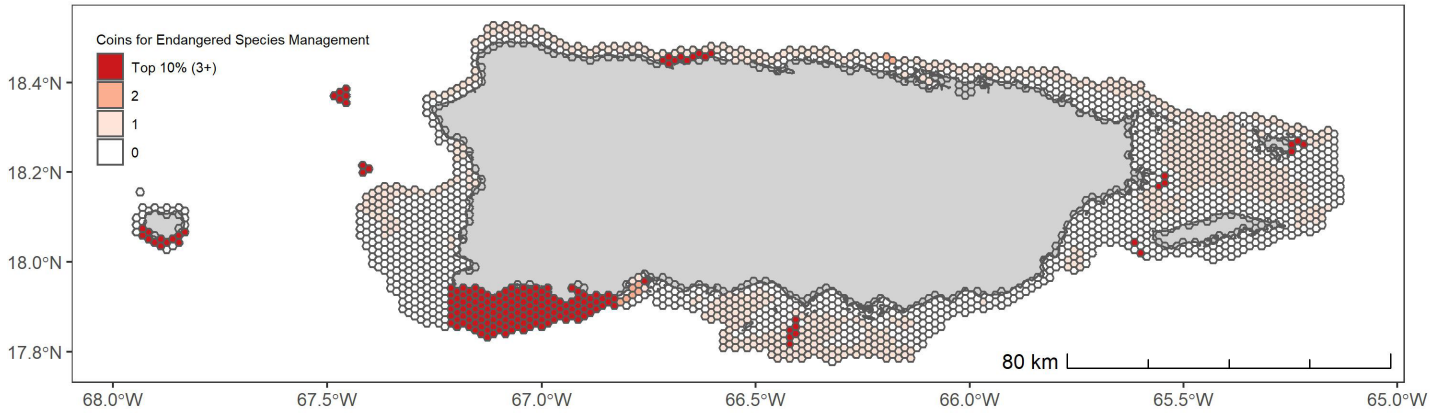

Figure B.6. Map of coins distributed for the Management Use *Endangered Species Management.*

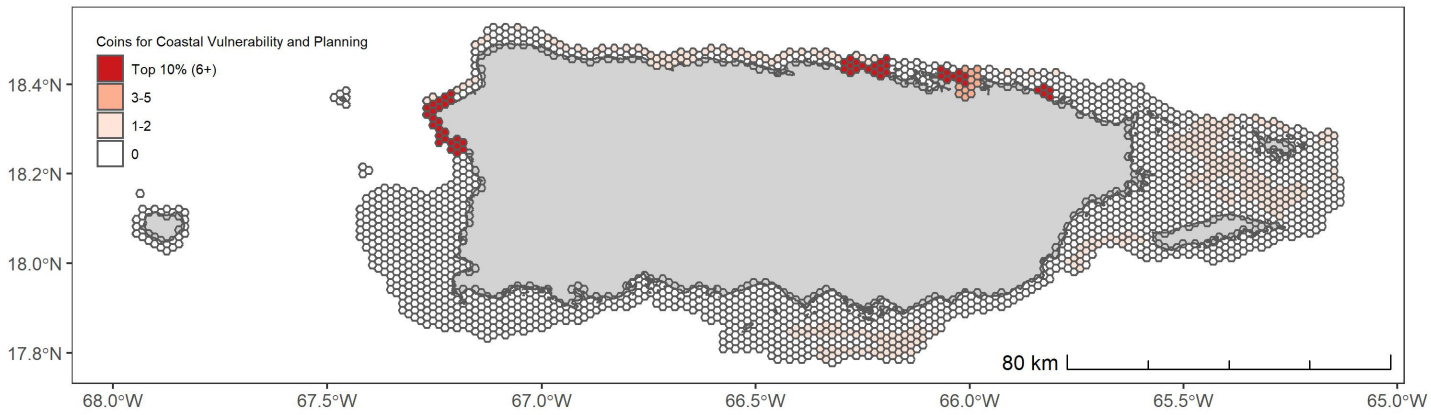

Figure B.7. Map of coins distributed for the Management Use *Coastal Vulnerability and Planning*.

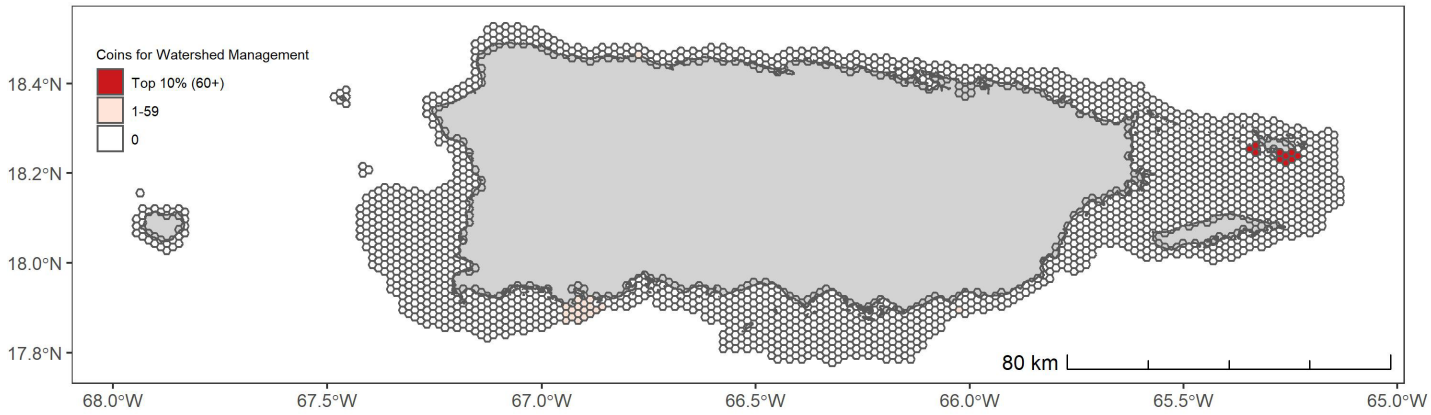

Figure B.8. Map of coins distributed for the Management Use *Watershed Management.*

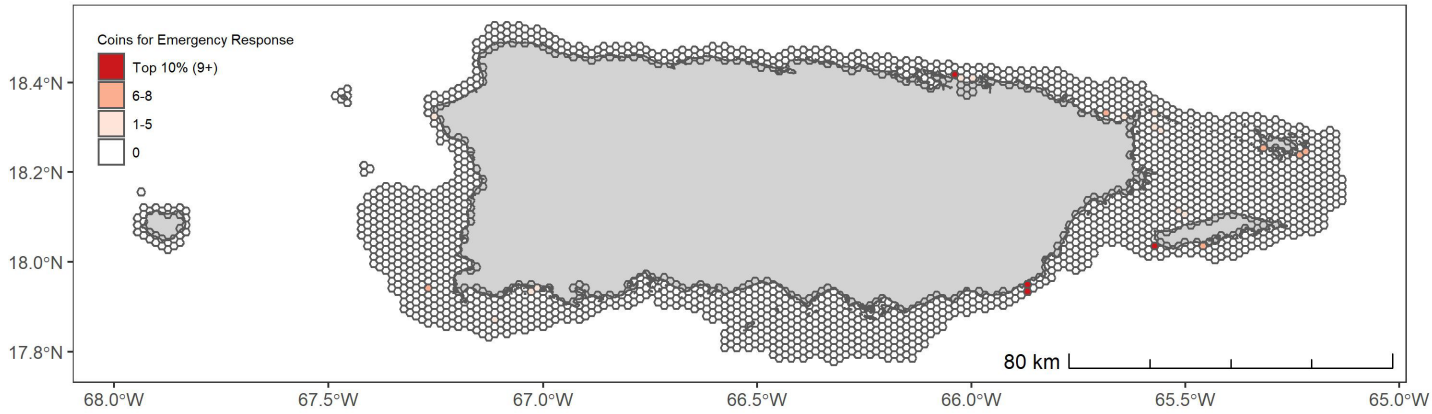

Figure B.9. Map of coins distributed for the Management Use *Emergency Response.*

Appendix C: Puerto Rico Individual Maps for Each Product Requirement

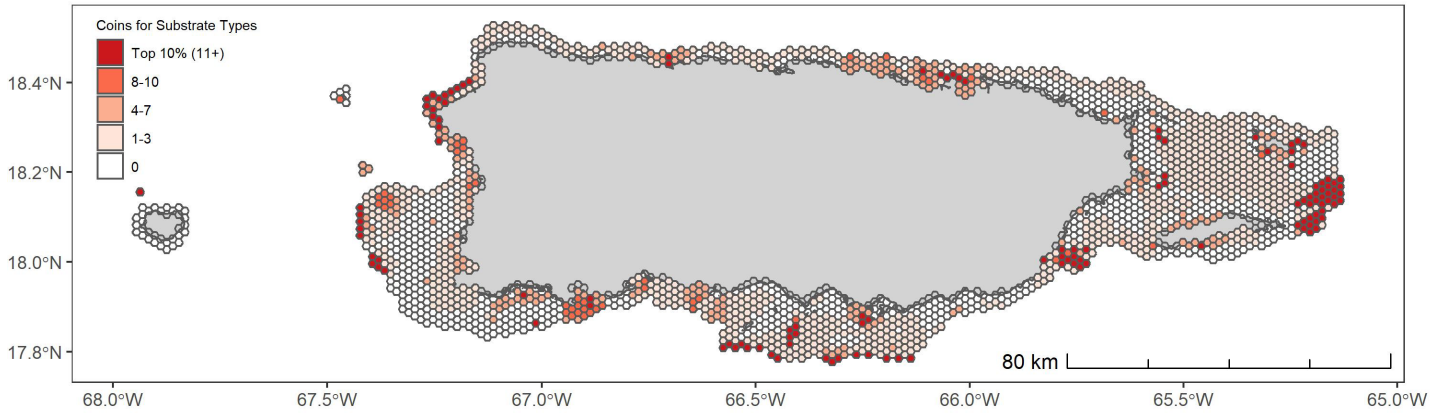

Figure C.1. Map of coins distributed for the Product Requirement *Substrate Types*.

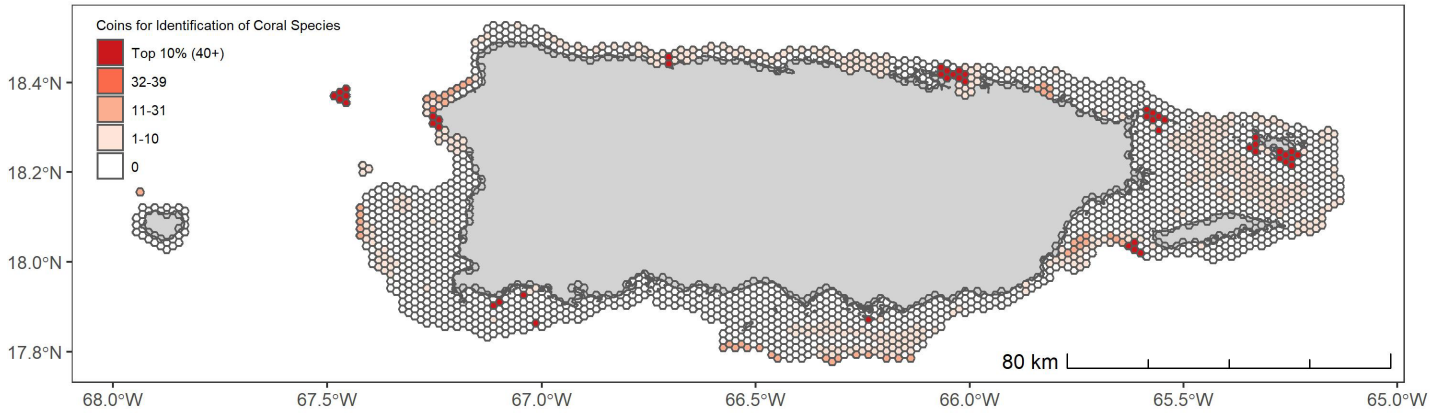

Figure C.2. Map of coins distributed for the Product Requirement *Coral Species.*

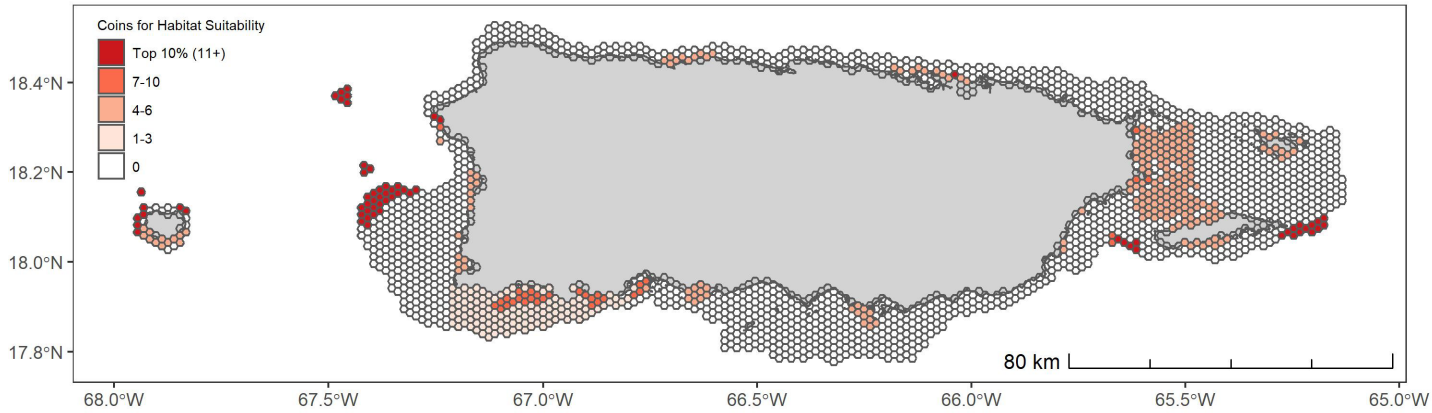

Figure C.3. Map of coins distributed for the Product Requirement *Habitat Suitability.*

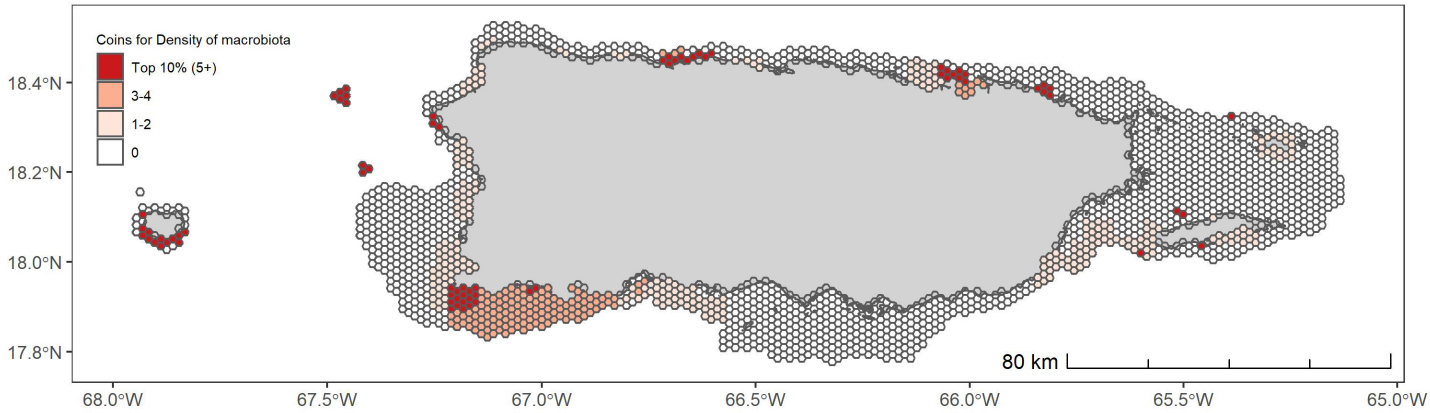

Figure C.4. Map of coins distributed for the Product Requirement *Density of Macrobiota.*

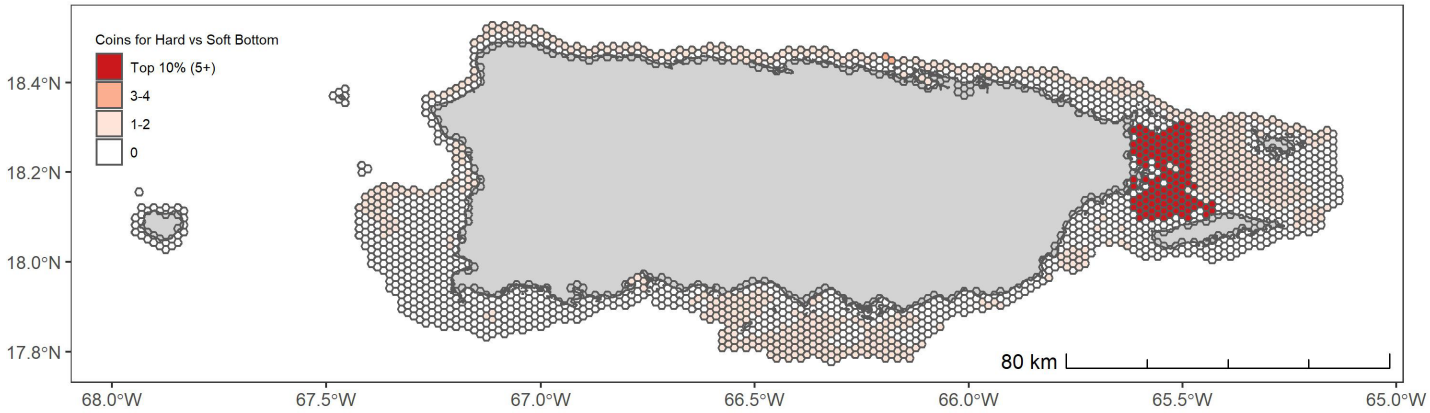

Figure C.5. Map of coins distributed for the Product Requirement *Hard vs. Soft Bottom.*

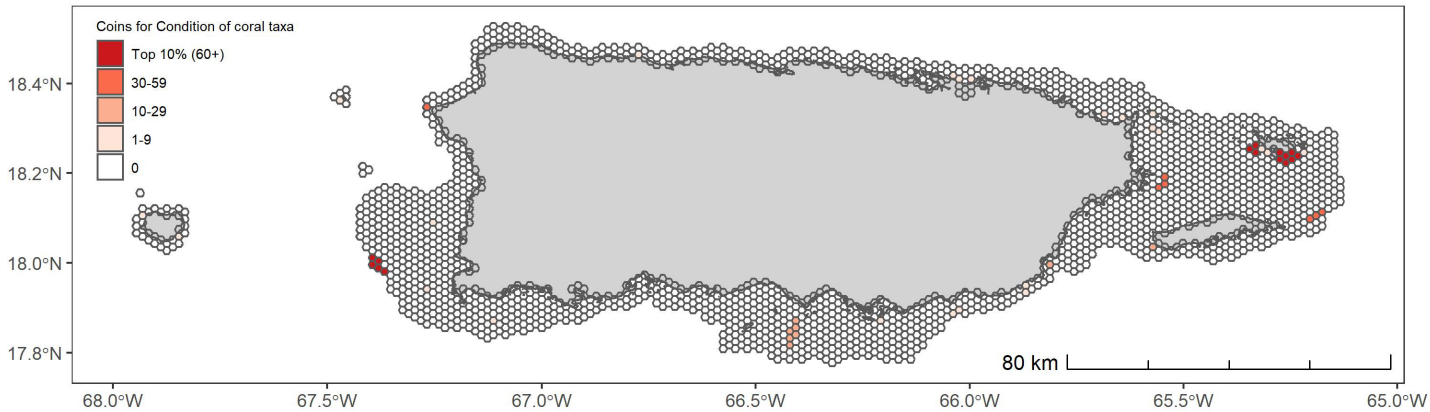

Figure C.6. Map of coins distributed for the Product Requirement *Condition of Coral Taxa.*

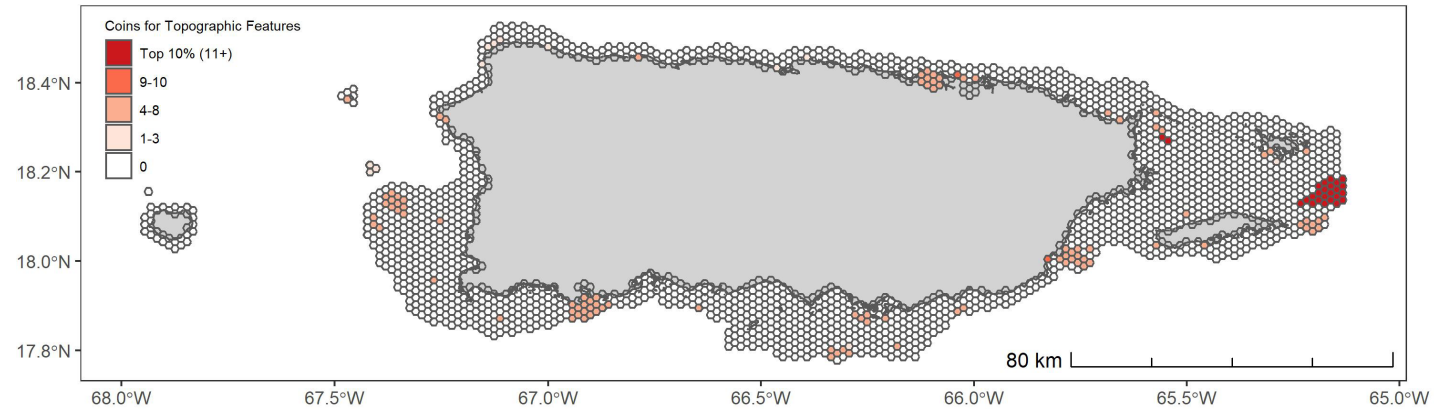

Figure C.7. Map of coins distributed for the Product Requirement *Topographic Features*

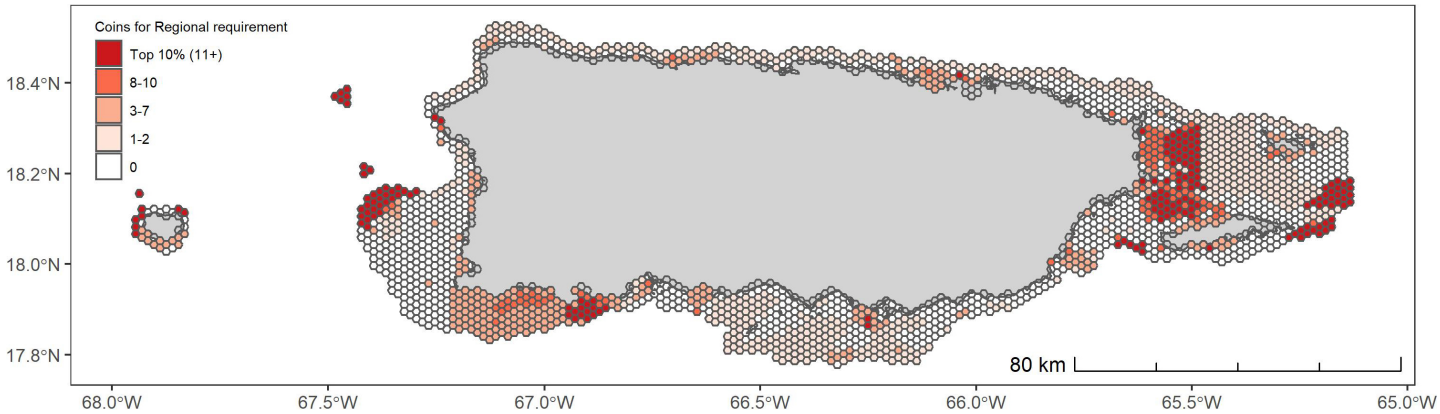

Figure C.8. Map of coins distributed for *Regional Scale* Product Requirements.

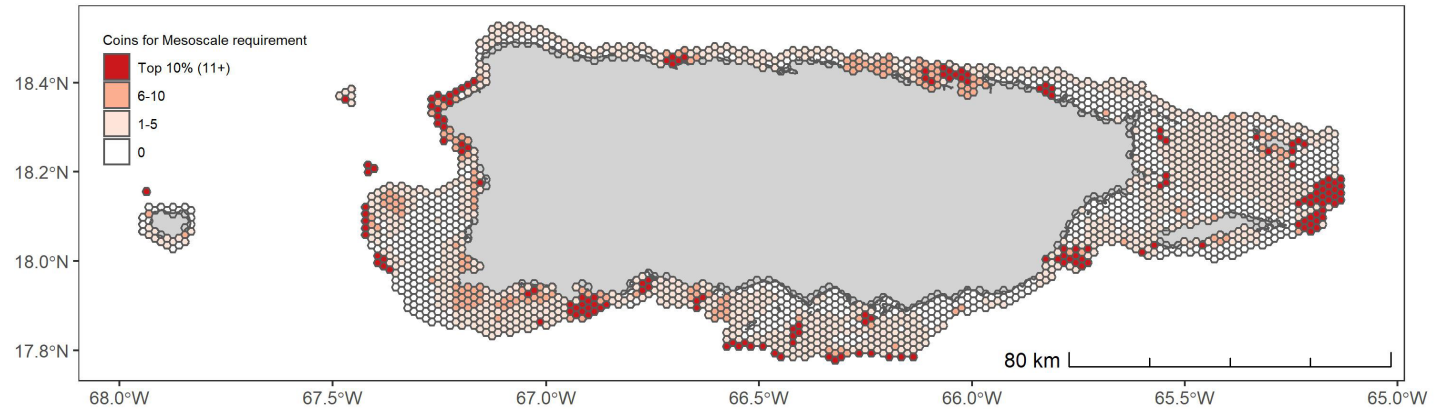

Figure C.9. Map of coins distributed for *Mesoscale* Product Requirements.

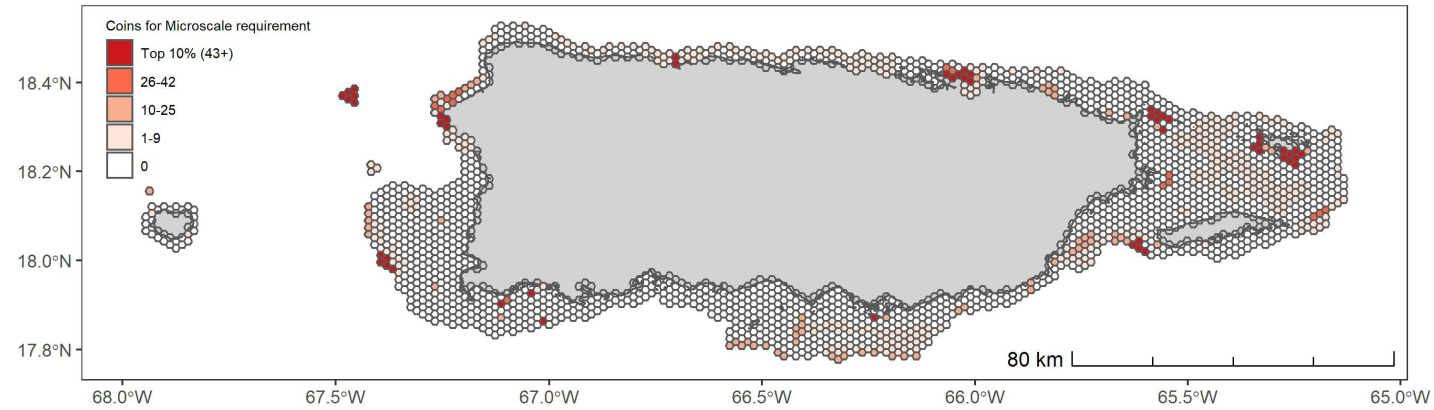

Figure C.10. Map of coins distributed for *Microscale* Product Requirements.

Appendix D: U.S. Virgin Islands Individual Maps for Each Management Use

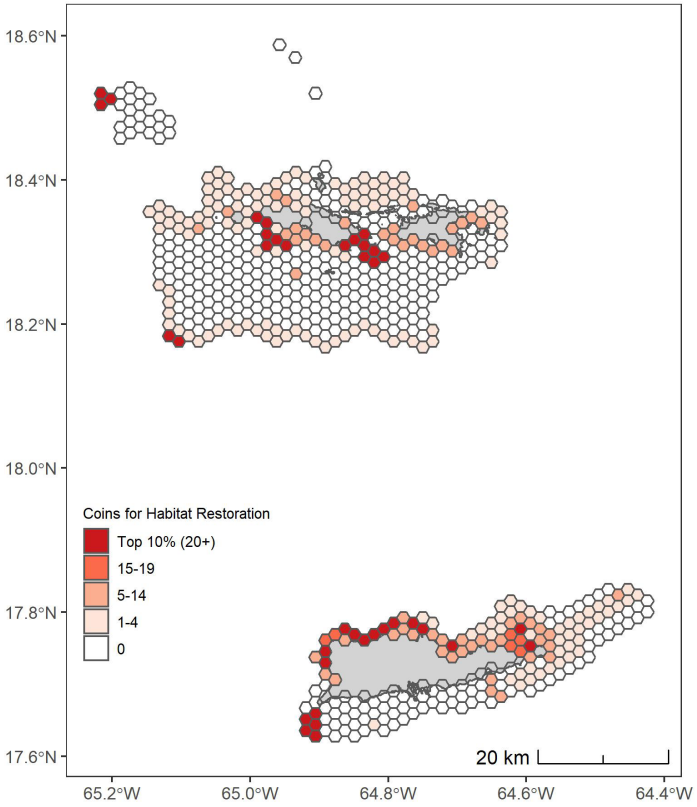

Figure D.1. Map of coins distributed for the Management Use *Habitat Restoration.*

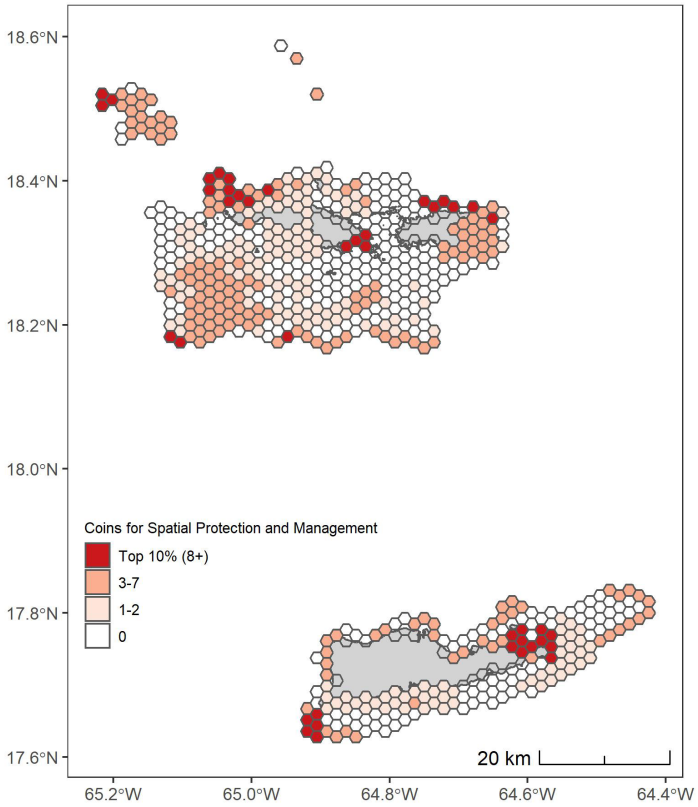

Figure D.2. Map of coins distributed for the Management Use *Spatial Protection & Management.*

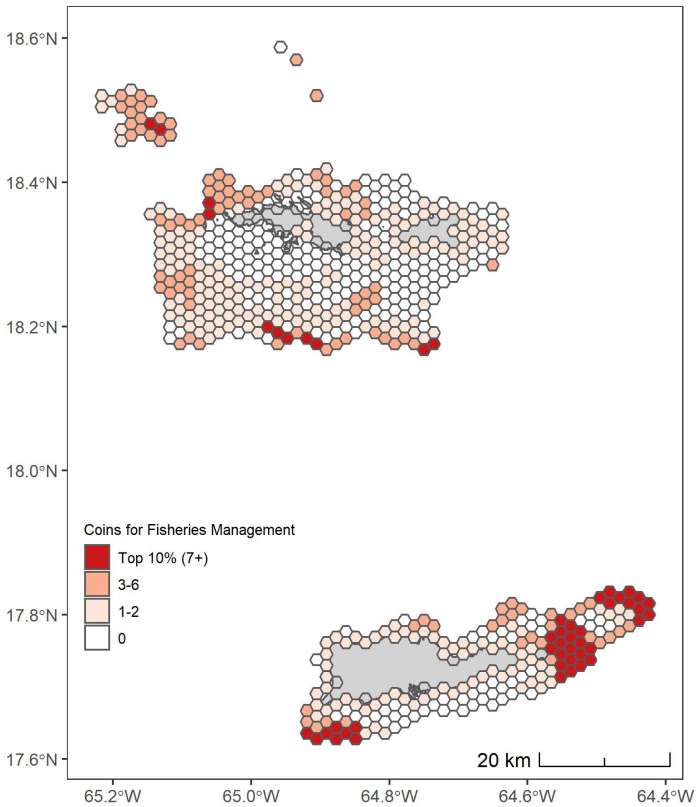

Figure D.3. Map of coins distributed for the Management Use *Fisheries Management.*

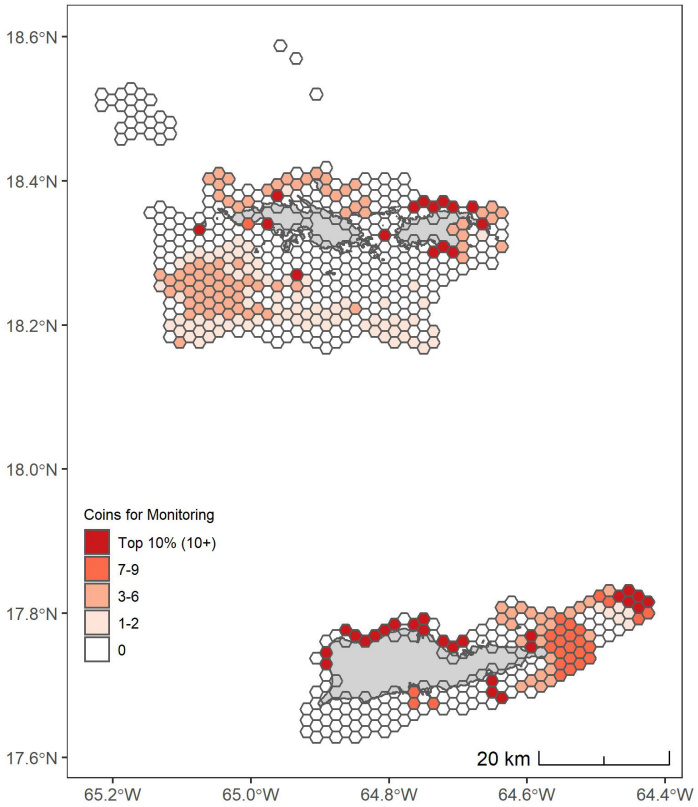

Figure D.4. Map of coins distributed for the Management Use *Monitoring.*

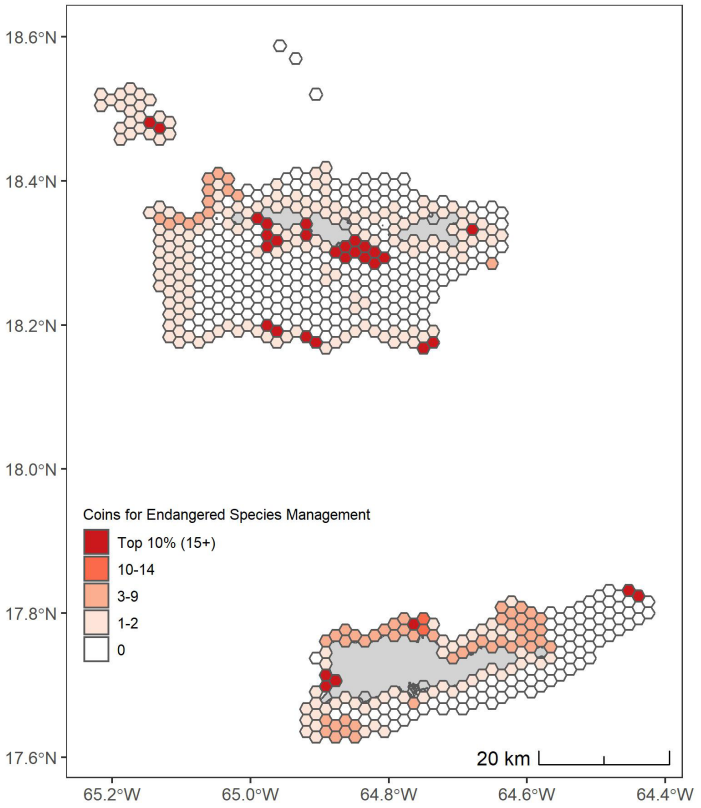

Figure D.5. Map of coins distributed for the Management Use *Endangered Species Management.*

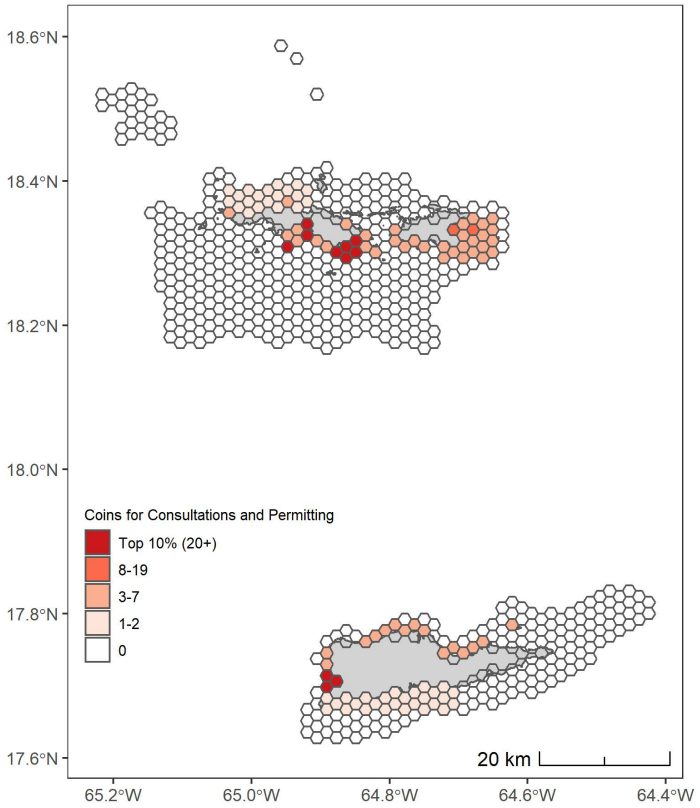

Figure D.6. Map of coins distributed for the Management Use *Consultations and Permitting.*

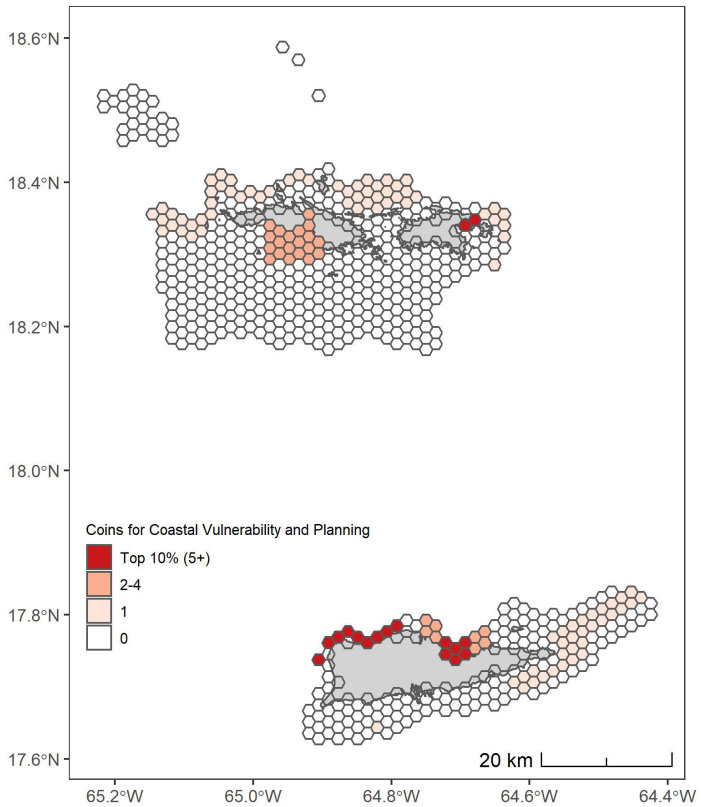

Figure D.7. Map of coins distributed for the Management Use *Coastal Vulnerability and Planning.*

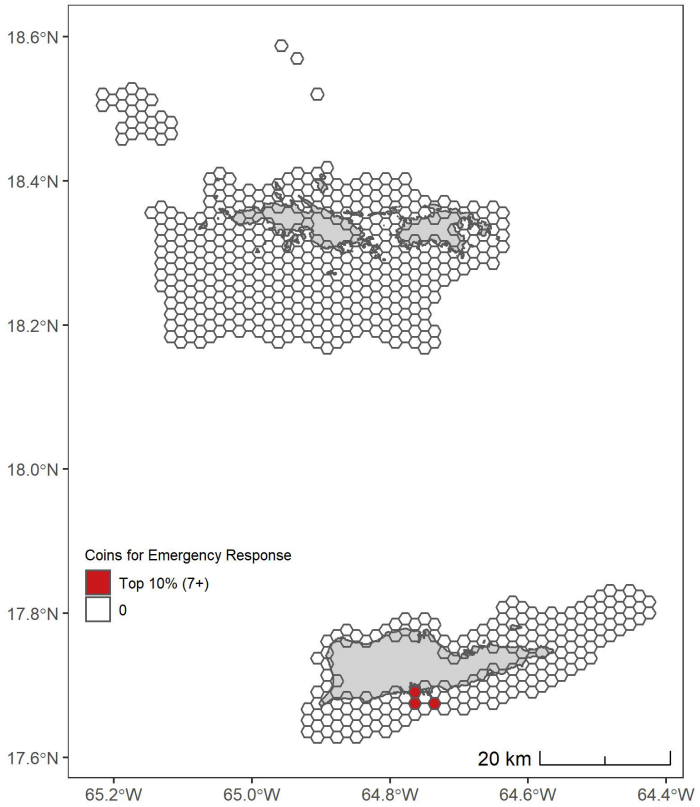

Figure D.8. Map of coins distributed for the Management Use *Emergency Response.*

Appendix E: U.S. Virgin Islands Individual Maps for Each Product Requirement

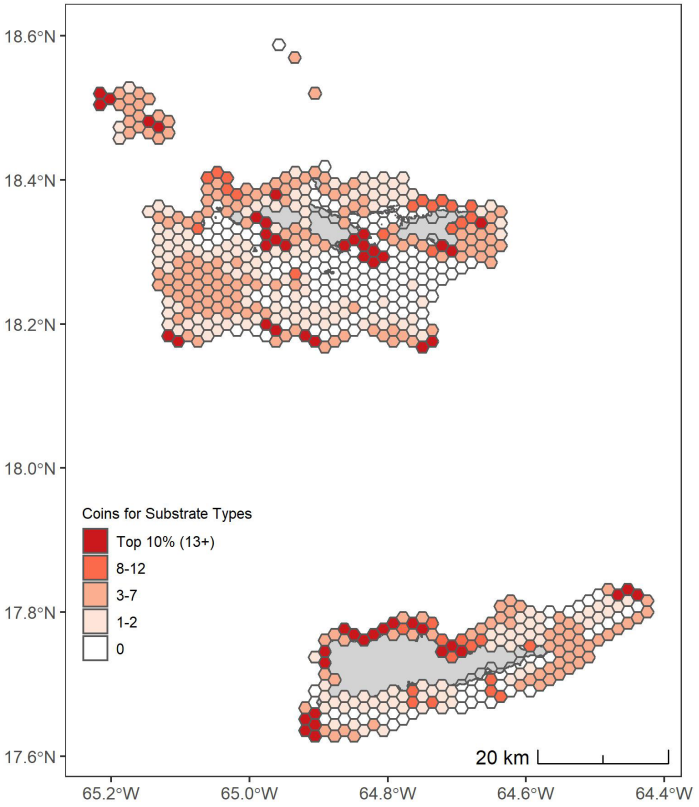

Figure E.1. Map of coins distributed for the Product Requirement *Substrate Types.*

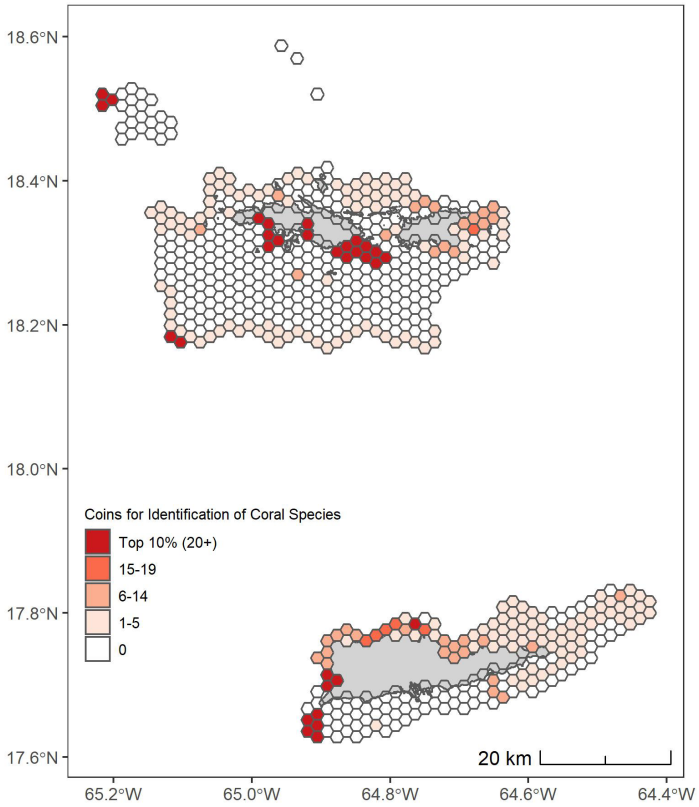

Figure E.2. Map of coins distributed for the Product Requirement *Coral Species*

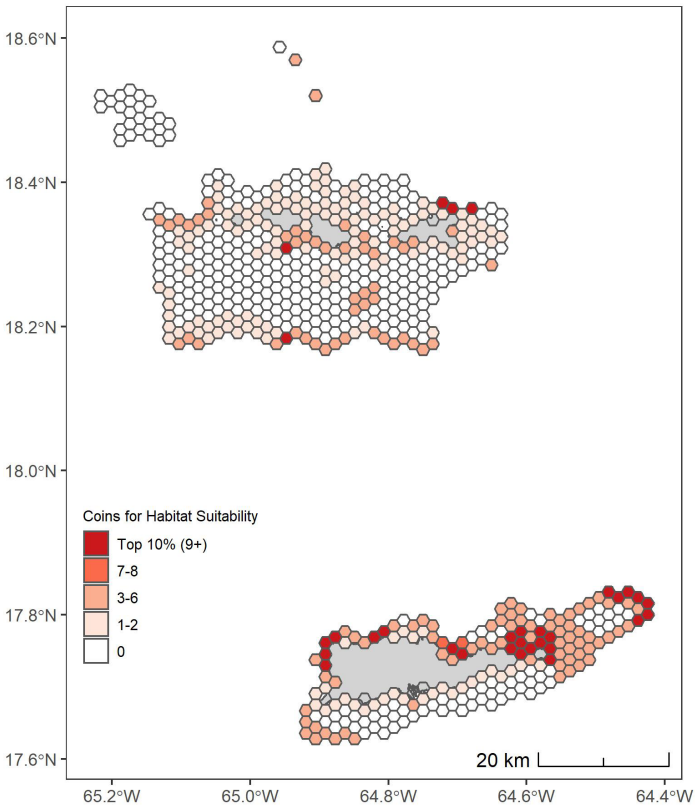

Figure E.3. Map of coins distributed for the Product Requirement *Habitat Suitability.*

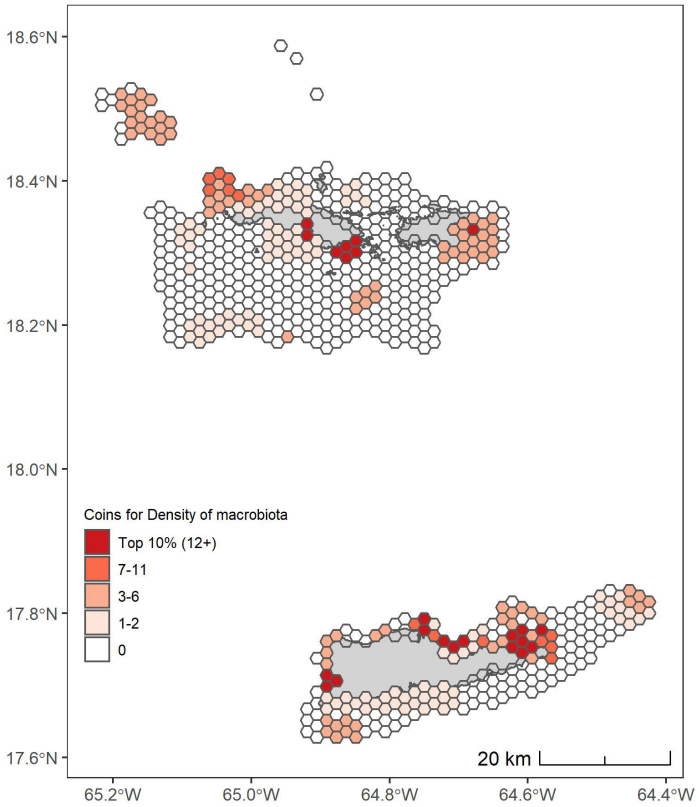

Figure E.4. Map of coins distributed for the Product Requirement *Density of Macrobiota.*

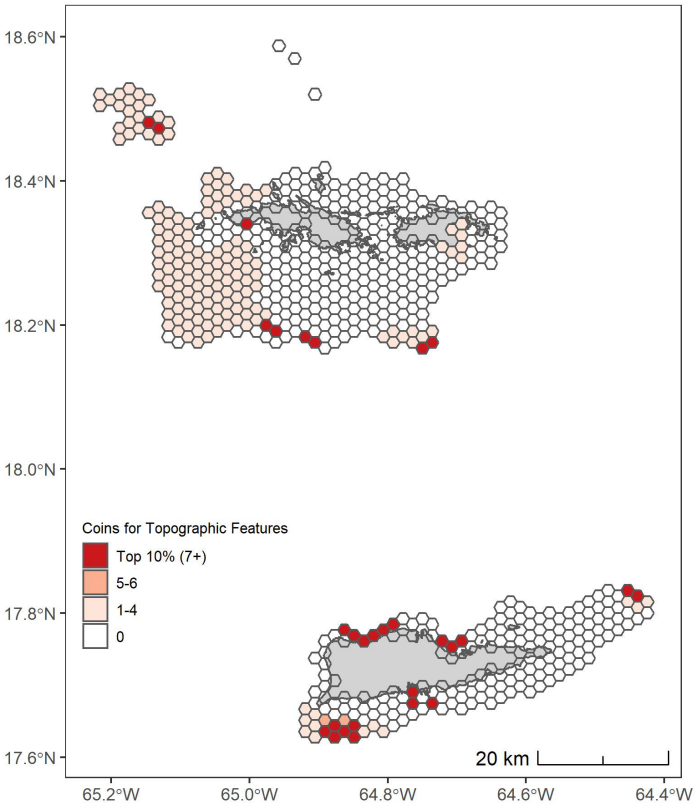

Figure E.5. Map of coins distributed for the Product Requirement *Topographic Features.*

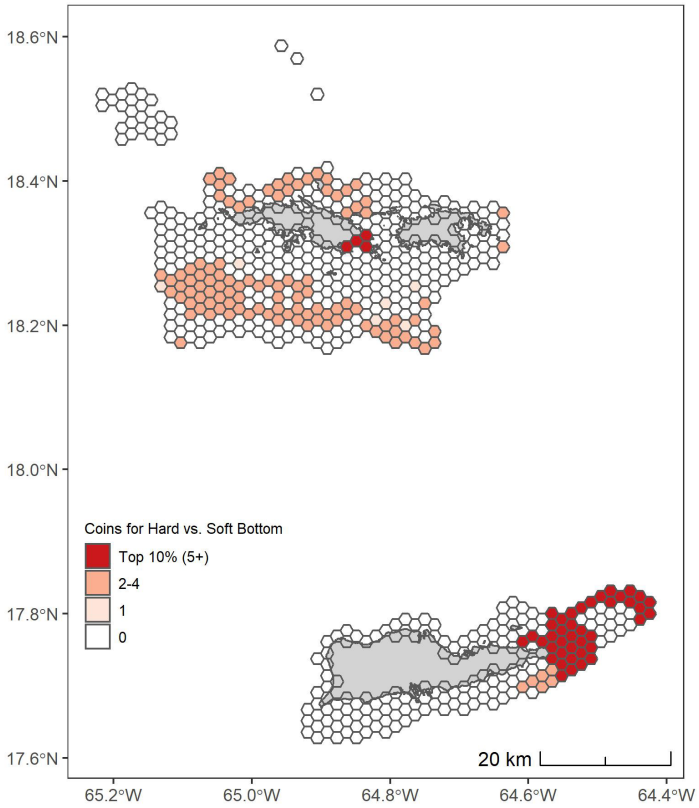

Figure E.6. Map of coins distributed for the Product Requirement *Hard vs. Soft Bottom.*

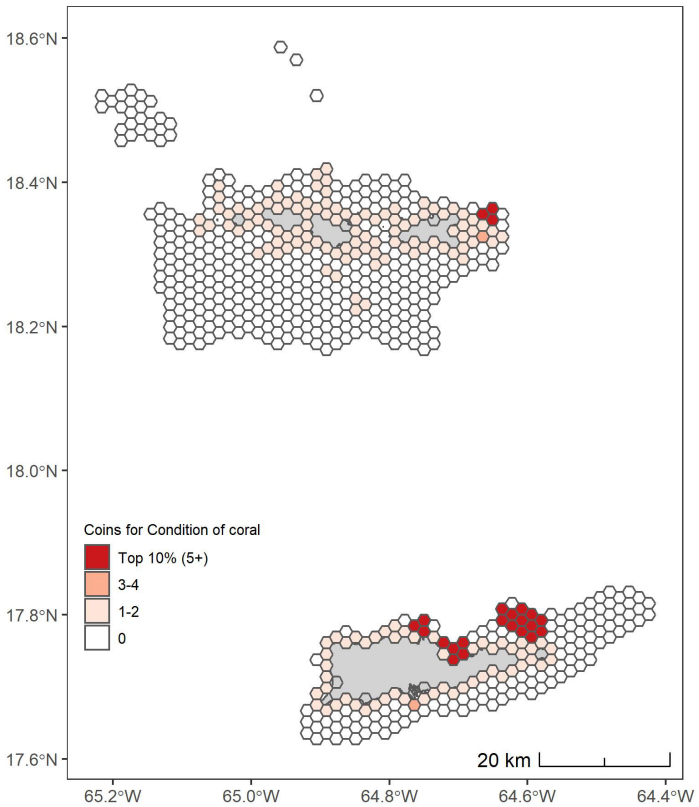

Figure E.7. Map of coins distributed for the Product Requirement *Condition of Coral Taxa.*

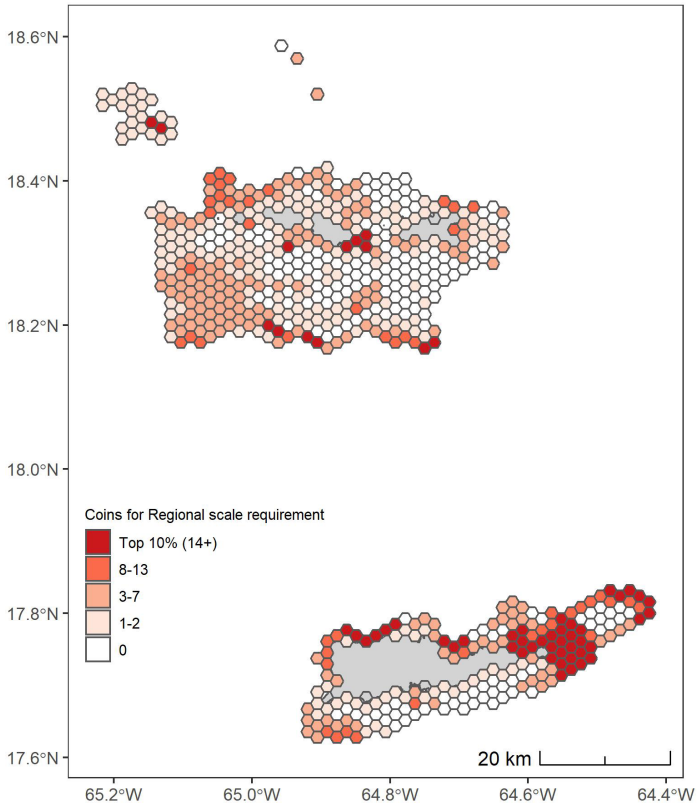

Figure E.8. Map of coins distributed for the *Regional Scale* Product Requirement.

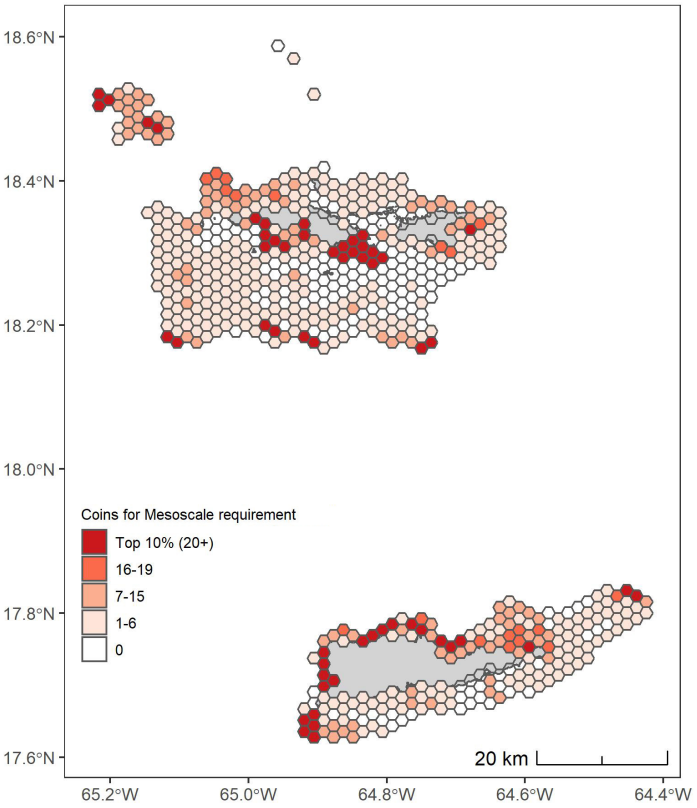

Figure E.9. Map of coins distributed for the *Mesoscale* Product Requirement.

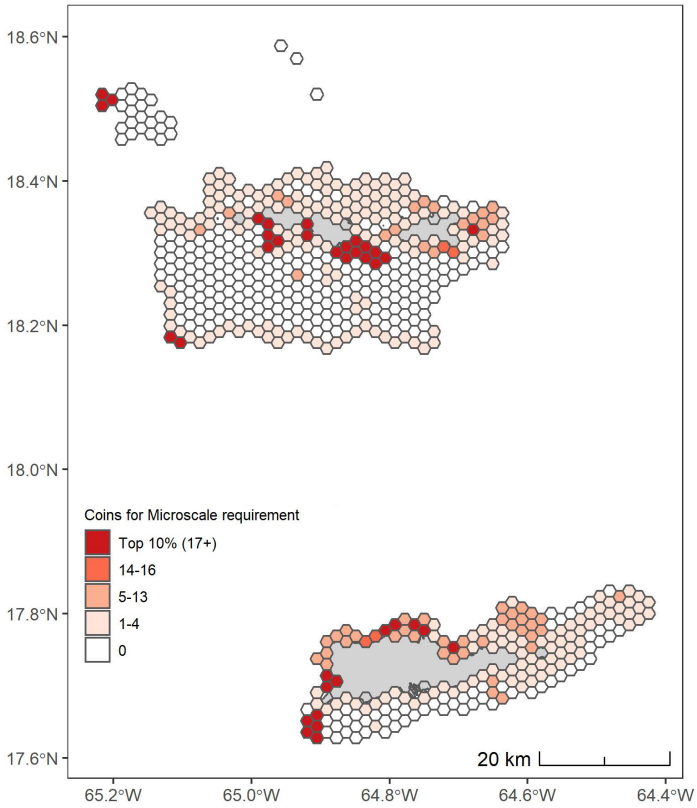

Figure E.10. Map of coins distributed for the *Microscale* Product Requirement.

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, *Acting Assistant Administrator for National Ocean Service*

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