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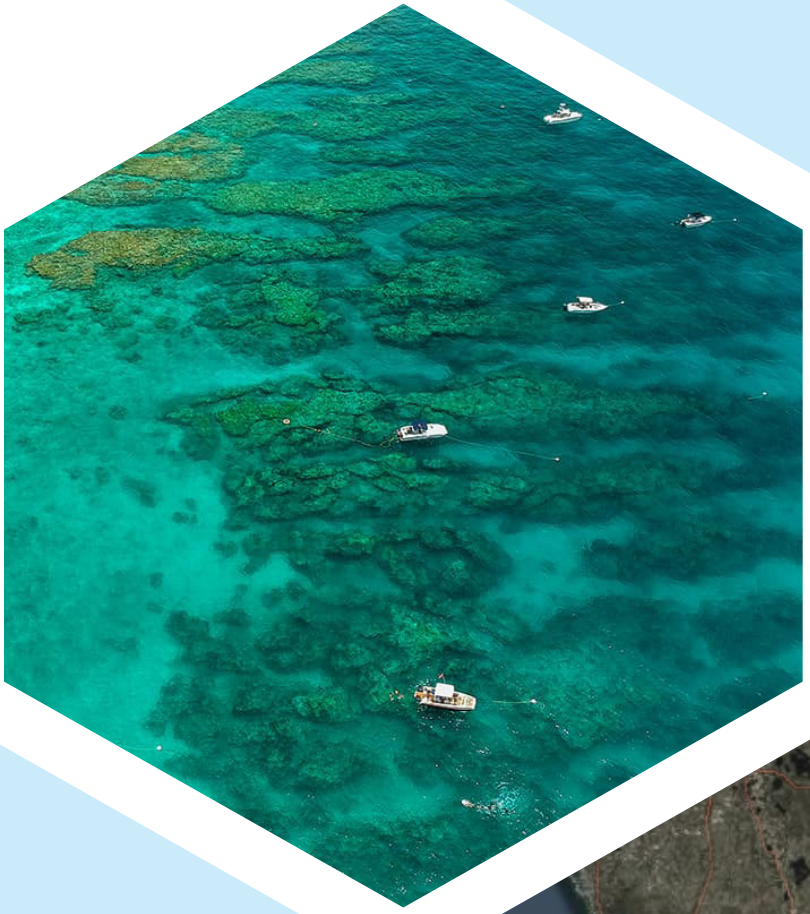
AGENCY PRIORITIES FOR MAPPING SOUTH FLORIDA'S CORAL REEF ECOSYSTEMS



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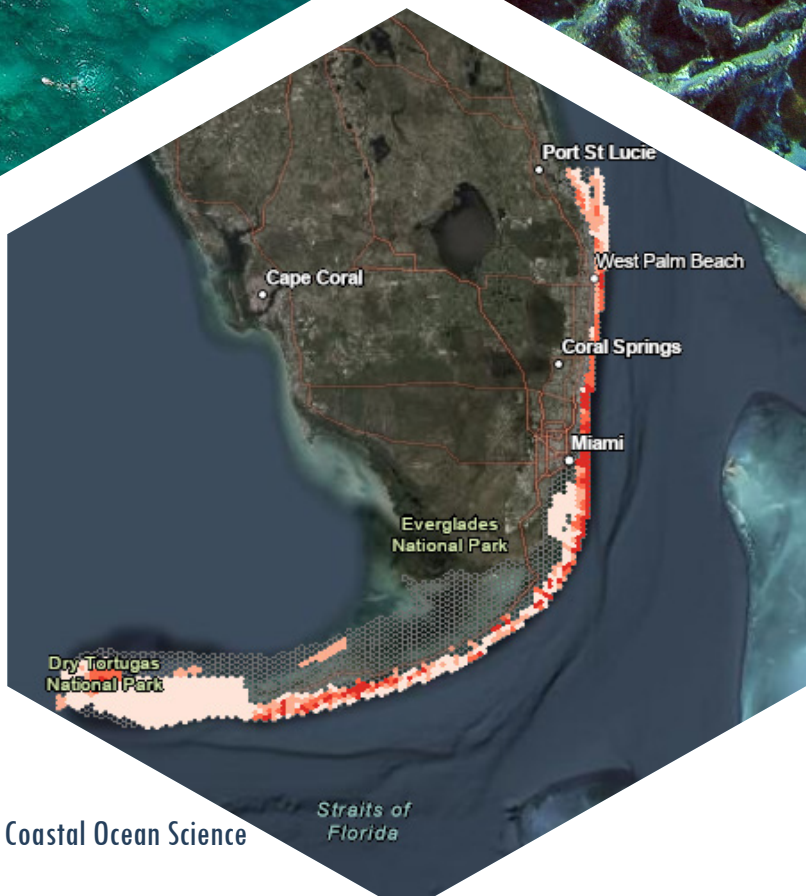

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NOAA National Centers for Coastal Ocean Science

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For more information on NOAA's Coral Reef Conservation Program (CRCP), please visit:
https://coralreef.noaa.gov/conservation/welcome.html

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

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https://coastalscience.noaa.gov/project/defining-future-seafloor-mapping-priorities-to-inform-shallow-coral-reef-management/

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Cover images are copyright and royalty free images from NOAA. Clockwise from top left: aerial image of Looe Key reef area, elkhorn coral and associated fish community, and map of total coins results from this study.

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Agency Priorities for Mapping South Florida's Coral Reef Ecosystems

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July 2022

NOAA NOS NCCOS TECHNICAL MEMORANDUM 304

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National Ocean Service

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List of Acronyms

AOML	Atlantic Oceanographic and Meteorological Laboratory
AUV	Autonomous Underwater Vehicles
CIMAS	Cooperative Institute for Marine & Atmospheric Studies
Coral ECA	Kristin Jacobs Coral Reef Ecosystem Conservation Area
CRCP	Coral Reef Conservation Program
DEM	Digital Elevation Model
DEP	Florida Department of Environmental Protection
DRTO	Dry Tortugas National Park
EPA	Environmental Protection Agency
FKNMS	Florida Keys National Marine Sanctuary
FL	Florida
FWRI	Florida Fish and Wildlife Research Institute
IOCM	Integrated Ocean and Coastal Mapping
MIR	Mission: Iconic Reefs
NCEI	National Centers for Environmental Information
NEPA	National Environmental Policy Act
NCCOS	National Centers for Coastal Ocean Science
NCRMP	National Coral Reef Monitoring Program
NGO	Non-governmental organization
NGS	National Geodetic Survey
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NOVA	Nova Southeastern University
NPS	National Park Service
RC	Restoration Center
ROV	Remotely operated vehicle
SERO	Southeast Regional Office
SPA	Sanctuary Preservation Area(s)
TAT	Technical Advisory Team
TNC	The Nature Conservancy
USGS	United States Geological Survey
U.S.	United States
USVI	U.S. Virgin Islands

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 south Florida coast, from Martin County to the Dry Tortugas.

To meet this need, NOAA's National Centers for Coastal Ocean Science (NCCOS) developed a systematic, quantitative approach and online application to gather 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 priority areas, which Management Uses will be met, what Map Data are needed, and any recommended Methodologies for new data collection.

A total of 18 participants from 13 participant groups entered their mapping priorities into the online tool. The proportion of coins assigned using the Management Use options revealed four (out of a total nine) most commonly selected options: Monitoring, Fisheries Management, Spatial Protection/Management, and Habitat Restoration. Coins that were assigned using the Map Product options revealed three (out of eight) main desired data types: Elevation, Habitat Map/Characterization, and Backscatter and Lidar Intensity. Participants identified several high priority areas based on the ranking and total number of coins: 1) Port of Fort Lauderdale, 2) deep reef edge from northern Miami to Key Largo and the Port of Miami, 3) Hawk Channel area including two Sanctuary Preservation Areas (SPAs, Looe Key and Newfound Harbor), 4) Dry Tortugas National Park, and 5) the Mission: Iconic Reefs. These high priority areas highlight some of the best opportunities for collaboration, with the potential to meet a variety of coral management goals.

Deliverables from this project provide a critical spatial framework for prioritizing mapping efforts in shallow coral reef ecosystems of south Florida. Results from the prioritization needs assessment are summarized and shared in this report. Summary results and inventory of existing mapping data for Florida and other completed jurisdictions are available at: https://us-shallow-coral-reef-mapping-priorities-noaa.hub.arcgis.com/

Coral reef habitat, Florida Keys, FL. Photo Credit: NOAA Photo Library

Chapter 1 Background

The health of U.S. coral reef ecosystems relies on the effective use of mapping data, science, tools, and strategies used 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 Office for Coastal Management's Coral Reef Conservation Program (CRCP) has 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 Years 2021–2022, this activity was focused on shallow coral reef areas off the coast of Florida, Puerto Rico, and the U.S. Virgin Islands (USVI).

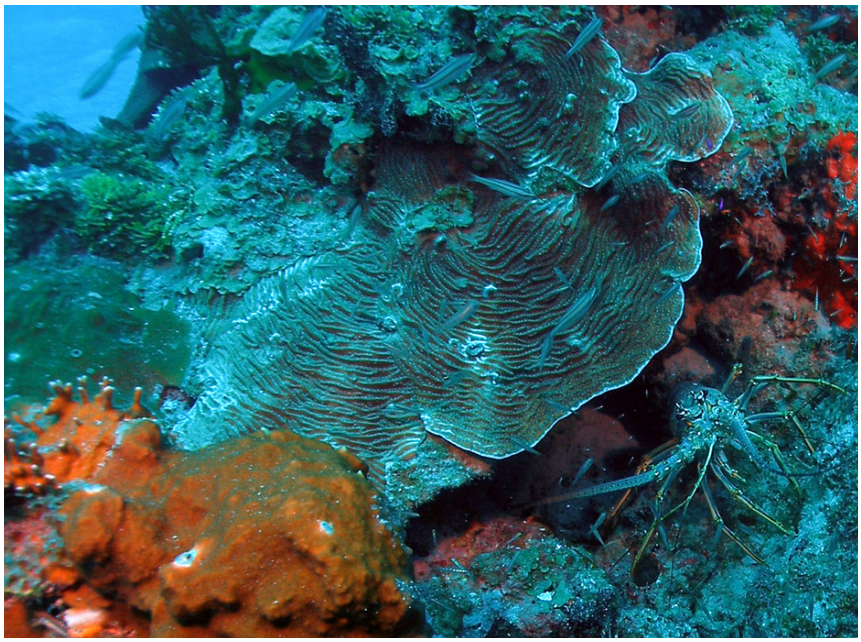


Photo of coral and Caribbean spiny lobster. Photo credit: NOAA NCCOS

Prioritization results will directly support CRCP's four focus topics:

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 identify locations of mutual interest, leverage expertise and resources, and identify potential partnerships. Groups who participated include a range of partners such as fishery management councils, federal, state, territorial, and municipal government agencies, nongovernmental organizations, and academia.

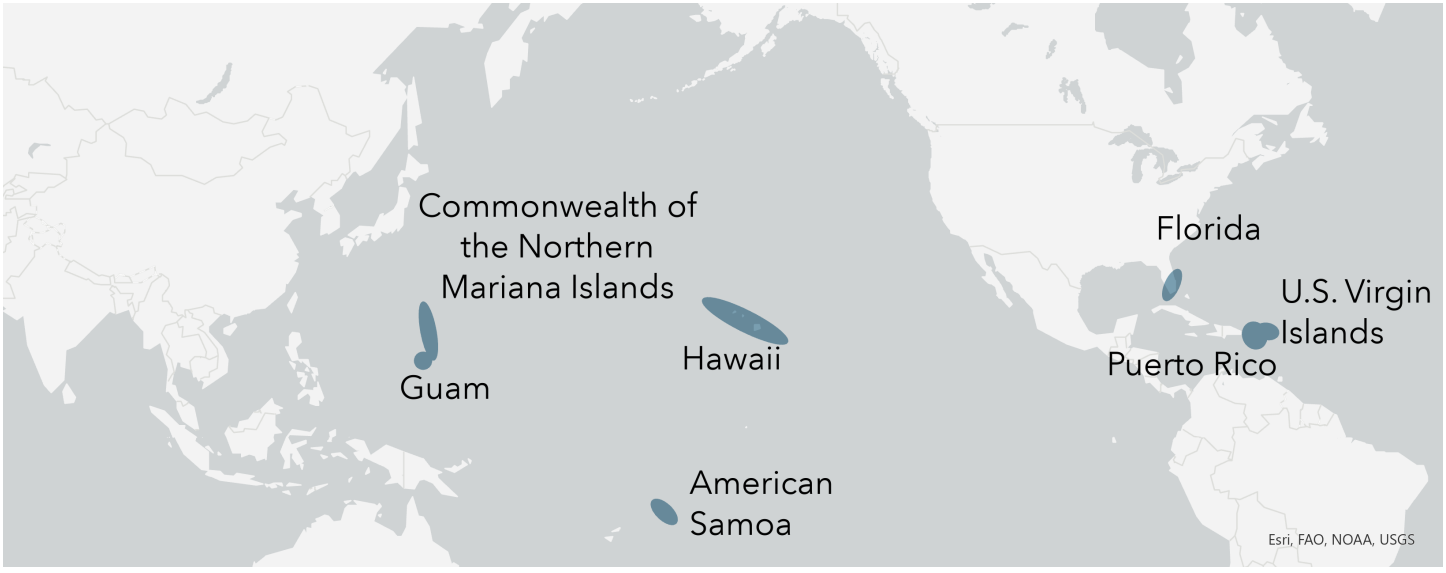


Figure 1. The seven U.S. coral reef jurisdictions that are the focal areas of this project.

Chapter 2 Methods

2.1 Advisory Team and Participating Groups

The technical advisory team (TAT) consisted of two representatives from CRCP and two liaisons from Florida regional NOAA offices (National Marine Fisheries Service [NMFS] and CRCP). The Florida liaisons were selected based on their knowledge of local coral reef and fisheries management groups, and their ability to provide key contacts and support coordination with local groups.

A list of potential agencies, organizations, and academics was created and approved by the TAT. This list included contacts from federal, state, and local partners who use mapping data to inform coral reef management in Florida. Thirteen participating groups had various levels of expertise related to coral reef management including reef 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.

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). The Environmental Protection Agency was contacted but was unable to provide input.

Participating Group	*Acronym*	*Type*
Florida Department of Environmental Protection	DEP	State
Florida Fish and Wildlife Research Institute	FWRI	State
National Park Service	NPS	Federal
NOAA Atlantic Oceanographic & Meteorological Laboratory	AOML	Federal
NOAA Florida Keys National Marine Sanctuary	FKNMS	Federal
NOAA National Centers for Coastal Ocean Science	NCCOS	Federal
NOAA National Coral Reef Monitoring Program	NCRMP	Federal
NOAA Restoration Center	RC	Federal
NOAA Southeast Regional Office	SERO	Federal
United States Geological Survey	USGS	Federal
Cooperative Institute for Marine & Atmospheric Studies	CIMAS	Academic
Nova Southeastern University	NOVA	Academic
The Nature Conservancy	TNC	NGO

2.2 Develop Prioritization Framework and Online Application

2.2.1 Develop Framework

The project area extended from Martin County southward to the Dry Tortugas. This geographic area was divided into hexagonal grid cells that were 2 km per side (10.4 km^2 area per cell; Figure 2). 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 40-m contour and coastline.

2.2.2 Compile Data

Existing seafloor mapping data were compiled and provided as background data to help participants understand the extent of information, locate data gaps, and identify areas to prioritize for future data collections. Most importantly, they included seafloor mapping information, described the geographic extent, type (e.g., multibeam, lidar, habitat map), and quality of existing data, and included results from any previous prioritization efforts. Spatial data layers also included existing political and administrative boundaries, for example, federal/state waters, marine protected areas, and essential fish habitat. These final datasets and web mapping services were published in an online web map. See Appendix A for a reference list of mapping services included in the Florida mapping inventory.

2.2.3. Spatial Prioritization Application

An online application was created using Esri's Web AppBuilder and was designed to enable participants to view and interact with existing spatial data and to enter their data needs. Each application consisted of two main components: (1) a data inventory (described in Section 2.2.2), and (2) the spatial prioritization widget. This widget is an online graphical user interface where participants enter their priorities using 'virtual coins' and a customized suite of selected 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 Puerto Rico and USVI (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). The widget allows participants to assign, edit and move their coin placement as often as they like until the prioritization deadline.

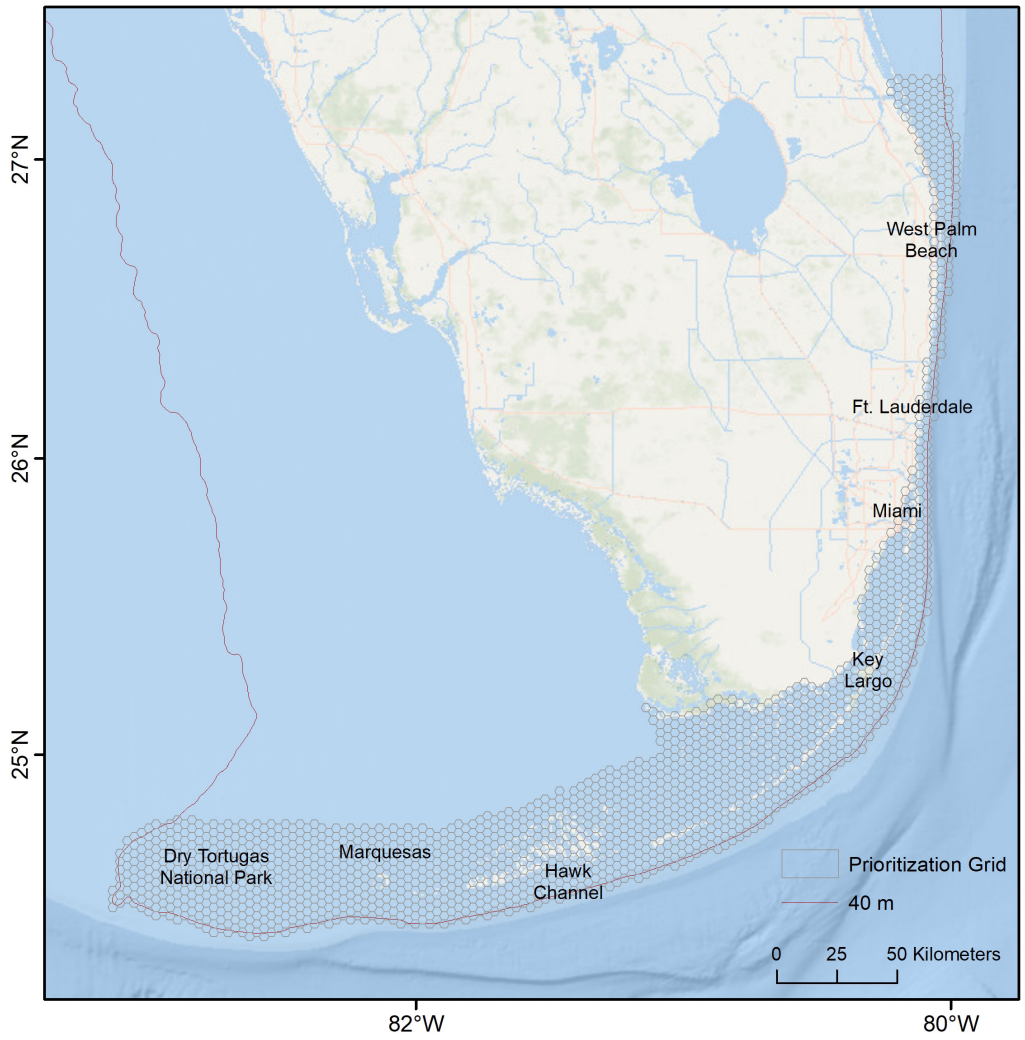


Figure 2. Hexagonal grid (2 km per side) for the Florida prioritization, stretching from Martin County to the Dry Tortugas. A 40-m depth contour is added to the map, which was used as the depth limit for this prioritization effort.

Each participant was given 530 virtual coins to place on the prioritization grid to indicate the locations of their mapping interest. This equaled approximately 30% of the total number of cells in the grid and encouraged participants to carefully allocate their coins. The application also restricted the maximum number of coins in any one cell, such that no single cell could receive greater than 10% (i.e., 53) of the total number of coins. This restriction on coin loading was specifically designed to ensure that participants' needs were comparable (i.e., everyone spent the same number of coins) and encouraged participants to distribute their priorities more broadly and thus increasing the chance of overlap among participant needs.

2.2.4 Management Use, Map Data, and Methodology

In addition to selecting cells and allocating coins to convey their spatial priorities, participants were also asked to identify why these areas were of interest to their group and a recommended methodology for future collection. First, participants chose from a list of nine pre-defined **Management Uses** (Table 2), which were based on the coral management focus of this 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 using pull-down menus in the prioritization widget. The option *Other* was also available, if the reason for a data need was not adequately described by this list. Participants who chose *Other* were asked to explain their data needs via email.

Participants were also asked to describe specific **Map Data** needed in the selected grid cells. These options provided information on what kind of data will be collected. Participants could choose up to two (primary and secondary) options listed in Table 3.
And finally, participants were asked to provide a preferred or recommended **Methodology** for collecting future mapping data in the selected grid cell (Table 4). **Methodology** was provided as a drop-down menu list with only a single (primary) option available.

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

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 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 [NEPA], 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.
10. *Other*	Please clarify via email to the project lead

Table 3. List of Map Data options participants were asked to chose from to indicate what type of data is needed.

Map Data	*Definition*
1. *Habitat Map/Characterization*	Models of habitat suitability using mapping data, imagery, etc.
2. *Shoreline Characterization*	Determine and monitor shoreline change and habitats
3. *Ground Truthing*	Photos and videos collected using remotely operated vehicles (ROV), autonomous underwater vehicles (AUV), or other camera platforms
4. *Elevation*	Bathymetry and topography collected using modern technology such as multibeam, sidescan, and lidar.
5. *Backscatter and Intensity*	Surfaces used to delineate between hard and soft substrates
6. *2D Map Product*	Static Images used to visualize bottom type, presence/absence of key taxa
7. *Georectified Photomosaics*	3D products created using a combination of methods such as Structure from Motion, satellite derived bathymetry, etc.
8. *Water Column*	Collected using multibeam sonars and typically used for fish biomass detection

Table 4. List of Methodology options participants were asked to choose from to suggest how data should be collected.

Methodology	*Definition*
1. *Satellite*	Using satellite images and various modeling techniques to classify benthic habitats and elevation
2. *Lidar*	Airborne acquisition technology which uses infrared wavelengths to penetrate the water column and measure seafloor depths
3. *Multibeam Echosounder*	Sonar system that emits acoustic waves in a fan shape to map the seabed
4. *Split Beam Echosounder*	Sonar that uses a single sound pulse used to detect anomalies on the seafloor and surveying organisms in the water column.
5. *Side-scan Sonar*	Sonar system that sends out acoustic signals on both of its sides and is used to detect objects and characterize the makeup of the seafloor
6. *Photogrammetry*	Recording, measuring, and interpreting photographic images and patterns to create 2D or 3D models and derivatives
7. *Drop Camera*	Stationary images and video of small areas of seafloor using a camera that lowered into the water column from a topside platform (i.e., boat or kayak).
8. *Uncrewed Systems*	Remotely controlled or guided vehicles that can be coupled with image and sonar equipment for autonomous surveying

2.3 Participants Enter Priorities Online

Participants entered their mapping needs and priorities in the online application that is hosted on the NOAA ArcGIS Online GeoPlatform. Each participant was given a link to the application, and instructed to access the widget using their NOAA account. Non-NOAA participants were given a temporary account to the NOAA GeoPlatform to access the web tool. The web link allowed participants to enter in priorities at their convenience from any computer with internet connection.

Guidance was provided to participants on how their placement of coins translated into levels of urgency. By assigning more coins to a cell (up to the 10% limit), participants could indicate the priority level and how quickly they need data. 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 zero coins indicated data was not needed for more than 10 years.

2.4 Summarize Priorities and Conduct Spatial Analysis

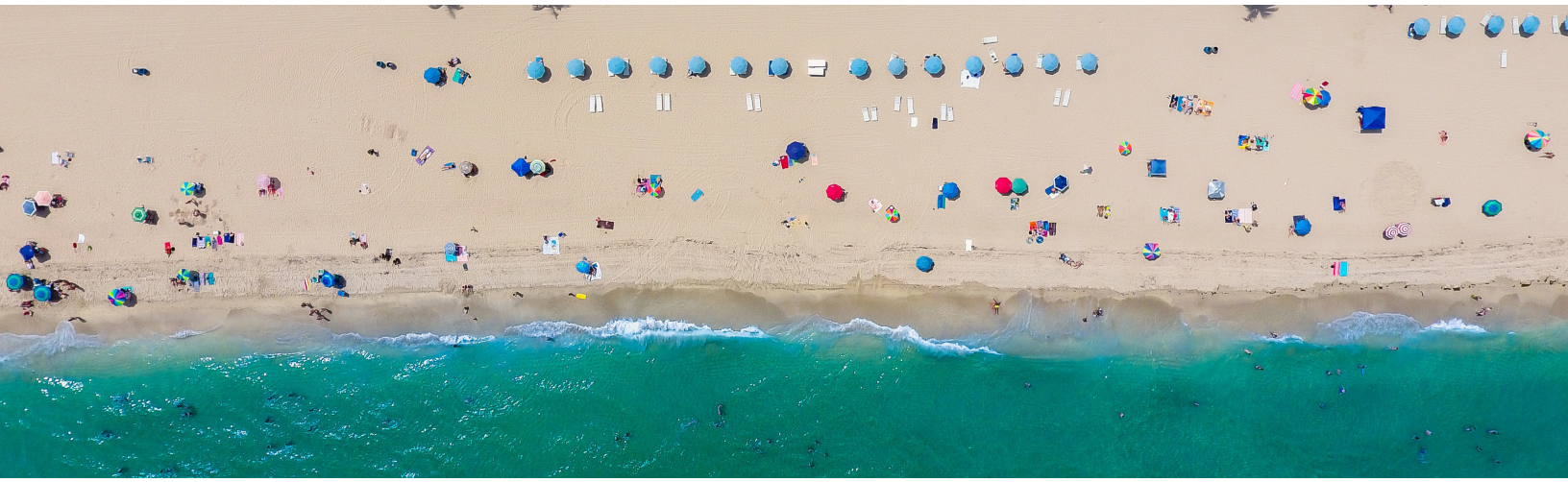
As participants entered and edited their selections, their responses were continuously saved to an online database. At the end of the data entry period, this information was downloaded, quality controlled, summarized, and analyzed to identify collective priorities within each coral reef jurisdiction. All quality control and data summarizations were performed in R (version 4.1.0; R Core Team, 2021).

2.4.1 Quality Control

This quality assurance process confirmed each participant allocated all their coins, and that no participant allocated more than 10% of their coins into a single cell. Once coin values were confirmed, cells with zero coins were examined to ensure no pull-down menu options were input with zero coins.

2.4.2 Data Analysis and Summary

To determine which Management Use and Map Data options were most commonly selected, the total number of coins were summed for each selection at the primary and secondary levels. The relative proportions of coins allocated under each option were visualized using stacked bar plots. To understand how coins were allocated overall, the average number of coins from each participant group was calculated then summed across all participant groups in each grid cell. This prevented groups with multiple participants from outweighing those with only a single participant. 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 Data options. The top 10% of cells with coins were identified and highlighted using the quantile function in R.



Beach in Miami, FL. Photo credit: Unsplash

2.4.3 Composite Ranking and High Priority Areas

To understand areas of greater importance based on multiple datasets, a composite rank analysis was conducted. First, each cell was ranked by their total number of coins, number of participant groups, and diversity of Management Uses, resulting in an overall rank for each cell. Cells with the same value were given an average rank among the cells. The rank values for each of these three categories 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 coral management uses supported if the cell were to be mapped.

High priority areas were selected by identifying adjacent cells that were in the Top 10% of overall coins. Majority of the cells with the Top 10% of coins were also ranked in the 'Highest' category, in part because the total number of coins is included in the composite ranking. Both the Top 10% of coins and Highest rank categories were used to select areas of high priority. Using the summary rank analysis helped to identify any additional high priority areas that did not contain Top 10% of data, but were still ranked in the Highest rank category, and may be of interest to stakeholders for future mapping and research.

2.5 Project Timeline

Participants were contacted in March of 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 April 19, 2021, and provided participants with details on the project background, methods, anticipated outcomes, and demonstrated use of the web tool. This also provided a platform for participants to ask questions. The data inventory was finalized in April, 2021, and any datasets that were collected or published after this date were not included. Participants were requested to input their priorities anytime between April 26 to May 24, 2021, giving them approximately four weeks to complete their inputs. After the inputs were analyzed, participants were briefed on the preliminary results during a webinar on September 2, 2021, and given the opportunity to make comments or suggestions.

Large elkhorn coral. Photo credit: Summit Foundation

Chapter 3 Results

Thirteen participating groups provided input on their Florida mapping needs. A total of 18 participants from the 13 groups entered their mapping priorities, as some participant groups had multiple experts with unique inputs and therefore were given separate accounts (total coins were averaged for these groups).

3.1 Management Use

The proportion of coins assigned to the Management Use options were dominated by four categories: *Monitoring*, *Fisheries Management*, *Spatial Protection/Management*, and *Habitat Restoration* (Figure 3). These top four Management Uses accounted for nearly 85% of all coins allocated, followed by *Endangered Species Management* at 9%. *Consultations and Permitting* and *Coastal Vulnerability* were identified at the primary level only, making up a total 4.7%. And lastly, *Watershed Management* was only assigned as a secondary option with 1.6% of coins. All the participating groups selected at least two different Management Uses, with one group selecting up to seven different options throughout their coin allocation (Figure 4). Maps of coin distributions for each Management Use can be found in Appendix B.

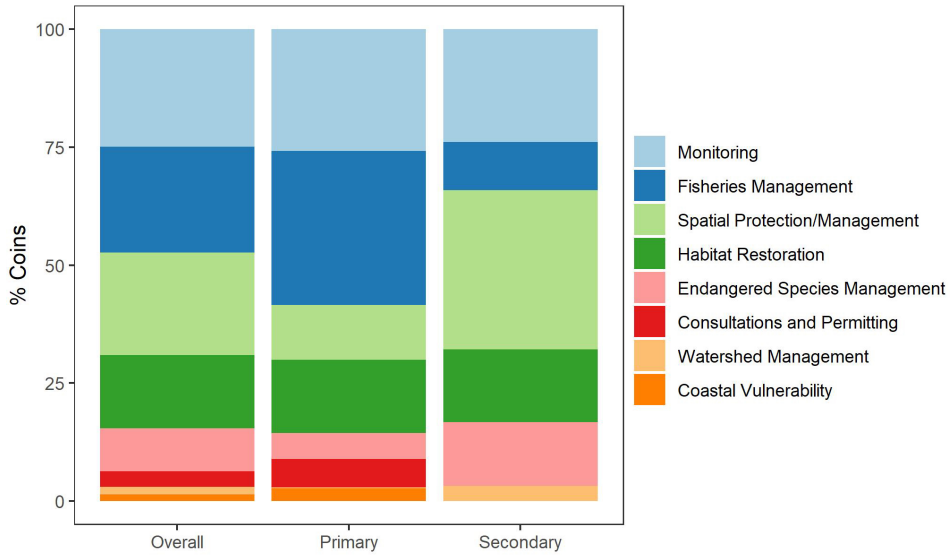


Figure 3. The percentage of coins for each Management Use selected at the overall, primary, and secondary level.

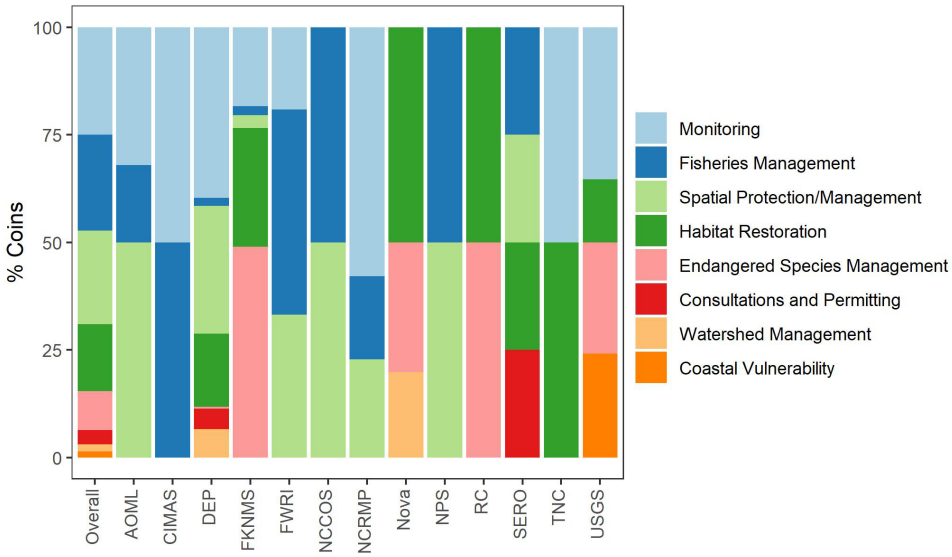


Figure 4. The percentage of coins for each Management Use selected per participant group.

3.2 Map Data Needs

The proportion of coins that were assigned to the Map Data options overall revealed three main desired data types: *Elevation*, *Habitat Map/Characterization*, and *Backscatter and Lidar Intensity* (Figure 5). Of the six mapping data selected, these top three comprised 85.6% of overall coins. *Georectified Photomosaics* were selected for 10.4% of all coins allocated, and *2D Map Product* and *Ground Truthing* were mainly selected as secondary options (except for 0.4% of *2D Map Product* selected as primary) totaling 4% of overall selections. Eleven of the thirteen participating groups identified *Elevation* and/or *Habitat Map/Characterization* as a necessary map product (Figure 6). *Backscatter and Lidar Intensity* were selected by eight groups, with a range of about 20–50% of coins allocated for this option. There was wide variation in the types of Map Data selected by group. Maps of coin distribution for each Map Product can be found in Appendix C.

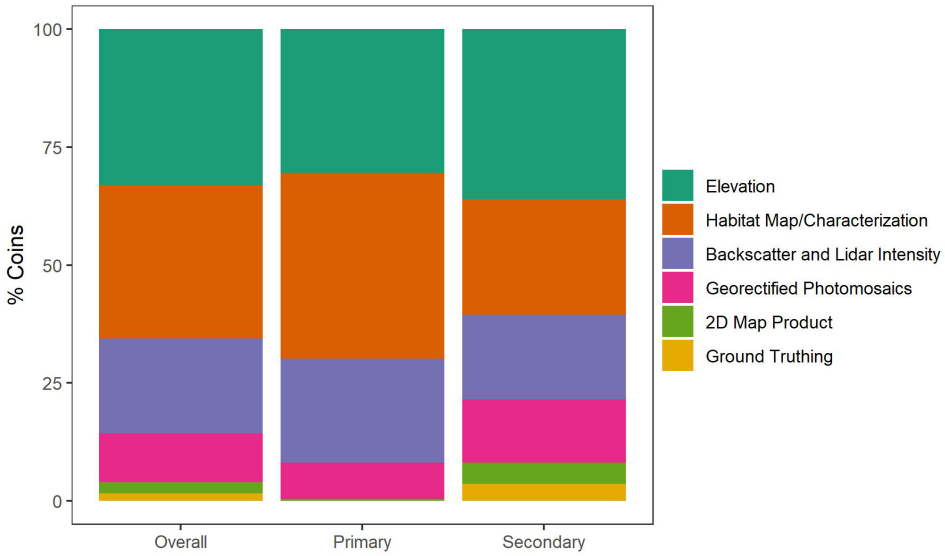


Figure 5. The percentage of coins for each Map Data option selected at the overall, primary, and secondary level.

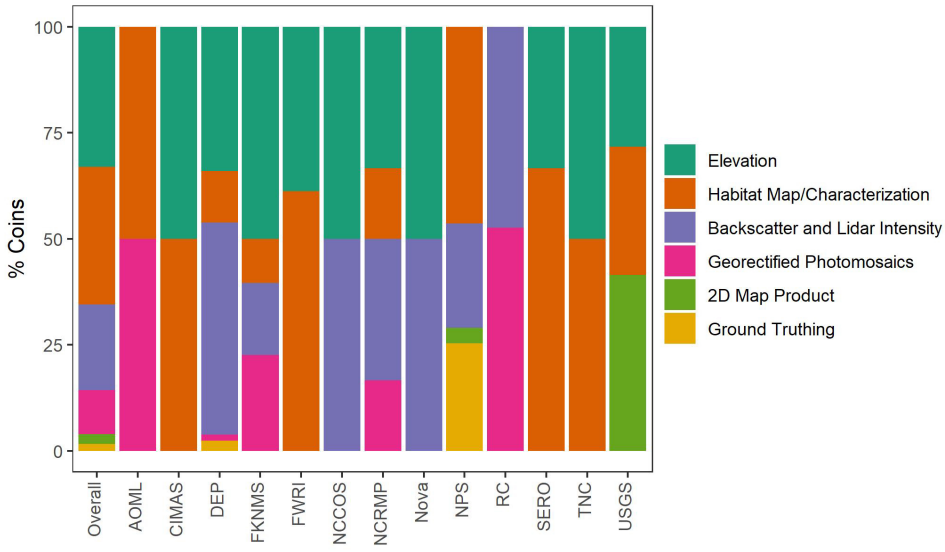


Figure 6. he percentage of coins for each Map Data option selected per participant group

3.3 Mapping Methodology

The two most commonly selected Methodologies were *Multibeam Echosounder* and *Lidar*, comprising 82.7% of total coins allocated. *Photogrammetry* and *Sidescan Sonar* were selected almost equally and totaled up 14.3% of selections. *Uncrewed Systems* made up 2.4%, followed by *Satellite* at only 0.4%, both of which were selected by just one participant group. *Drop Camera* and *Split Beam Echosounder* were not selected by any participant. It should be noted that this question was ancillary and further investigation should be done to conclude the best Methodology for an area based on funding, location access, navigational hazards, and data needs. Appendix D contains coin distribution maps for each Methodology.

3.4 Total Coins and Summary Rank

Cells with the highest total number of coins (Top 10%) among all participants occurred primarily along the southeast Florida Reef Tract, almost exclusively along the oceanside of the Florida Keys (Figure 7). Two cells in the Top 10% were also located within the Dry Tortugas National Park (DRTO) boundary. Cells containing the Top 10% of coins covered an area of 893 km^2. The region between DRTO and Key west was identified as relatively low priority.

Most cells that did not receive coins were located on the bay side of the Florida Keys. Much of this area's habitat is dominated by seagrass, but was included in the project area due to some scattered coral reef and hard bottom habitats (see Unified Florida Reef Tract Map).

A similar pattern was found when considering the number of groups that allocated coins into each cell, which ranged from one to eight individual inputs per cell (Figure 8). DRTO, however, contained several more top priority cells, based on agency representation when compared to total coins.

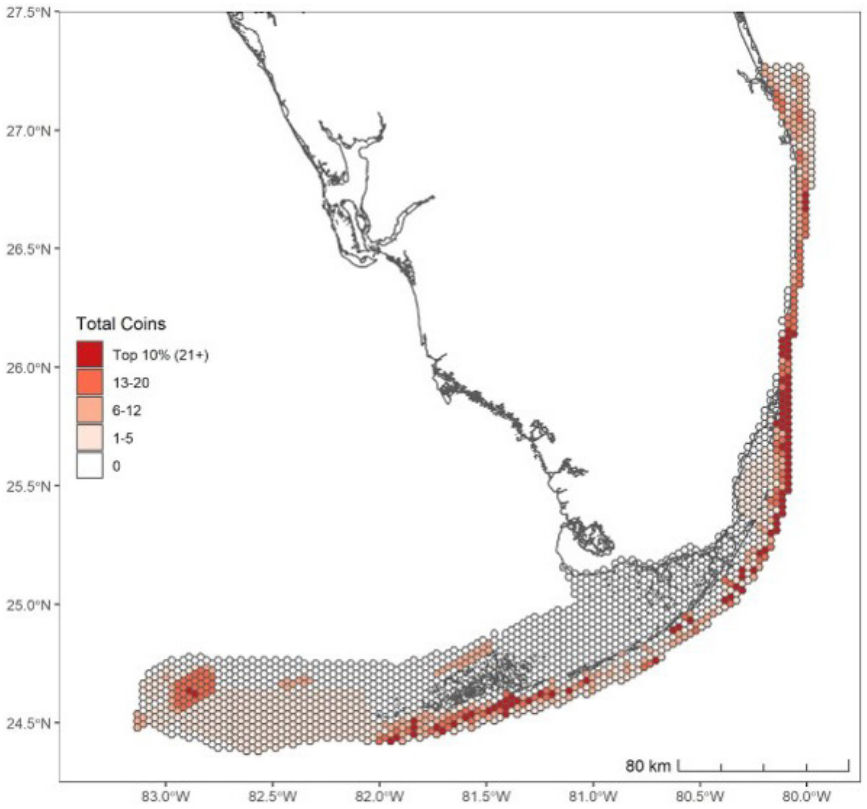


Figure 7. Map of total coins.

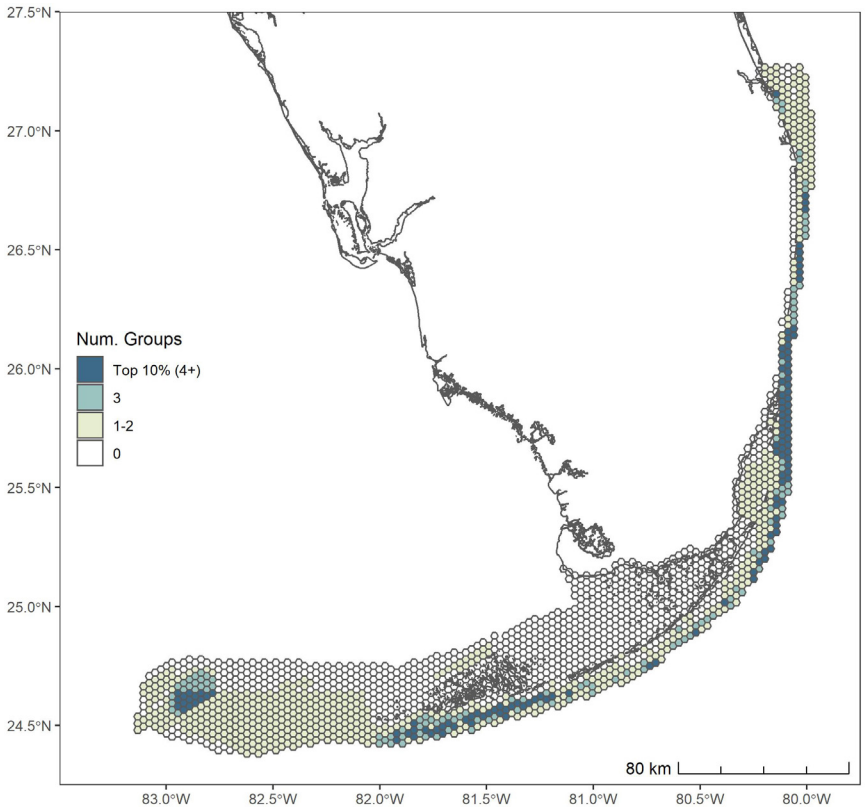


Figure 8. Number of groups who allocated at least one coin into each cell. A maximum of eight groups provided input into a single cell.

The total number of Management Uses selected per cell showed a similar pattern to total coins and number of groups, but with a higher number of cells located in the southeast stretching north from Fort Lauderdale to North Palm Beach (Figure 9).

By combining multiple aspects of cell importance into a single layer, we were able to highlight cells that were of greater importance along the Florida Reef Tract (Figure 10). Highest ranked cells (dark green) extended from West Palm Beach to Key Largo along the deeper edge of the Reef Tract, Hawk Channel from Big Pine Key to Key West, and in the lower half of DRTO. Moderately high (teal) values generally surrounded Highest ranking cells, expanding most high interest areas.

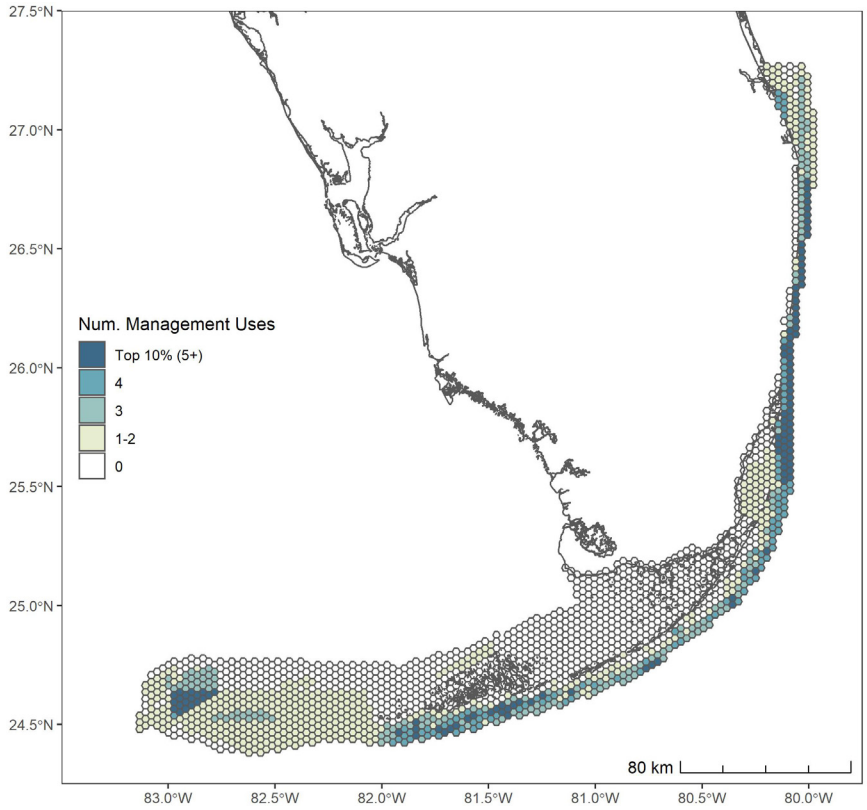


Figure 9. Number of Management Use options that were selected in each cell.

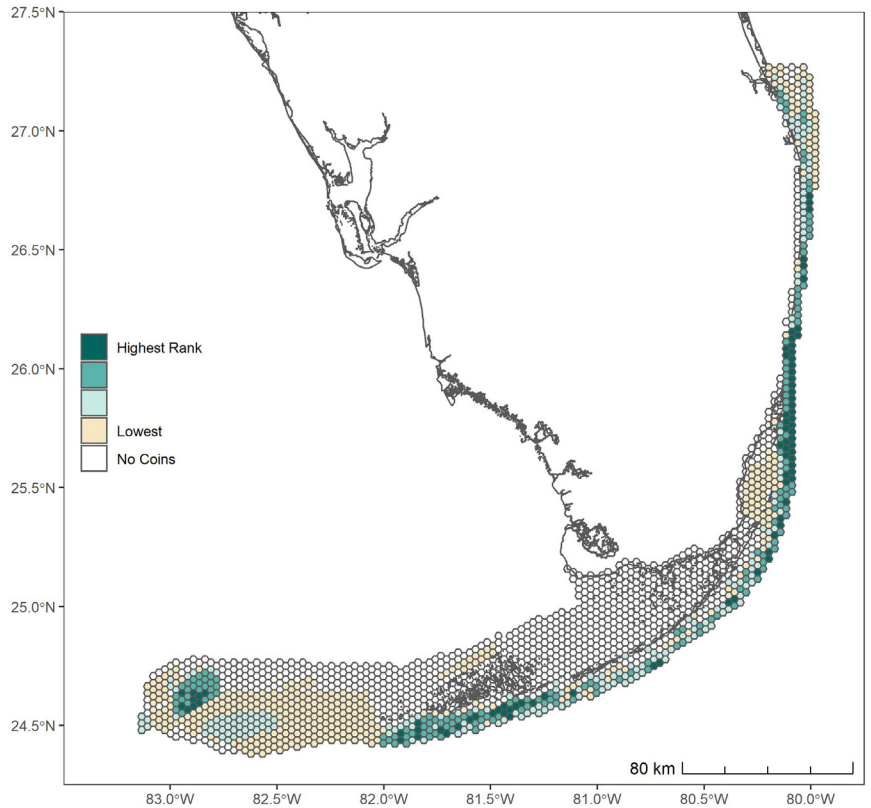


Figure 10. Sum of cell ranks based on total coins, number of participant groups, and diversity of Management Uses in each cell.

3.5 Gap Analysis and High Priority Areas

There were four areas identified as high priority: 1) Fort Lauderdale and offshore, 2) deep reef edge from northern Miami to Key Largo and the Port of Miami, 3) Hawk Channel area including two Sanctuary Preservation Areas (SPAs, Looe Key and Newfound Harbor), 4) southern portion of Dry Tortugas National Park (Figure 11). In addition, high priority cells were observed over several of the Florida Mission: Iconic Reef sites and thus were discussed as another potential interest for future mapping. These five focal areas are discussed here because of their potential for future mapping projects. These areas lacked existing or

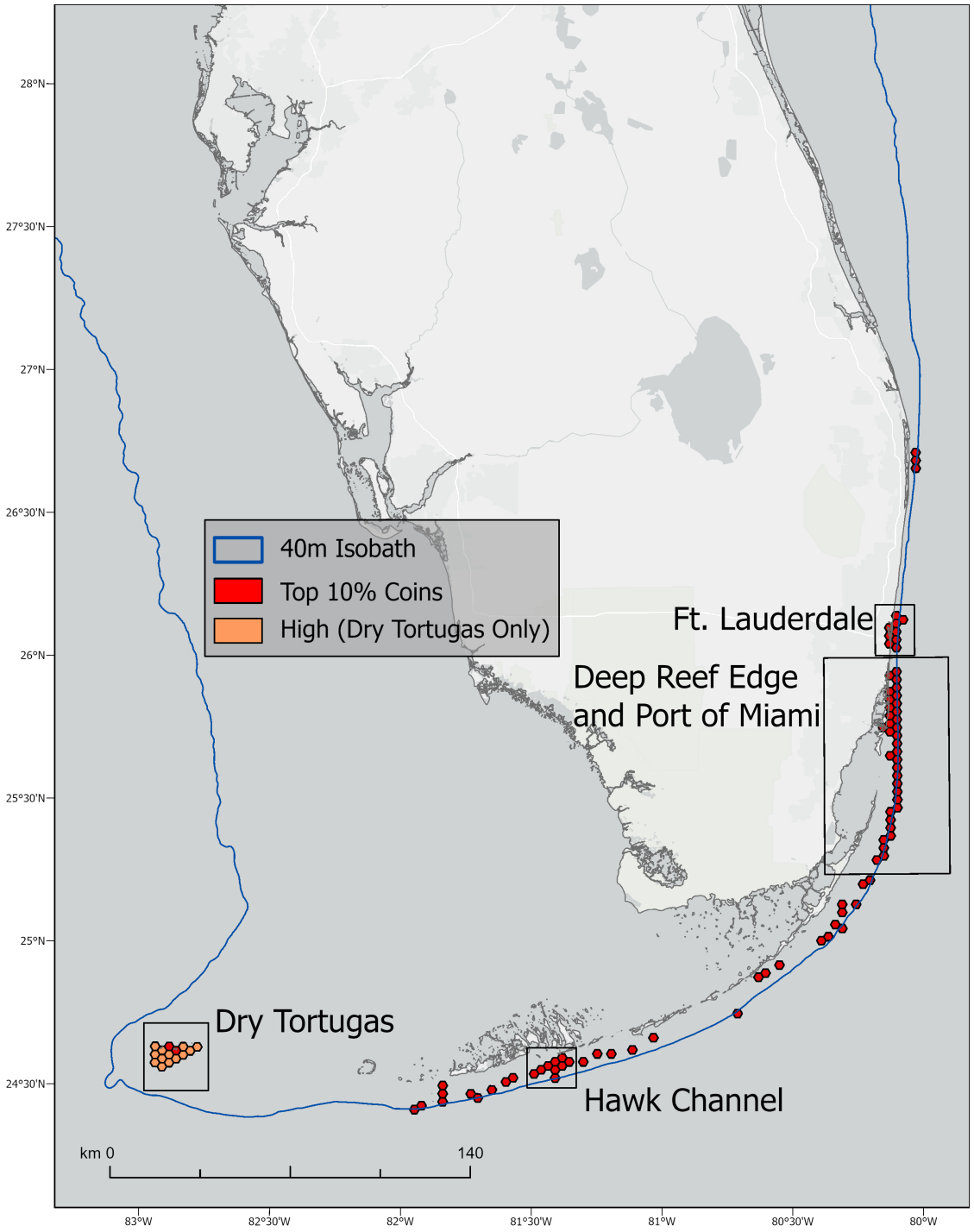


Figure 11. High priority areas identified using the cells with the total coins Top 10% and 'High' (Dry Tortugas only) categories.

contemporary data, contained numerous adjacent high priority cells, and covered several federal and state regulatory zones.

3.5.1 Fort Lauderdale

Off the coast of Fort Lauderdale (Figure 12), nine hexagons (total area of 94 km^2) were identified as a high priority by seven participant groups (Table 5). Available lidar and multibeam data covers this region almost entirely, with some gaps in the eastern-most cells. However, the most recent multibeam data available are from 2009. Lidar data covers most of these cells and was collected in 2016 and 2017 (Figure 13).

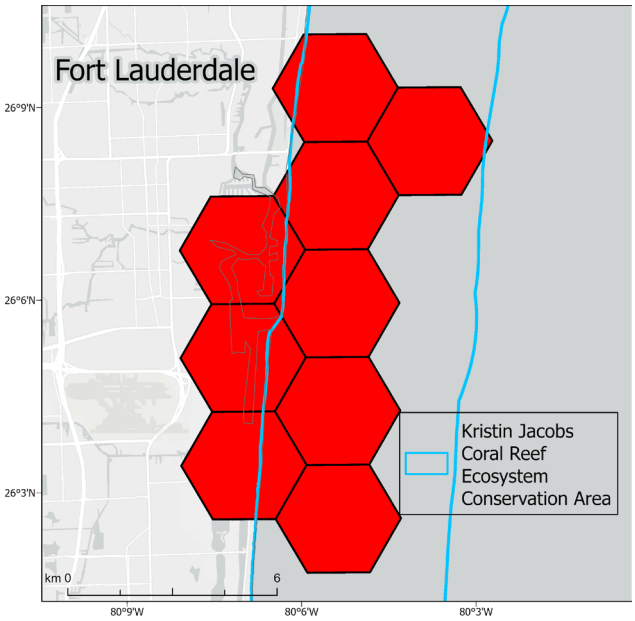


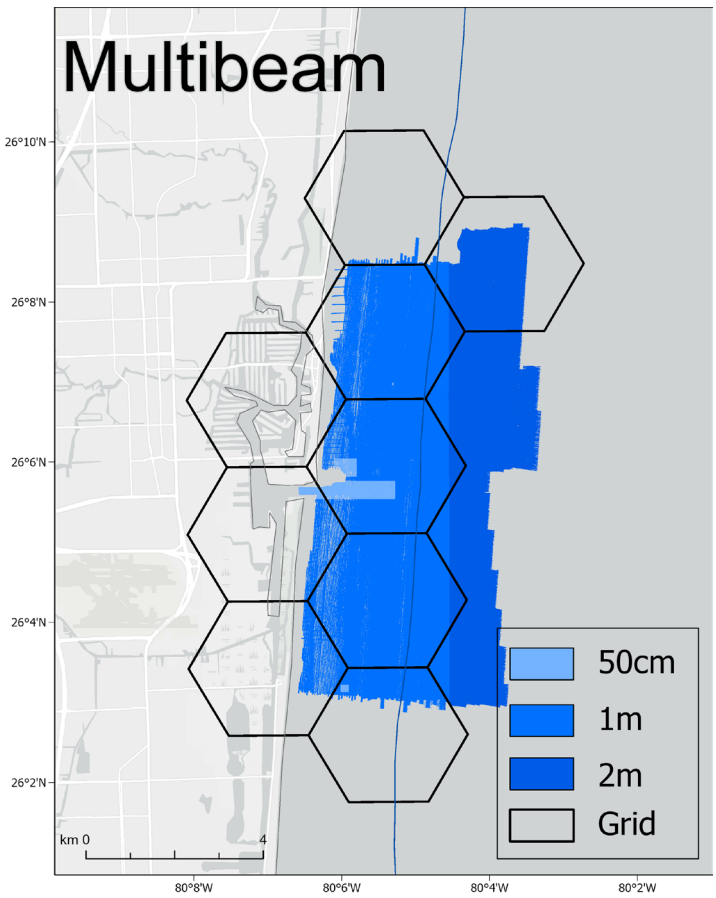
Figure 12. High priority cells offshore of Fort Lauderdale.

Covering this region is the Kristin Jacobs Coral Reef Ecosystem Conservation Area (Coral ECA) which includes the sovereign submerged lands and state waters offshore of Martin, Palm Beach, Broward, and Miami-Dade counties. Although lidar data does cover the majority of the Coral ECA, participants identified the resolution as too coarse (>3 m resolution) for their data needs. Lidar might be adequate for regional-scale projects, however, a finer-scale resolution using multibeam sonar is needed for project-specific mapping that may be impacted by planned port expansion (under consultation with Section 7 of the Endangered Species Act and Magnuson-Stevens Act for port expansions). In addition, Walker and Klung (2014) created a shallow - water habitat map in this area from about 0–10 m depth, however data is likely outdated and does not extend to deeper reef edge.

Table 5. Data summary of participant input for the Fort Lauderdale high priority area. Percent coins are calculated based on the Map Data, Management Use, and Methodology coin totals within these nine hexagons only.

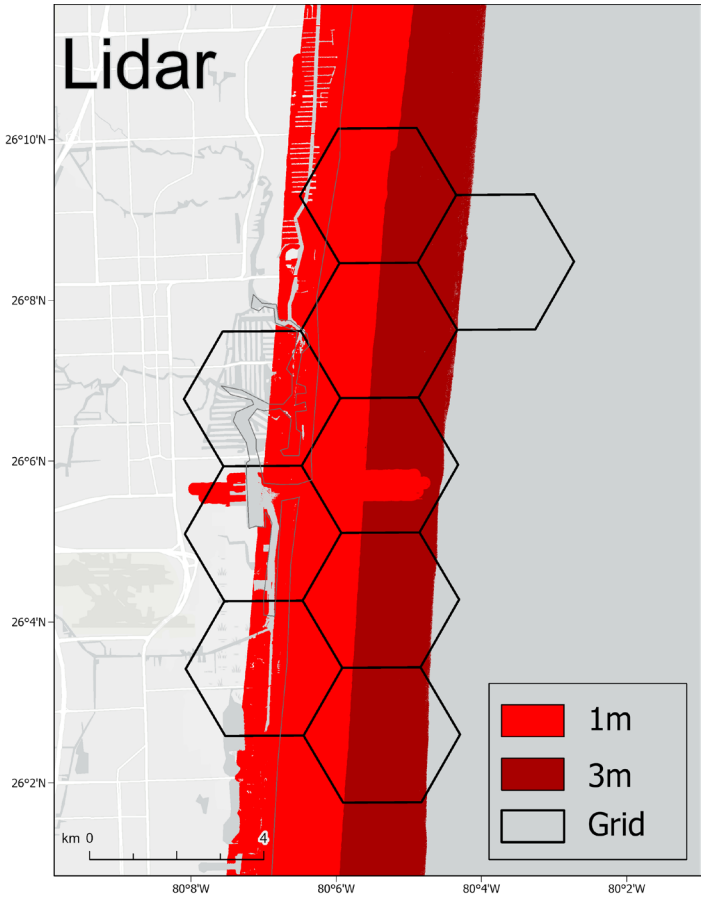
Total Coins (# hexagons):	**Rank** (# hexagons):	**Number of Participant Groups:**
Top 10% (9)	Highest (8)	7
	High (1)	
Map Data (% coins):	**Management Uses** (% coins):	**Mapping Methodology** (% coins):
Elevation (46%)	Habitat Restoration (40%)	Multibeam Echosounder (81%)
Habitat Map (43%)	Consultations/Permitting (37%)	Lidar (16%)
Backscatter (9%)	Monitoring (7%)	Sidescan (3%)
Photomosaics (1%)	Spatial Protection/Mgmt. (5%)	

Shoreline Miami, FL. Photo credit: Unsplash



Multibeam data coverage, 50 cm in areas outside Port Everglades opening, 1m along nearshore areas, and 2m along the reef break

2009: 50 cm, 1 m, 2 m – H11896



Lidar data coverage, 1 m along nearshore areas, 3 m along the offshore margin out to roughly 50 m depth

2017: 1 m, 3 m – USACE FEMA Topobathy Lidar
2016: 1 m – USACE NCMP Topobathy Lidar
2008: 3 m – H12117, H12118

Figure 13. Outlines of existing Fort Lauderdale datasets for multibeam (left) and lidar (right). List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data.

3.5.2 Miami Port Area and Reef Edge

Just south of the Fort Lauderdale high priority area is a 77 km long group of cells that runs from north Miami, along the deeper edge of the southeast Florida Reef Tract, down to North Key Largo (Figure 14). This priority area contains 35 hexagons (364 km^2), consists of coin values in the top 10%, was of interest to 11 groups, and were within the top two rank categories (Table 6). Multibeam data from 2009 is available from North Miami to Key Biscayne. Recent lidar data (2016–2019) covers most of the nearshore cells, however a large data gap exists along the deeper edge of the cell area (Figure 15).

Multibeam should be considered as the preferred method for collecting new mapping data because it contains Backscatter, one of the top Map Data selected in this region, and a key dataset needed to determine substrate hardness and reef characteristics. Participants have indicated that data are needed past the lidar penetration depth (approximately 40 m) for all outer reefs and along the Reef Tract. Existing multibeam data may be sufficient where it exists, however due to the age (2009)

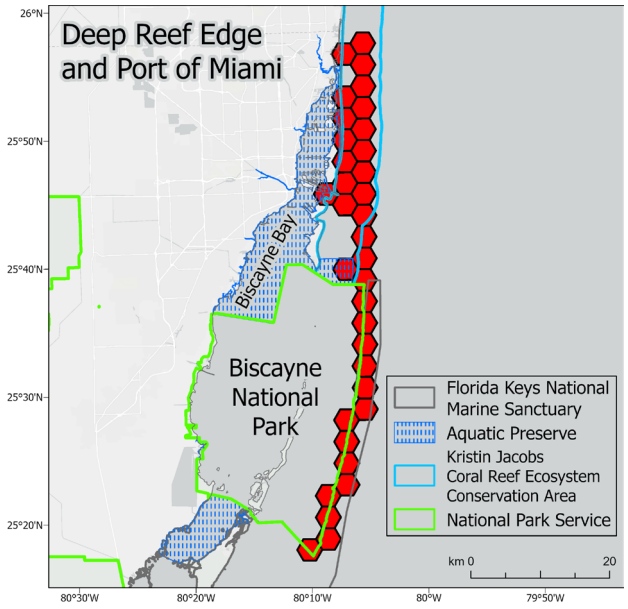
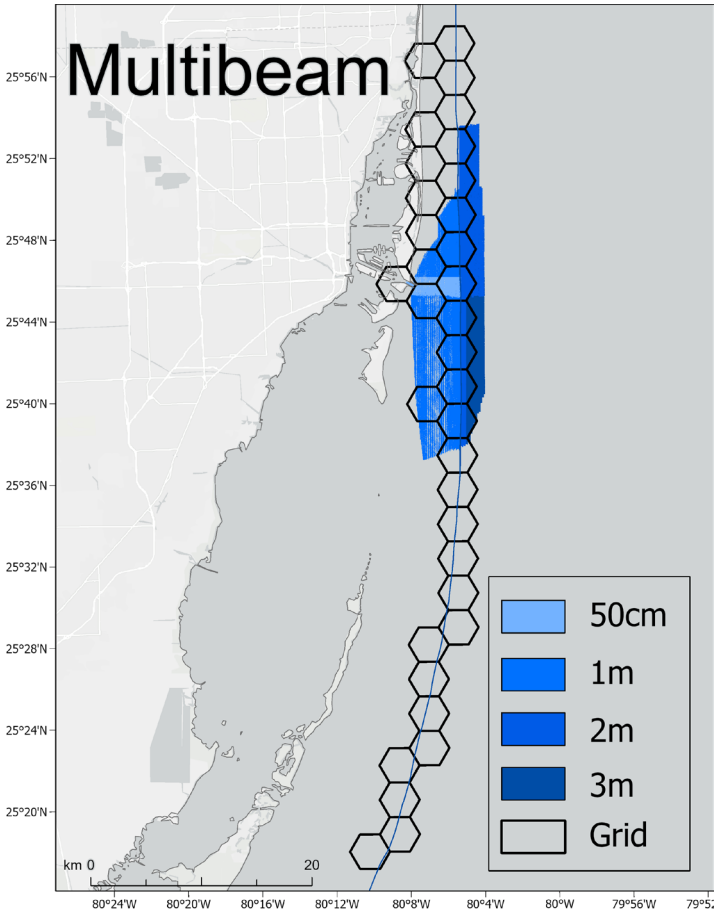


Figure 14. High priority cells offshore of Port Miami.

it is unlikely to contain backscatter data. Additionally, sediment movement and dredging in the Miami port area have also likely changed the characteristics of the bathymetry since 2009. Much of the northern section of this area also falls within the Coral ECA. A better understanding of the reef edge including low-relief pavement and outer reefs is needed to support reef fish and habitat assessments, identification of spawning aggregations and their conservation, and habitat condition and ecosystem assessments within this conservation area.

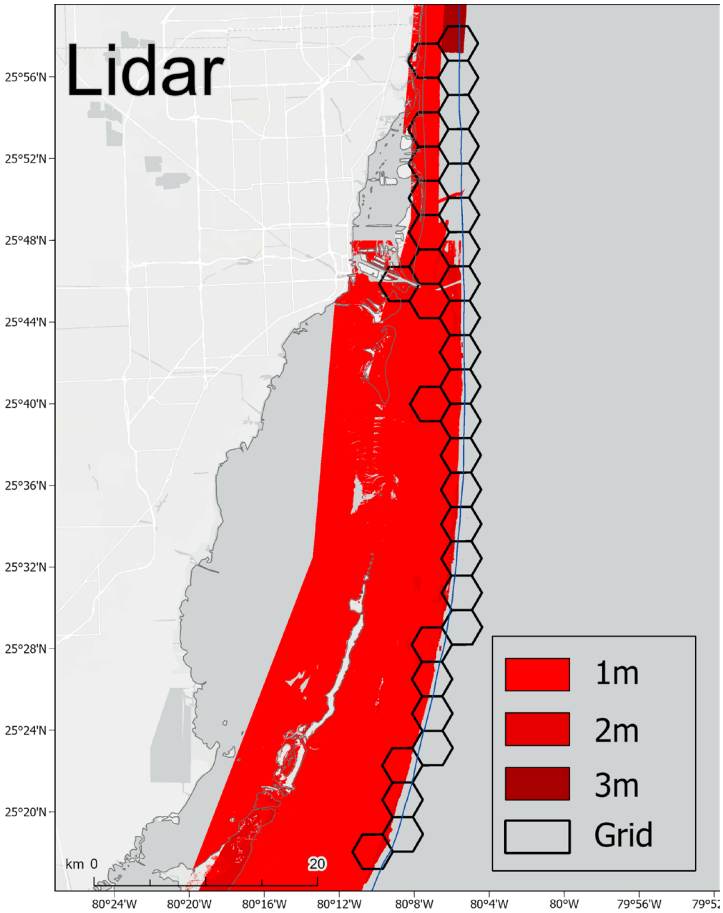
Table 6. Data summary of participant input for the Port of Miami high priority area. Percent coins are calculated based on the Map Data, Management Use, and Methodology coin totals within these 35 hexagons only.

Total Coins (# hexagons):	**Rank** (# hexagons):	**Number of Participant Groups:**
Top 10% (35)	Highest (24)	11
	High (11)	
Map Data (% coins):	**Management Uses** (% coins):	**Mapping Methodology** (% coins):
Elevation (35%)	Fisheries (25%)	Multibeam (38%)
Habitat Map (28%)	Spatial Protection / Management (24%)	Lidar (37%)
Backscatter (25%)	Monitoring (22%)	Uncrewed Systems (15%)
Ground Truthing (8%)	Habitat Restoration (17%)	



Multibeam data coverage, 50 cm in areas outside Port of Miami opening, 1 m along nearshore areas, 2 m along the offshore margin, and 4m past the reef break

2009: 50 cm, 1 m, 2 m, 4 m - H11898, H11897
**surveys included variable resolutions based on depth*



Lidar data coverage, 1 m along nearshore areas and out to the reef break, 3 m along the offshore margin in the northernmost cell

2018–2019: 1 m – NOAA NGS Topobathy Lidar DEM: Miami to Key Largo
2017: 1 m – USACE FEMA Topobathy Lidar (Post Irma)
2017: 2 m – NOAA NGS Topobathy Lidar: FL Keys Outer Reef Block 04
2016: 1 m – USACE NCMP Topobathy Lidar

Figure 15. Outlines of existing datasets for multibeam (left) and lidar (right). List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data.

3.5.3 Hawk Channel

A group of nine hexagons (covering 94 km^2) were identified in the lower Keys in Hawk Channel, spanning from Big Pine Key west to Cudjoe Key (Figure 16). This area was of interest to nine participant groups, and were within the top two rank categories (Table 7). Large data gaps exist within Hawk Channel, likely due to high turbidity and several navigational hazards (shoals, reefs, shipwrecks, etc.; Figure 17).

Multibeam coverage is limited to a portion of the southernmost hexagons, some of which was recently collected by NOAA's Office of Coast Survey in 2021. Multibeam data from 2017 does cover Looe Key, which is likely of high interest to coral reef managers due to its status as a Mission: Iconic Reef. Lidar data covers some portion of this high priority area, however there are several large data gaps in depths of 40-45 m. Not only would filling in data gaps fulfill a need for continuous bathymetric data, but collecting multibeam backscatter data would also help understand patch reef habitats along the cross-shelf reef zones. This high priority area also contains two Mission: Iconic Reefs (Looe Key and Newfound Harbor) and three FKNMS Marine Zones (https://floridakeys.noaa.gov/zones/).

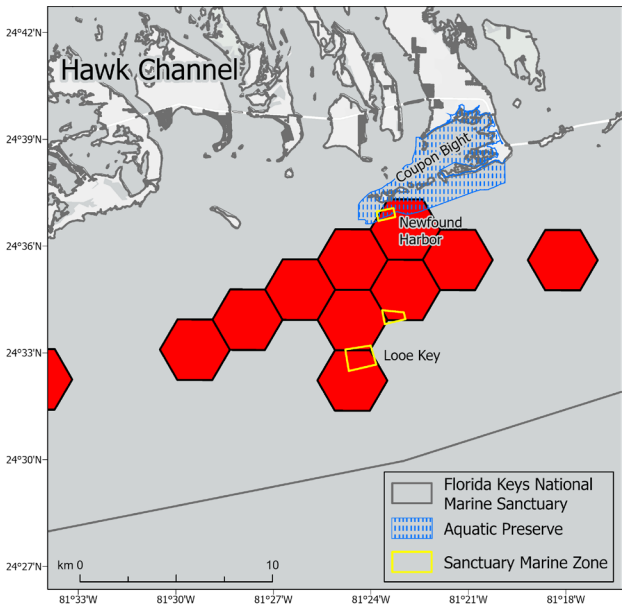
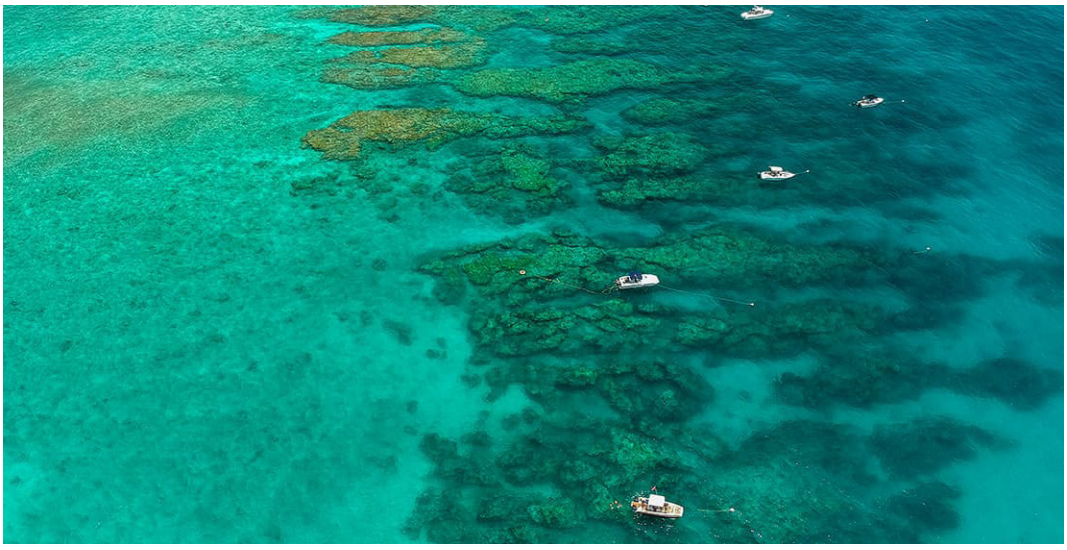


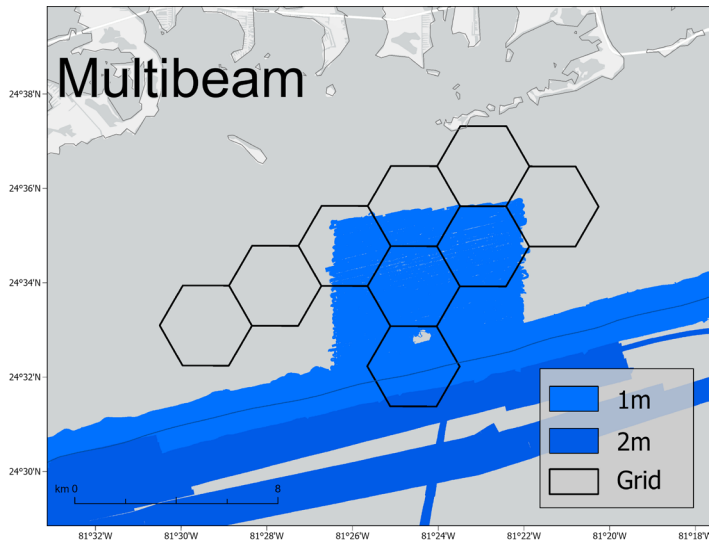
Figure 16. High priority cells in Hawk Channel.

Table 7. Data summary of participant input for the Hawk Channel high priority area. Percent coins are calculated based on the Map Data, Management Use, and Methodology coin totals within these nine hexagons only.

Total Coins (# hexagons):	**Rank** (# hexagons):	**Number of Participant Groups:**
Top 10% (9)	Highest (7) High (2)	9
Map Data (% coins):	**Management Uses** (% coins):	**Mapping Methodology** (% coins):
Elevation (29%)	Monitoring (25%)	Multibeam (40%)
Photomosaics (29%)	Habitat Restoration (24%)	Lidar (31%)
Backscatter (23%)	Endangered Species Mgmt. (17%)	Photogrammetry (28%)
Habitat Map (18%)	Fisheries Management (17%)	
	Spatial Protection/Mgmt. (16%)	

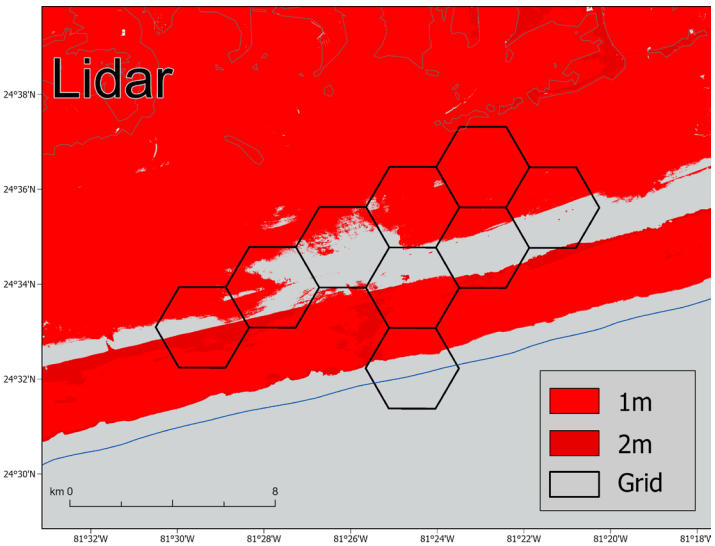


Spur and groove reef at Looe Key Sanctuary Preservation Area. Credit: Unspalsh



Multibeam data coverage, 1 m around the Looe Key area and along the offshore reef bar, 2 m past the reef break

2021: 1 m, 2 m – NOAA Office of Coast Survey (in progress)
2010–2018: 2 m – Compilation (see here for map service, download available through the FKNMS Digital Atlas NCEI accession)
2017: 1 m – USGS Multibeam Bathymetry



Lidar data coverage, 1 m along most of the nearshore and offshore reef bar areas, 2 m filling some gaps along very shallow nearshore areas and the offshore reef bar

2018–2019: 1 m – NOAA NGS Topobathy Lidar: Miami to Marquesas Keys, FL
2017: 2 m – USACE FEMA Topobathy Lidar (Post Hurricane Irma)
2016: 2 m – NOAA NGS Topobathy Lidar: FL Keys Outer Reef Block 01
2016: 1 m – NOAA NGS Topobathy Lidar: Sugarloaf Key to Big Pine Key

Figure 17. Outlines of existing datasets for multibeam (left) and lidar (right). List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data.

3.5.4 Dry Tortugas National Park

Participants showed significant interest in the entirety of the Dry Tortugas National Park (Figure 18). The southern portion of DRTO is highlighted in this section because it consisted mainly of cells in the Highest rank category. This 15-hexagon area (155.85 km^2) was of interest to four participant groups with two hexagons in the Top 10% of total coins (red), and 13 in the High category (orange). The rank categories were also significant, with all 15 cells in the top two rank categories. This indicates that not only were there a high number of coins in this area, but also the highest number of Management Uses and interested groups (Table 8). Due to the abundance of shoals, reefs, and keys within DRTO, there may be limits to where vessels equipped with multibeam echosounders can safely access.

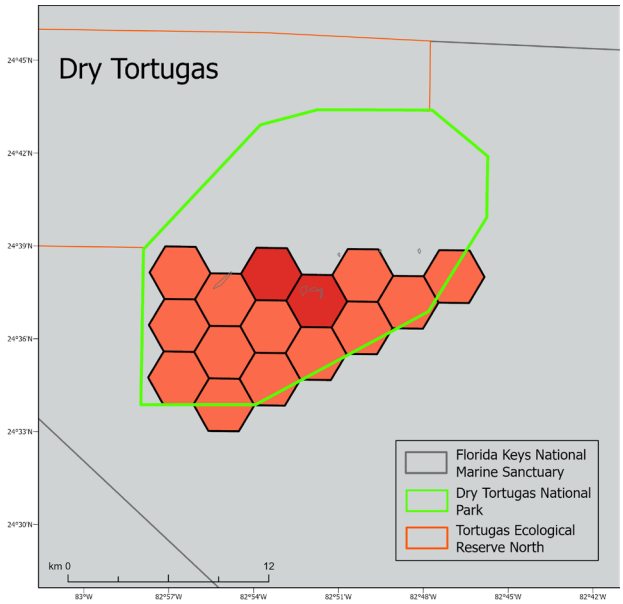
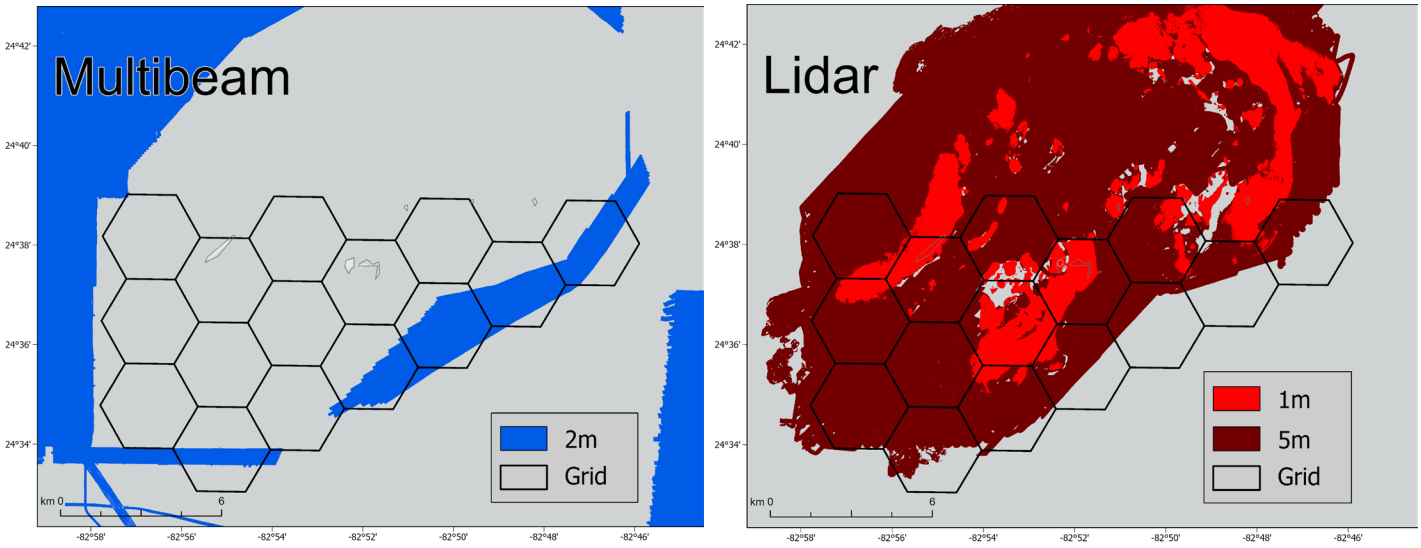


Figure 18. High priority cells in Dry Tortugas National Park.

This area is nearly completely covered by lidar data collected in 2015 by NOAA's National Geodetic Survey (Figure 19). However most of this lidar data is only available at 5 m resolution, which is too coarse to detect coral reef features needed to understand key habitats within DRTO. There is a small portion of this area with a 1 m resolution surface, however it only covers the shoal areas. An additional limitation with the existing lidar is that it does not contain backscatter data, and thus cannot be used to distinguish hard vs. soft substrate (i.e. reef structures vs. sand). Ault et al., (2020) identified DRTO as the highest priority location to re-map with multibeam sonar. DRTO is a key region for understanding ecological fish-habitat relationships with relatively low human impacts on fish populations and their habitats. Updated data to monitor changes in habitat characteristics within the park are important for collecting fish status metrics for continued coral reef monitoring efforts and updated sampling protocols. Specifically, high resolution bathymetry will allow local managers to accurately estimate habitat rugosity, an important metric used to plan reef fish surveys and produce precise abundance estimates.

Table 8. Data summary of participant input for the Dry Tortugas high priority area. Percent coins are calculated based on the Map Data, Management Use, and Methodology coin totals within these 15 hexagons only.

Total Coins (# hexagons):	**Rank** (# hexagons):	**Number of Participant Groups:**
Top 10% (2)	Highest (9)	4
High (13)	High (6)	
Map Data (% coins):	**Management Uses** (% coins):	**Mapping Methodology** (% coins):
Elevation (38%)	Monitoring (46%)	Multibeam (87%)
Habitat Map (31%)	Fisheries Management (37%)	Lidar (13%)
Backscatter (27%)	Spatial Protection/Mgmt. (12%)	
Photomosaics (4%)	Endangered Species (2%)	
	Habitat Restoration (2%)	



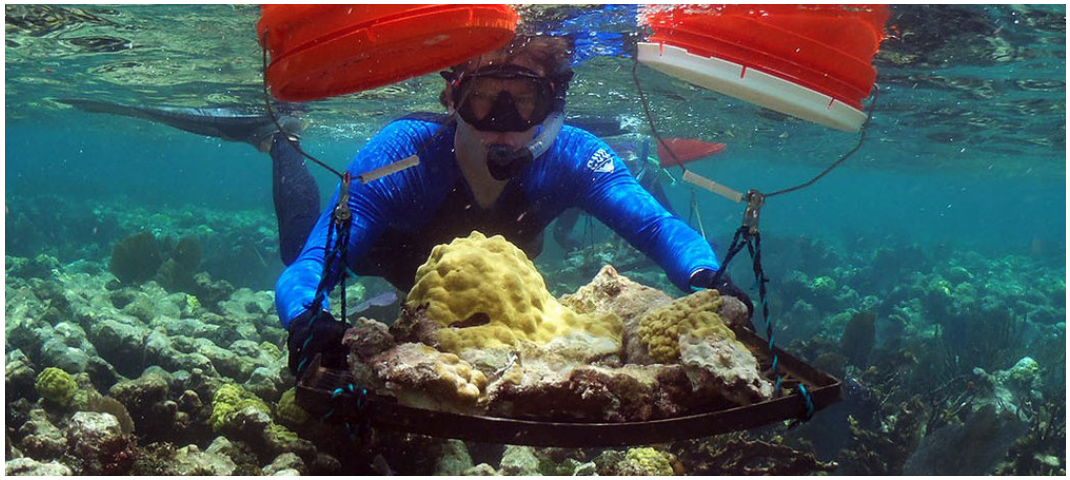
Multibeam data coverage, 2 m around the boundary of the Dry Tortugas National Park overlapping with the south and eastern cells

2021: 2 m – NOAA NCCOS (W00603 - in progress)
2004–2018: 2 m – Compilation (see here for map service, download available through the FKNMS Digital Atlas NCEI accession)

Lidar data coverage, 5 m covering most of the Dry Tortugas National Park with sporadic gaps. Data collected over shoal areas processed to 1 m resolution.

2015:1 m, 5 m – NOAA NGS Lidar DEM: Dry Tortugas (source – 5 m, source – 1 m)
**1 m data combined with 5 m footprint in above graphic*

Figure 19. Outlines of existing datasets for multibeam (left) and lidar (right). List of available data contains the year the survey was completed, data resolution (in meters), and a source link to the data.



Snorkeler conducting coral restoration efforts. Credit: NOAA Photo Library

3.5.5 Mission: Iconic Reefs

NOAA and its partners have developed a designation called *Mission: Iconic Reefs* (MIR) to restore seven ecologically and culturally significant reef sites in the Florida Keys (Figure 20). Cells located at each of the seven MIR sites all contained the Top 10% of coins and were in the top two rank categories (Table 9). Lidar is the only existing modern-day bathymetry data over the MIR sites, and no multibeam has been collected over these locations since 1991, apart from multibeam collected over Looe Key in 2017.

NOAA has identified the most immediate actions necessary to restore these coral reef sites (Mission: Iconic Reefs 2022–2025 Priorities), one of which is to "Acquire reef-scale imagery [sub-cm] at sufficient resolution to all MIR sites, to serve as baselines for comparison in future restoration years". High resolution imagery using methods such as drones or scuba divers equipped with a digital SLR or high-quality camera is crucial for creating detailed photomosaics over each reef site. Reef-scale imagery can be used to create high quality base maps, which will improve the ability to identify outplant locations for specific species and improve the overall long-term success of coral restoration. Lidar data covers most MIR sites and is likely sufficient for bathymetric and subsequent derivative data needs, however updated multibeam data (including backscatter) will also help improve site monitoring.

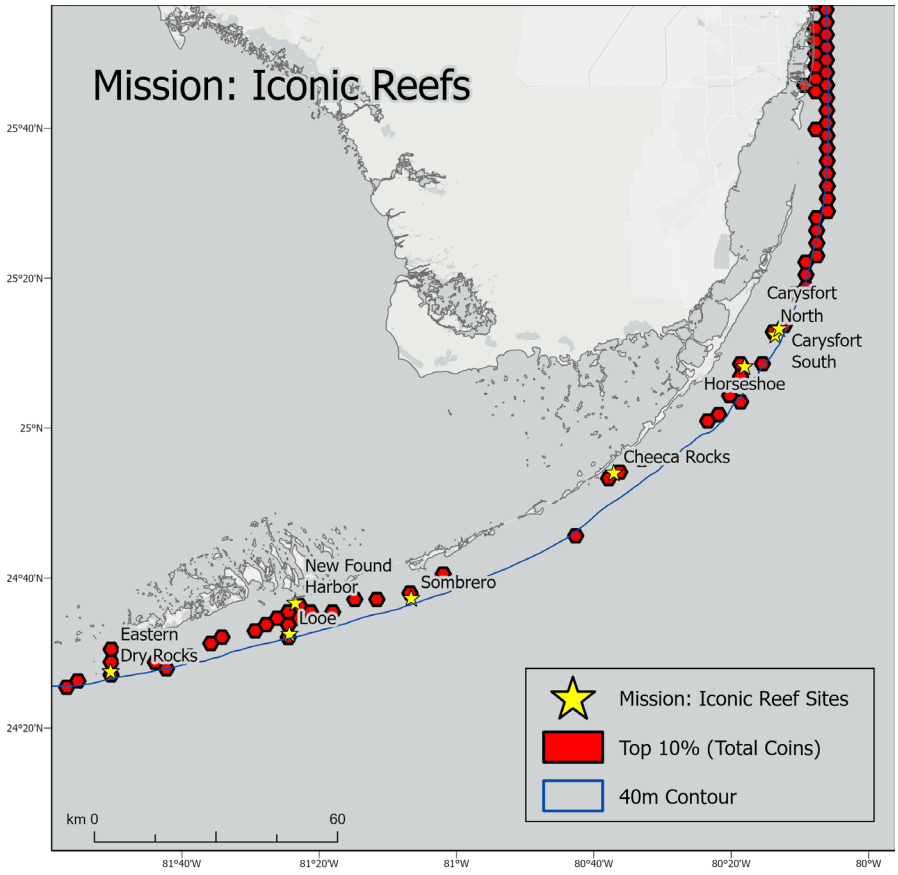


Figure 20. The seven iconic reef sites along the Florida Reef Tract, overlaying cells with the Top 10% of coins.

Table 9. Data summary of participant input for the Mission: Iconic Reefs. Percent coins are calculated based on the Map Data, Management Use, and Methodology coin totals within these hexagons only.

Total Coins (# hexagons):	**Rank** (# hexagons):	**Number of Participant Groups:**
Top 10% (9)	Highest (4) High (5)	9
Map Data (% coins):	**Management Uses** (% coins):	**Mapping Methodology** (% coins):
Photomosaics (46%)	Habitat Restoration (41%)	Multibeam (70%)
Backscatter (25%)	Endangered Species (26%)	Photographs (19%)
Elevation (18%)	Spatial Protection/Mgmt. (7%)	Lidar (9%)
Habitat Map (10%)	Monitoring (6%)	

Chapter 4 Conclusion

We used an online application to gather data needs from 18 local experts regarding their priorities for benthic mapping within Florida's coral reef jurisdiction. This system allowed participants to indicate where mapping data is needed, the urgency of the need, what coral management actions will be addressed with this data, and what type of data is needed. There are several areas that participants identified as a high priority for future mapping. These areas had the highest overall coin totals, a significant number of participant groups who allocated coins into those cells, and a diversity of Management Uses. Most of the high priority areas were distributed along the ocean side of the Reef Tract, from Fort Lauderdale to Key West, and included the Dry Tortugas and all seven of the Mission: Iconic Reef sites. There were little to no data needs identified within the Florida Bay, likely due to sparse coral reef habitat.

These high priority areas highlight some of the best opportunities for collaboration, with the potential to meet a variety of coral management goals. As an example, a large group of cells within Hawk Channel (directly south of Ramrod Key) were priority for nine different groups. This region also contains two Mission: Iconic Reef sites, Looe Key and Newfound Harbor, and three Sanctuary Marine Zones. It was identified by participants that long-term biophysical monitoring and restoration planning for these cells is crucial for continued coral reef management. Furthermore, these cells often had the same suite of desired Map Data including *Elevation* and *Photomosaics*, which can be used to help identify patch reef habitats and support long term monitoring and restoration efforts. These data can often be collected on a vessel with sonar capabilities, combined with an ROV for benthic imaging.

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 coast of Jupiter had 'medium' to 'high' number of coins, however were only identified by one or two groups, despite an increasing need for management and protection in this area. Similarly, a large portion of the south Florida coast was identified as a great interest for the Management Use *Coastal Vulnerability* (See Appendix B, Figure B.8) but was only identified by one agency as a primary justification. These examples illustrate the diversity of goals across participating groups and, in some cases, the uniqueness of agency needs. And finally, areas that received no coins at all (i.e. majority of Florida Bay), were simply not a priority to this group of coral reef experts and managers, at the time of this project, relative to other parts of the study area. Participant groups primarily contained coral reef managers, experts, and researchers within the coral management scope of this project. Had experts in mangrove and seagrass been included, areas such as Florida Bay may have shown more interest. Additionally, most participant groups selected the same menu options (i.e. Management Use) throughout the entire grid rather than selecting unique options based on different geographic areas. This could have been intentional to indicate consistent Management Use, Map Data, and Methodology among all the selected cells, or the participant neglected to change the menu option when selecting new areas to prioritize. Thus, it's difficult to make a direct connection between an agency's menu selection and data needs in any specific area, group of cells, or feature.

Underwater photo of vibrant coral. Photo credit: Greg McFall (NOAA)

For future project planning, targeting some combination of cells with highest total coins and summary rank will ensure that data collection will fulfill a variety of coral reef management purposes, meet the data requirements of 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 data may be outdated, too coarse resolution, poor quality, or lack ancillary data such as backscatter. Future surveys may exclude these areas that have already been mapped, however further consideration should be made on if these existing data meet the needs of local agencies.

Links to Access Data

Final maps and results from this prioritization are freely available 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 and Web Services:

- 2022: Spatial Prioritization Data in Florida (Martin County to Dry Tortugas) for Future Coral Reef Mapping from 2021-04-26 to 2021-05-24
  - Zenodo Accession *in progress*
- 2021: Dashboard - Florida Shallow Coral Mapping Prioritization Results
  https://noaa.maps.arcgis.com/apps/dashboards/085bfe4db42241b19b5a76cc58faf8b4
- 2021: Project Site - Coral Reef Prioritization | A Roadmap for Future Mapping
  https://us-shallow-coral-reef-mapping-priorities-noaa.hub.arcgis.com/
- 2021: NCCOS Website - Defining Future Seafloor Mapping Priorities to Inform Shallow Coral Reef Management
  https://coastalscience.noaa.gov/project/defining-future-seafloor-mapping-priorities-to-inform-shallow-coral-reef-management/

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Appendices

Appendix A: Florida Mapping Inventory Reference

Table A.1. Florida Mapping Inventory References Map. Map service URLs accessed on January 15, 2022.

Category	Item Name (name of web service)	SE Coast	Keys	Tortugas	Description	Map Service URL
Multibeam	NOAA 2020 Multibeam Bathymetry: NF-20-08, Preliminary (Tiled)		x	x	2 m resolution. Two strips of bathymetry, one directly south of Riley's Hump and the other south west of the Marquesas Keys and south east of the Dry Tortugas, collected in 2020	https://noaa.maps.arcgis.com/home/item.html?id=59b04016103f417eb558ebc921228275
	Dry Tortugas Multibeam Bathymetry (collected by NOAA March-April 2021)			x	2 m resolution. Bathymetry surrounding the Tortugas Ecological Reserve primarily on the north and north west sides with a small band on the south east, collected in 2021	https://noaa.maps.arcgis.com/home/item.html?id=59b04016103f417eb558ebc921228275
	Bathymetric Attributed Grid (BAG) Image Services with Survey Polygons	x	x	x	Various resolution spanning many years. Circumglobal compilation of bathymetry data cropped to the Florida area of interest	https://noaa.maps.arcgis.com/home/item.html?id=26ee4c6159b842219cb9729b9ef1b881
Lidar	SE Florida Lidar (Tiled)	x	x		Various resolutions. Collection of Lidar datasets spanning from the Marquesas keys up the Florida Reef Tract to Martin County from 2008-2019	https://noaa.maps.arcgis.com/home/item.html?id=6055a548e45e48b88a892e7c467b8a39
	Martin County_Lidar (2008–2009)	x			Various resolutions. Nearshore Lidar from Martin County south to Biscayne Bay from 2008-2009	https://ocean.floridamarine.org/arcgis/rest/services/Projects_Other/OFR_Lidar/MapServer
Habitat Maps	Unified Reef Map Level 0	x	x	x	Broad, generalized habitat types based on a variety of bathymetry, ground truth methods, and aerial imagery, completed in 2017	https://ocean.floridamarine.org/arcgis/rest/services/Projects_FWC/Unified_Florida_Reef_Tract_Map_FWC/MapServer/8
	Unified Reef Map Level 1	x	x	x	More refined habitat types based on a variety of bathymetry, ground truth methods, and aerial imagery, completed in 2017	https://ocean.floridamarine.org/arcgis/rest/services/Projects_FWC/Unified_Florida_Reef_Tract_Map_FWC/MapServer/7
Boundaries	Southeastern United States 40m Isobath	x	x	x	40 m bathymetric contour of the south east Florida area of interest, created in 2021	https://www.arcgis.com/home/item.html?id=0f0270271a7f4ab0b2c43c8e8bd984c3
	FY21 NOAA Planned Mapping Polygons - Florida		x	x	Office of Coast Survey and Navigation Response Teams contracted mapping polygons, from 2021	https://noaa.maps.arcgis.com/home/item.html?id=ccd6eecefed349019d0374601795d3d1
	NCRMP 50m Sampling Grid	x	x	x	50 m sampling grid used by the National Coral Reef Monitoring Program, from 2021	https://noaa.maps.arcgis.com/home/item.html?id=ed1273b24c8744549f5f13394b21e657
	Mapping Priority Index	x	x	x	Results from the Florida Fish and Wildlife Conservation Commission Mapping Priority Index, updated November, 2020	https://noaa.maps.arcgis.com/home/item.html?id=21682ab695cf44da8bea591002fc1856
	Florida_Counties	x	x	x	Shapefile delineating Florida counties along the Florida Reef Tract, accessed 2021	https://noaa.maps.arcgis.com/home/item.html?id=7dfafae7586945b291ac9ddc3dbdda95
	FKNMS Regulatory Areas		x	x	Areas of various regulation priorities and concern within the Florida Keys National Marine Sanctuary, last updated in 2019	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/FKNMS_final/FeatureServer/0
	National Park Service Lands		x	x	Shapefile showing the areas of land serviced by the National Park Service, compiled in 2022	https://services.arcgis.com/P3ePLMYs2RVChkJx/arcgis/rest/services/USA_National_Park_Service_Lands_20170930/FeatureServer/0
	National Wildlife Refuge System Boundaries		x		Shapefile showing the areas of land serviced by the National Wildlife Refuge System, last updated in 2021	https://services.arcgis.com/QVENGdaPbd4LUkLV/arcgis/rest/services/National_Wildlife_Refuge_System_Boundaries/FeatureServer/0
Points	Mission Iconic Reef Sites		x		Key reef areas pertaining to the Mission: Iconic Reef project, as of 2021	https://noaa.maps.arcgis.com/home/item.html?id=317855112f5946fa8f14adfd9cda8609
	Artificial Reefs in Florida	x	x		A collection of artificial reef locations in Florida's coastal waters, managed by Florida Fish and Wildlife Conservation Commission, but not 100% ground validated, as of 2022	https://noaa.maps.arcgis.com/home/item.html?id=eb2bfd225149405bba23604f20159f56
	Coastal Deepwater Ports	x	x		Deep water ports of Florida, last updated in 2018	https://noaa.maps.arcgis.com/home/item.html?id=152777db40cb41c0a49d295da11289ff
	Coral Reef Monitoring (SECREMP, CREMP) Locations	x	x	x	Regular sampling sites (2021) for Southeast Florida Coral Reef Evaluation and Monitoring Project and Coral Reef Evaluation and Monitoring Project	https://atoll.floridamarine.org/arcgis/rest/services/FWC_GIS/OpenData_MarineEco/MapServer/14
Misc	Florida Keys National Marine Sanctuary Benthic Habitat Data viewer		x	x	A collection of bathymetric and ground truth data throughout the Florida Keys National Marine Sanctuary	https://noaa.maps.arcgis.com/home/item.html?id=59b04016103f417eb558ebc921228275

Appendix B: Individual Maps for Each Management Use

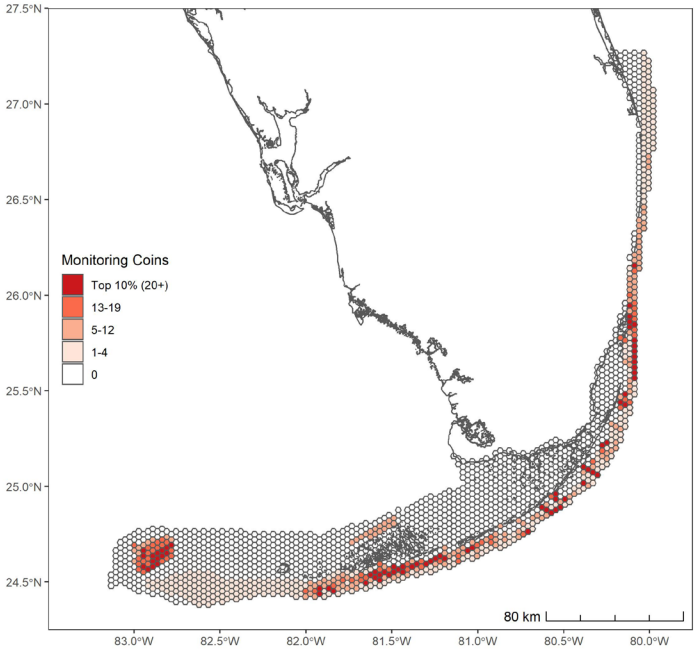

Figure B.1. Map of coins distributed for *Monitoring.*

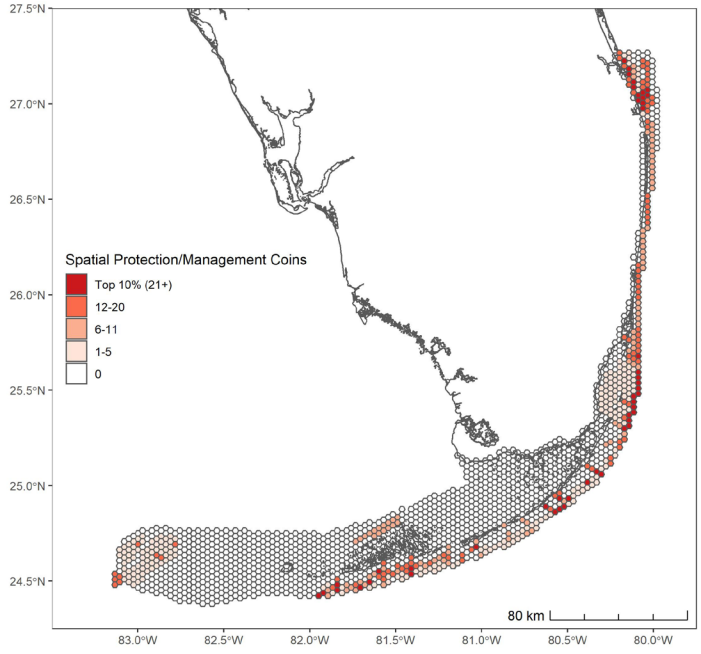

Figure B.2. Map of coins distributed for *Spatial Protection & Management.*

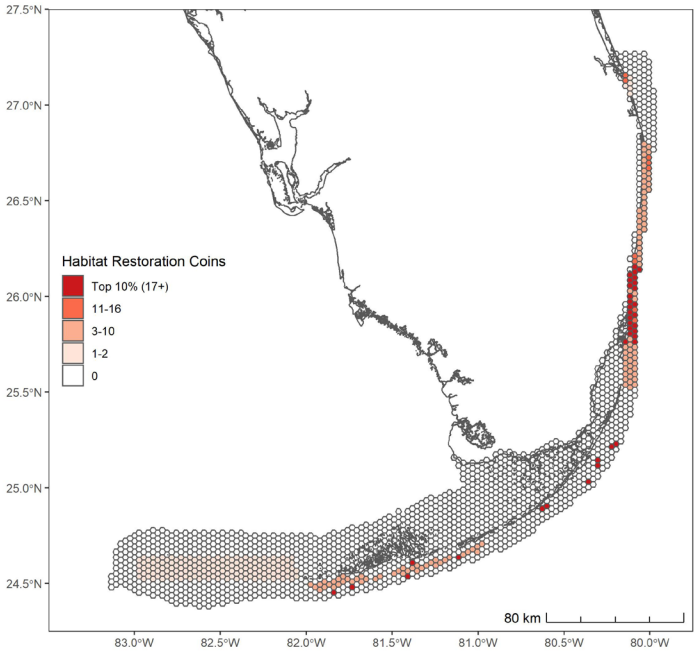

Figure B.3. Map of coins distributed for *Habitat Restoration.*

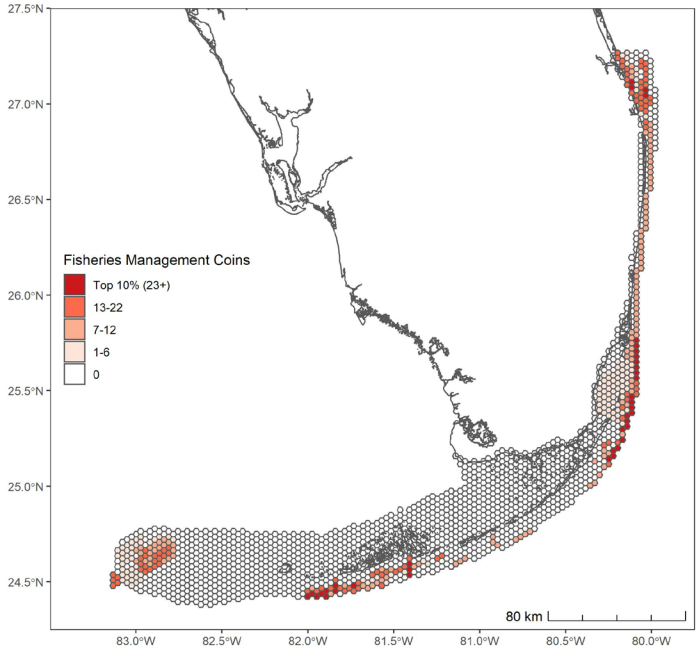

Figure B.4. Map of coins distributed for *Fisheries Management.*

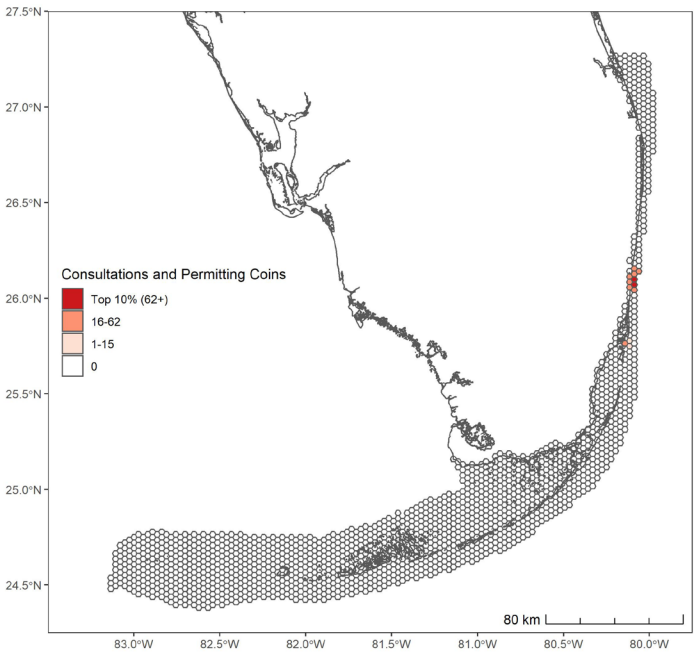

Figure B.5. Map of coins distributed for *Consultations and Permitting.*

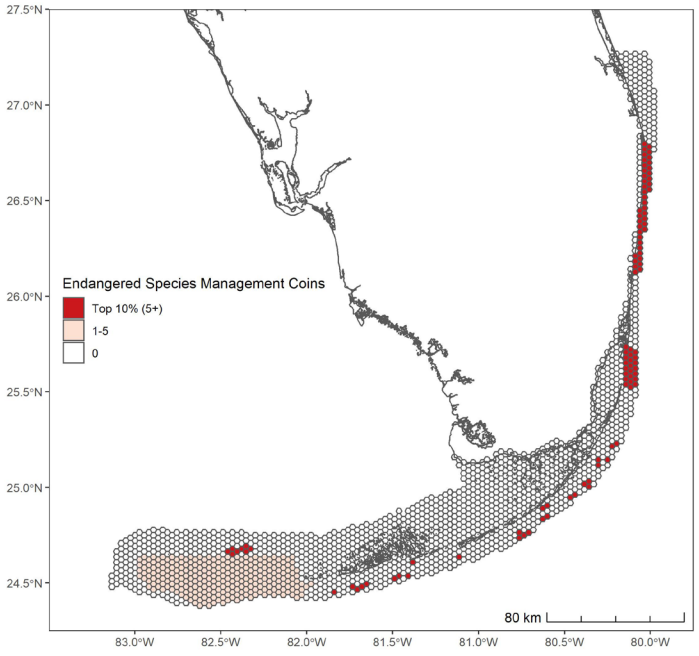

Figure B.6. Map of coins distributed for *Endangered Species Management.*

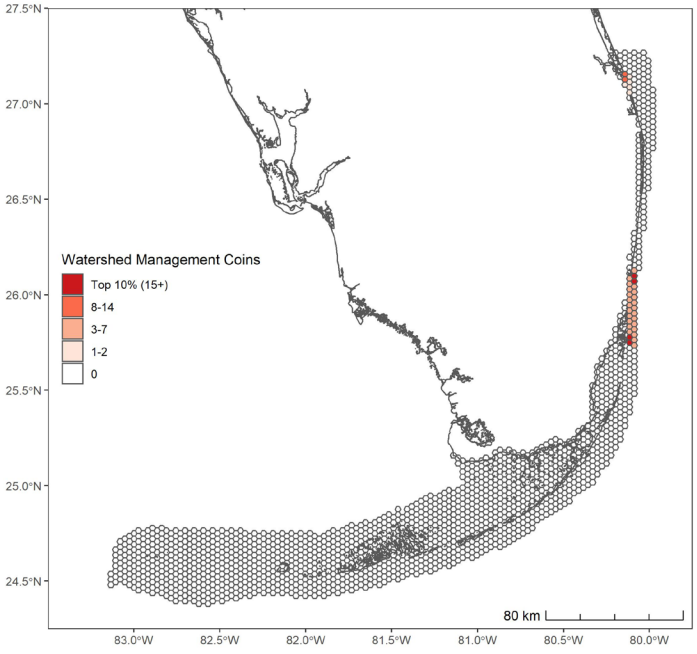

Figure B.7. Map of coins distributed for *Watershed Management*.

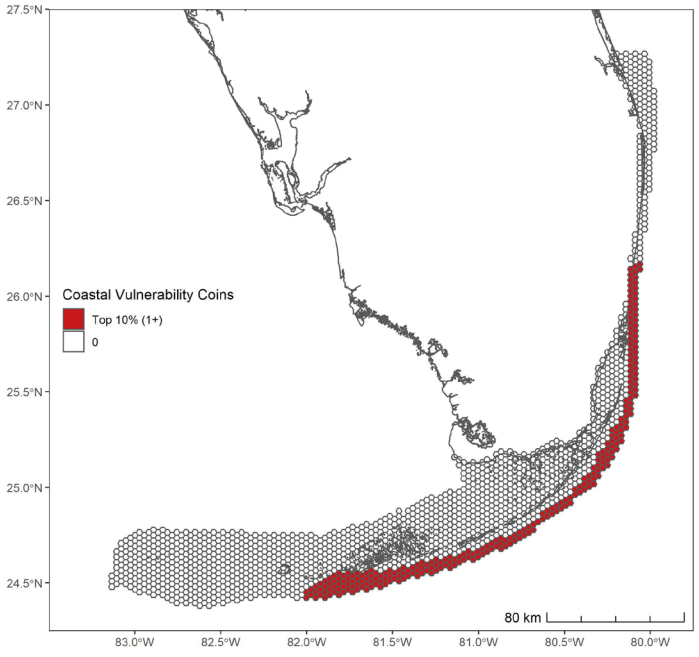

Figure B.8. Map of coins distributed for *Coastal Vulnerability.*

Appendix C: Individual Maps for Each Map Data

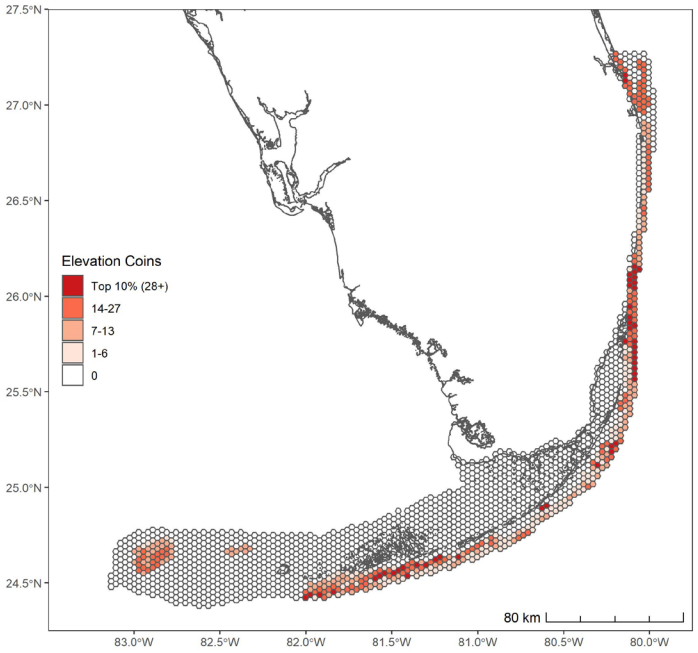

Figure C.1. Map of coins distributed for *Elevation*.

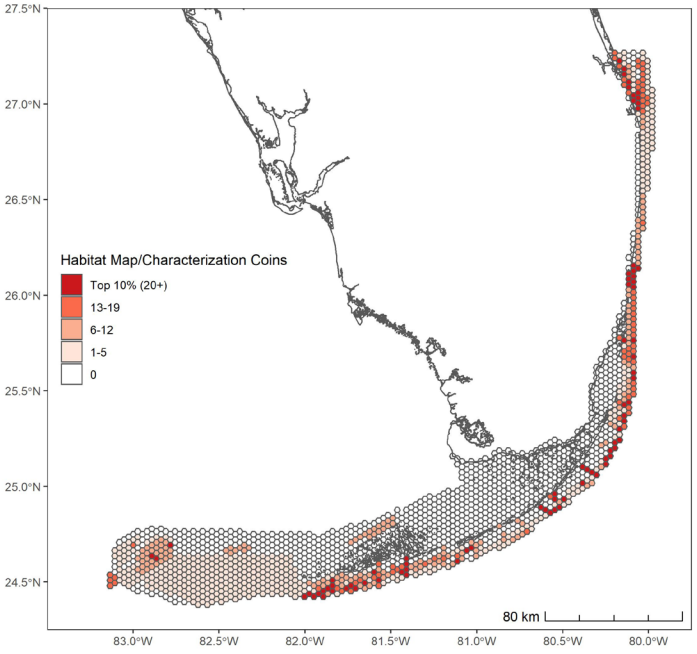

Figure C.2. Map of coins distributed for *Habitat Map/Characterization.*

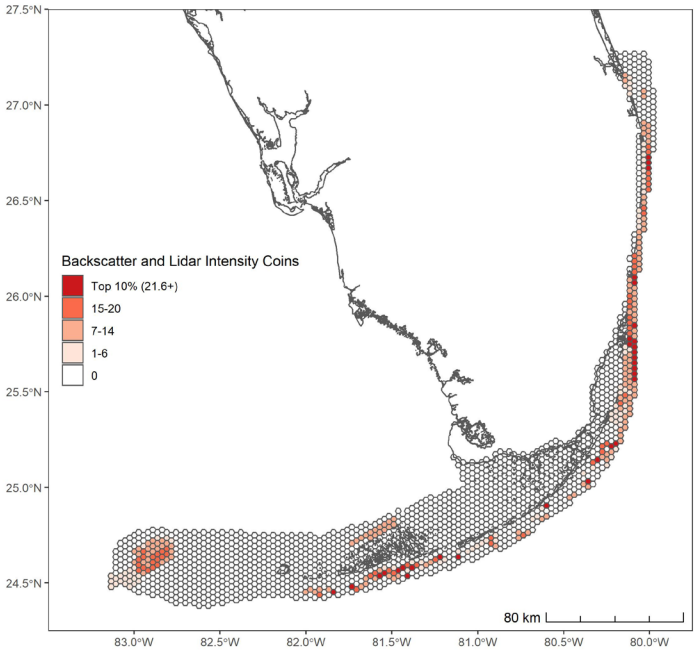

Figure C.3. Map of coins distributed for *Backscatter and Lidar Intensity.*

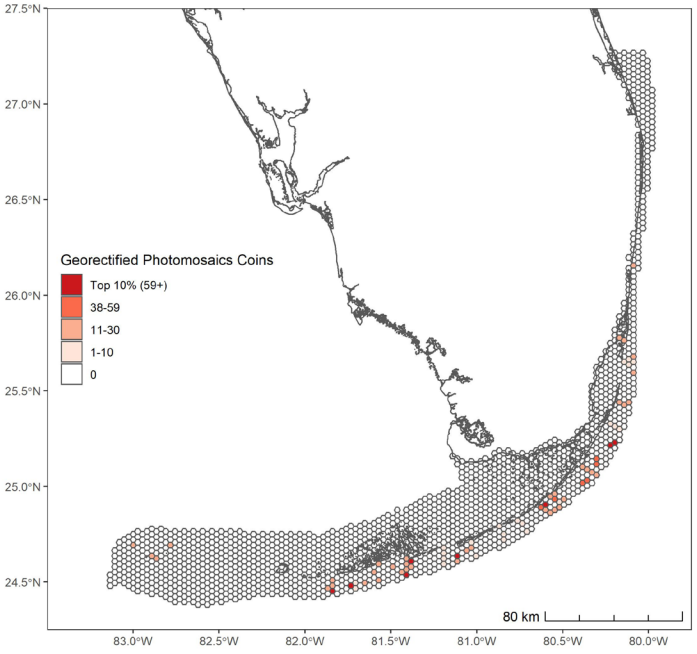

Figure C.4. Map of coins distributed for *Georectified Photomosaics.*

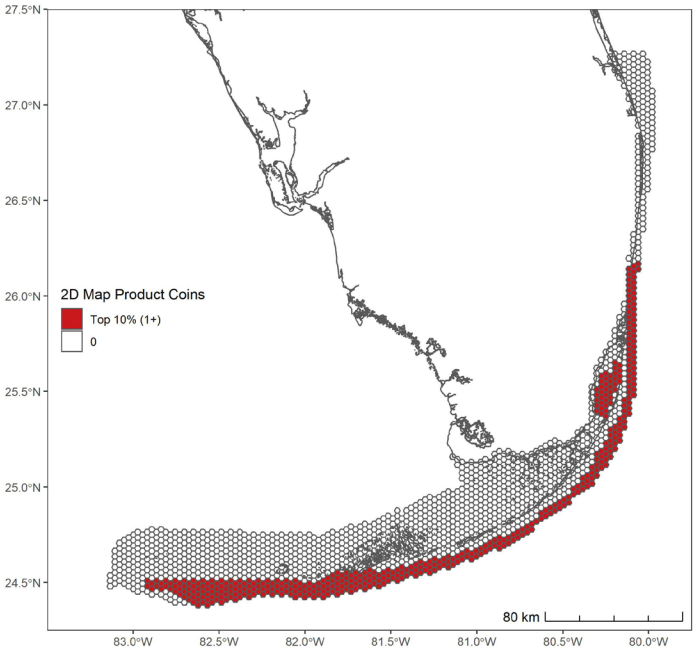

Figure C.5. Map of coins distributed for *2D Map Product*.

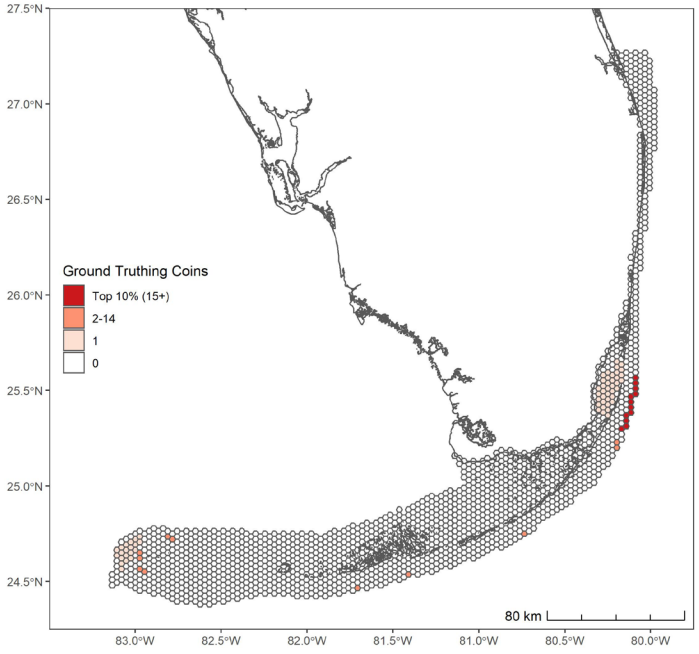

Figure C.6. Map of coins distributed for *Ground Truthing.*

Appendix D: Individual Maps for Each Mapping Methodology

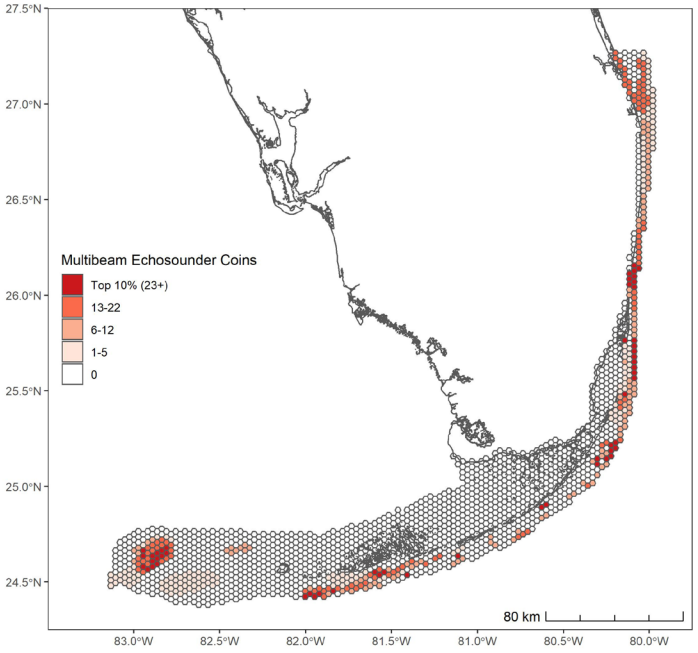

Figure D.1. Map of coins distributed for *Multibeam Echosounder.*

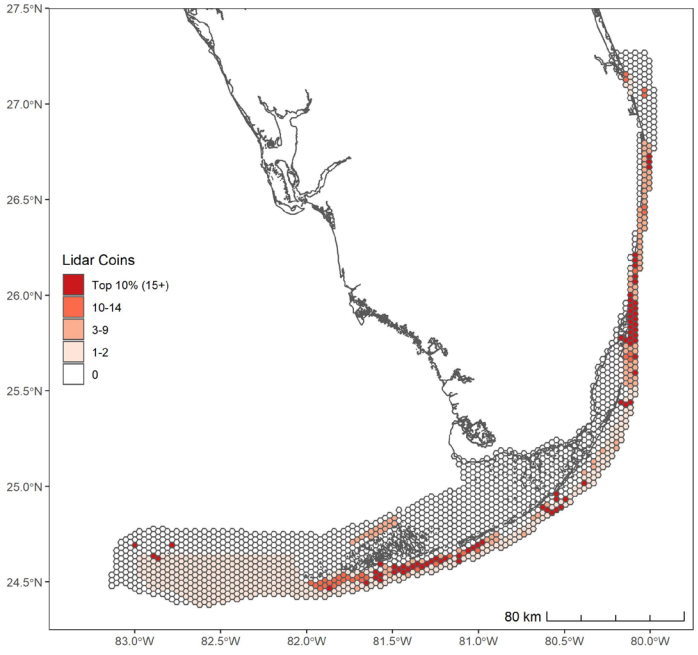

Figure D.2. Map of coins distributed for *Lidar.*

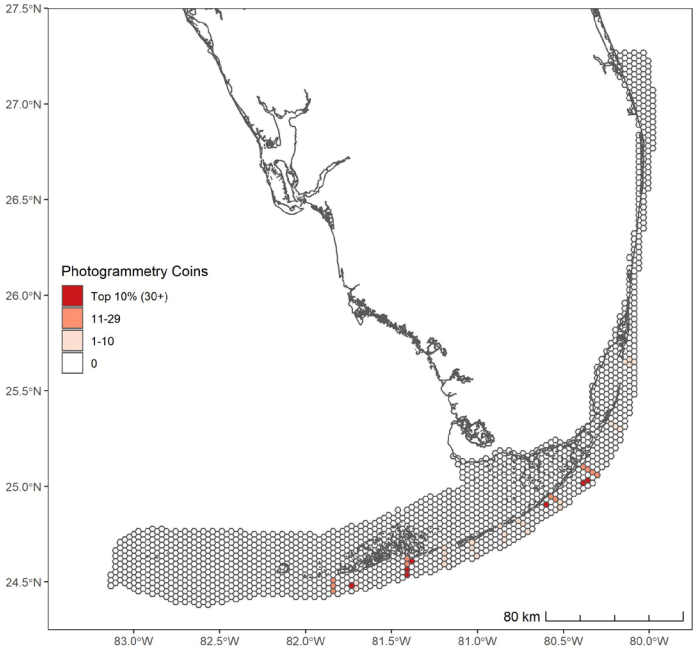

Figure D.3. Map of coins distributed for *Photogrammetry.*

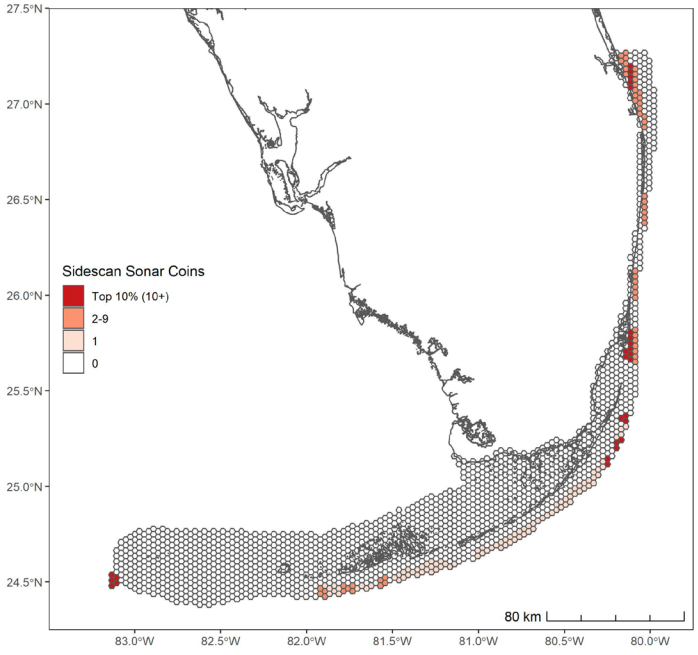

Figure D.4. Map of coins distributed for *Sidescan Sonar.*

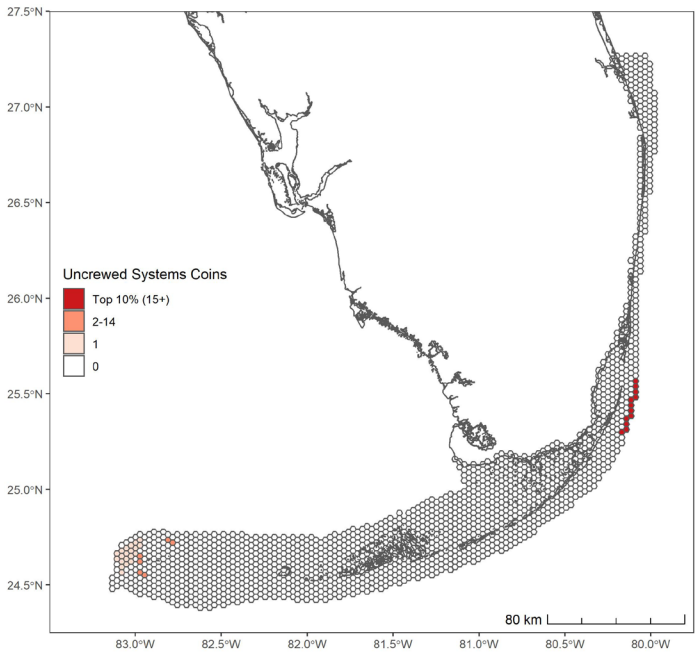

Figure D.5. Map of coins distributed for *Uncrewed Systems.*

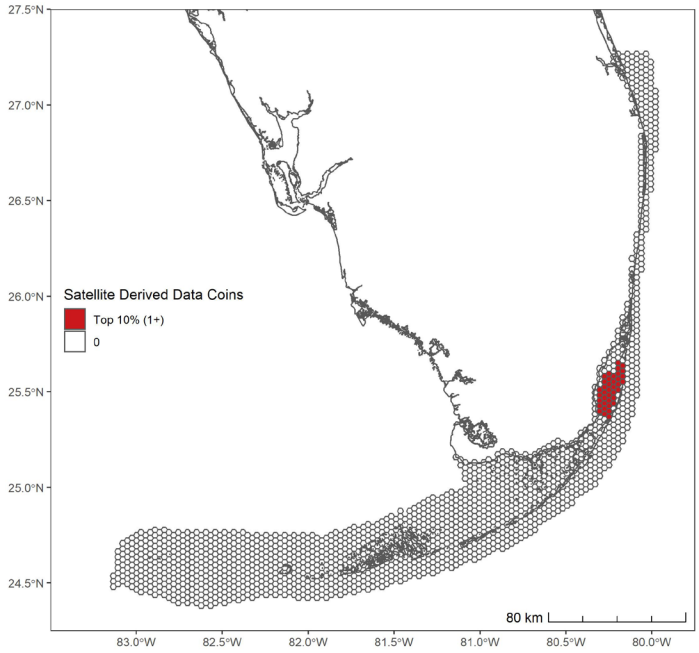

Figure D.6. Map of coins distributed for *Satellite Derived Data.*

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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