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AGENCY PRIORITIES FOR MAPPING CORAL REEF ECOSYSTEMS IN THE MAIN HAWAIIAN ISLANDS

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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/
and
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DISCLAIMER

Agency Priorities for Mapping Coral Reef Ecosystems in the Main Hawaiian Islands

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Executive Summary

NOAA's Coral Reef Conservation Program (CRCP) utilizes benthic mapping data on coral reef ecosystems to support a diversity of science-based management decisions. To efficiently allocate limited mapping resources, CRCP identified the need for current priority locations based on emerging management requirements. Specifically, this effort focuses on coral reef areas up to 40 m deep surrounding the Main Hawaiian Islands, which include the Island of Hawaiʻi, Maui, Kahoʻolawe, Molokaʻi, Lānaʻi, Oʻahu, Kauaʻi, and Niʻihau.

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 data requirements.

A total of 17 participant groups from local federal and state agencies, academic institutions, and non-governmental organizations entered their mapping priorities into the online tool from July 11 to August 1, 2022. The proportion of coins assigned using the Management Use options revealed three (out of a total nine) most selected options: *Monitoring*, *Fisheries Management*, and *Spatial Protection/Management*. The top Map Product Requirement options revealed two main desired data types (out of a total seven): *Substrate Types* and *Identification of Coral Species*. To further explore areas of high interest and need by participants, clusters of top-ranking cells, or focal areas, were identified. Focal areas were based on the summary rank, which combined total number of coins, number of participating groups, and number of unique Management Uses. Three focal areas were identified: 1) Olowalu and 2) Māʻalaea Bay in west Maui, and 3) Māmala Bay and Maunalua Bay, off the south shore of Oʻahu. These areas were of interest to participants for various reasons including the management of land-based pollution, recent bleaching events (2015 and 2019), and coral resiliency. Existing bathymetry data and habitat classification maps are insufficient because they predate the latest bleaching events, do not fully cover the depth range (e.g., data gaps in >20 m), and/or do not meet the resolution requirements (1 m or less) needed to monitor corals at the species level.

This report and interactive online maps provide a critical spatial framework for understanding shallow coral reef mapping priorities and data needs of the Main Hawaiian Islands. Results from this mapping-needs assessment are summarized in this report, and an inventory of existing mapping data for Hawaiʻi and other completed jurisdictions are available at https://us-shallow-coral-reef-mapping-priorities-noaa.hub.arcgis.com/.

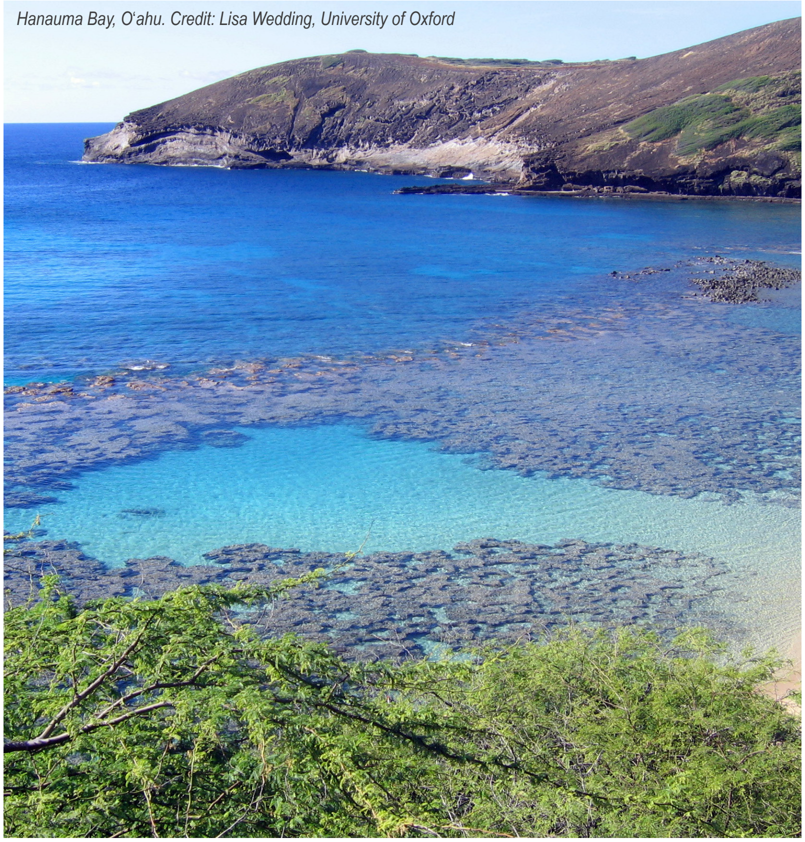
Green sea turtle, HIHWNMS. Credit: Ed Lyman, NOAA

Yellow tang at Kealakekua Bay, Hawaiʻi. Credit: Lisa Wedding, University of Oxford

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 m depth in all seven of the U.S. coral reef management jurisdictions (Figure 1). During 2022, this activity was focused on the Hawai'i jurisdiction, which included the shallow coral reef areas surrounding Main Hawaiian Islands (MHI), which include the Island of Hawai'i, Maui, Kaho'olawe, Moloka'i, Lāna'i, O'ahu, Kaua'i, and Ni'ihau.

Prioritization results directly support CRCP's four thematic 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, leverage expertise and resources, and identify partnerships for future mapping efforts.



Hanauma Bay, O'ahu. Credit: Lisa Wedding, University of Oxford

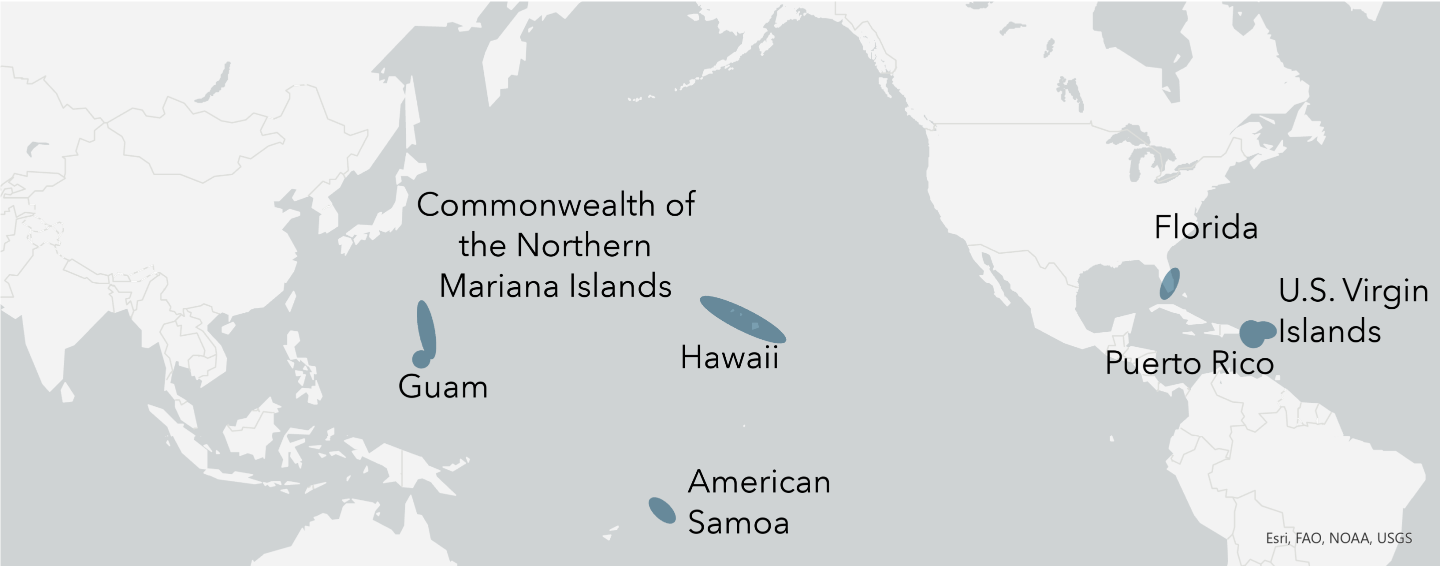


Figure 1. The seven U.S. coral reef management jurisdictions used in this prioritization effort.

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 local NOAA offices (National Marine Fisheries Service 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 key contacts from local state, federal, territorial, academic, and non-governmental organizations was created and approved by the TAT. This list is composed of groups who use mapping data to inform coral reef management in the MHI Seventeen of the 23 groups who were contacted participated in this effort. These groups included experts in coral reef management, including reef mapping, conservation, fisheries, and habitat classification (Table 1). Some participants were the sole respondent for their group, whereas others consulted with colleagues to input a collaborative mapping need.

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

Participating Groups	*Acronym*	*Type*
Bureau of Ocean Energy Management	BOEM	Federal
Conservation International	CI	NGO
Department of Land and Natural Resources - Division of Aquatic Resources	DAR	State
Environmental Protection Agency	EPA	Federal
Hawai'i Pacific University	HPU	Academic
Hawai'i Monitoring and Reporting Collaborative	HIMARC	Academic
National Park Service	NPS	Federal
The Nature Conservancy	TNC	NGO
NOAA National Coral Reef Monitoring Program	NCRMP	Federal
NOAA Office for Coastal Management	OCM	Federal
NOAA Pacific Islands Fisheries Science Center	PIFSC	Federal
NOAA Pacific Islands Regional Office	PIRO	Federal
Ridge to Reefs	RTR	NGO
University of Hawai'i - Oceanography Department	UH	Academic
U.S. Army Corps of Engineers	USACE	Federal
U.S. Fish and Wildlife Service - Pacific Islands Fish and Wildlife Office	USFWS - PIFWO	Federal
U.S. Fish and Wildlife Service - Pacific Islands Refuges and Monuments Office	USFWS - PIRMO	Federal

The following groups or agencies were contacted but were unable to provide input: U.S. Geological Survey, NOAA Restoration Center, NOAA Office of National Marine Sanctuaries, Naval Facilities Engineering Systems Command, Hawai'i Institute of Marine Biology, and The Harold K.L. Castle Foundation.

2.2 Develop Prioritization Framework and Online Application

2.2.1 Develop Framework

The prioritization project area (Figure 2) extended around the MHI and was divided into hexagon grid cells that were 1 km per side (2.6 km^2 per cell; Figure 3). 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-meter contour and coastline.

2.2.2 Data Inventory

Existing 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 include various types of seafloor mapping data (e.g., multibeam, lidar), noting year of collection, extent, resolution, 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 an online web map and served as the basemap for the spatial prioritization application. See Appendix A for a reference list of map services included in the inventory.

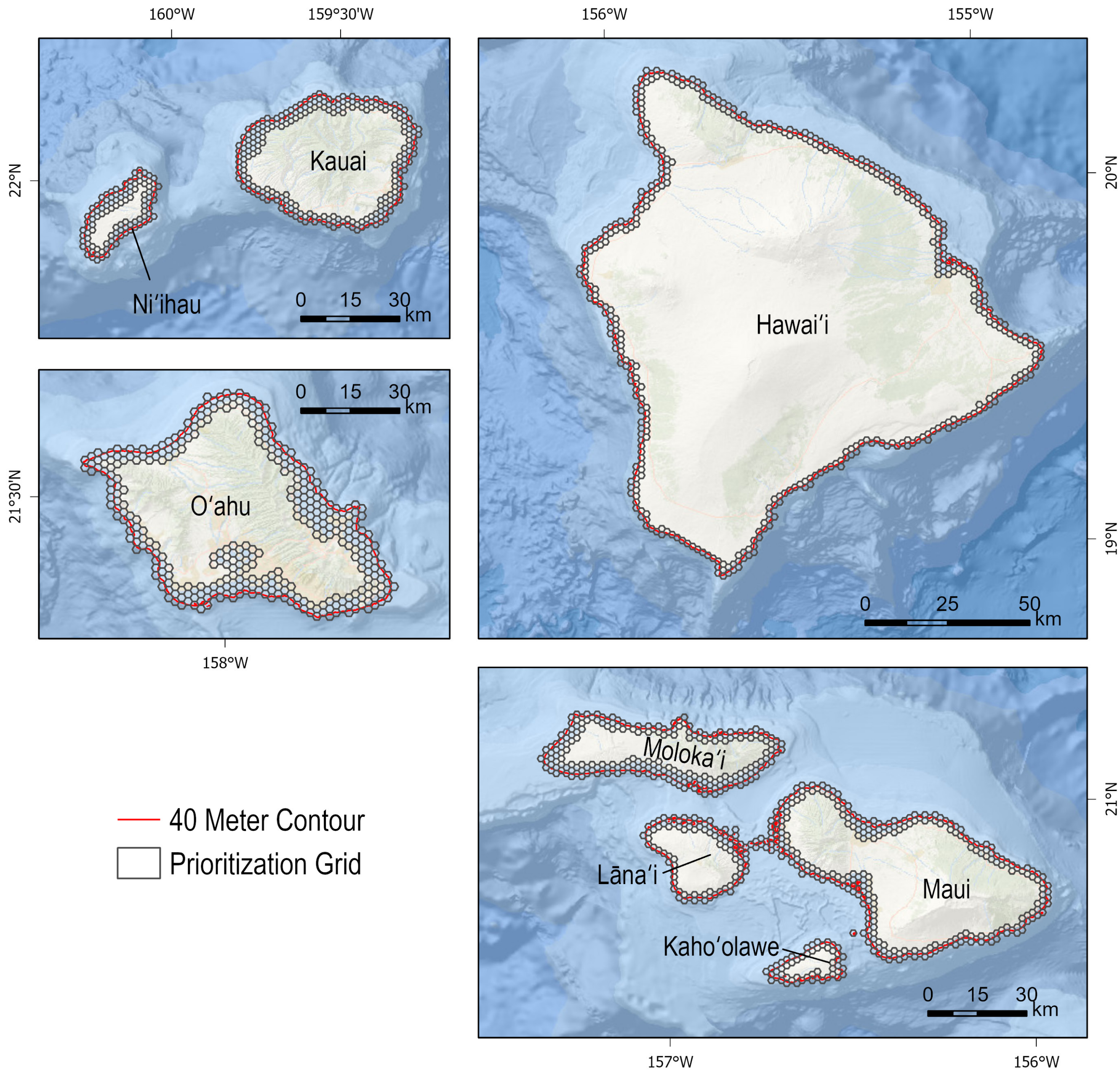


Figure 2. The spatial framework used to identify benthic mapping priorities in shallow coastal areas (0–40 m) around the Main Hawaiian Islands.

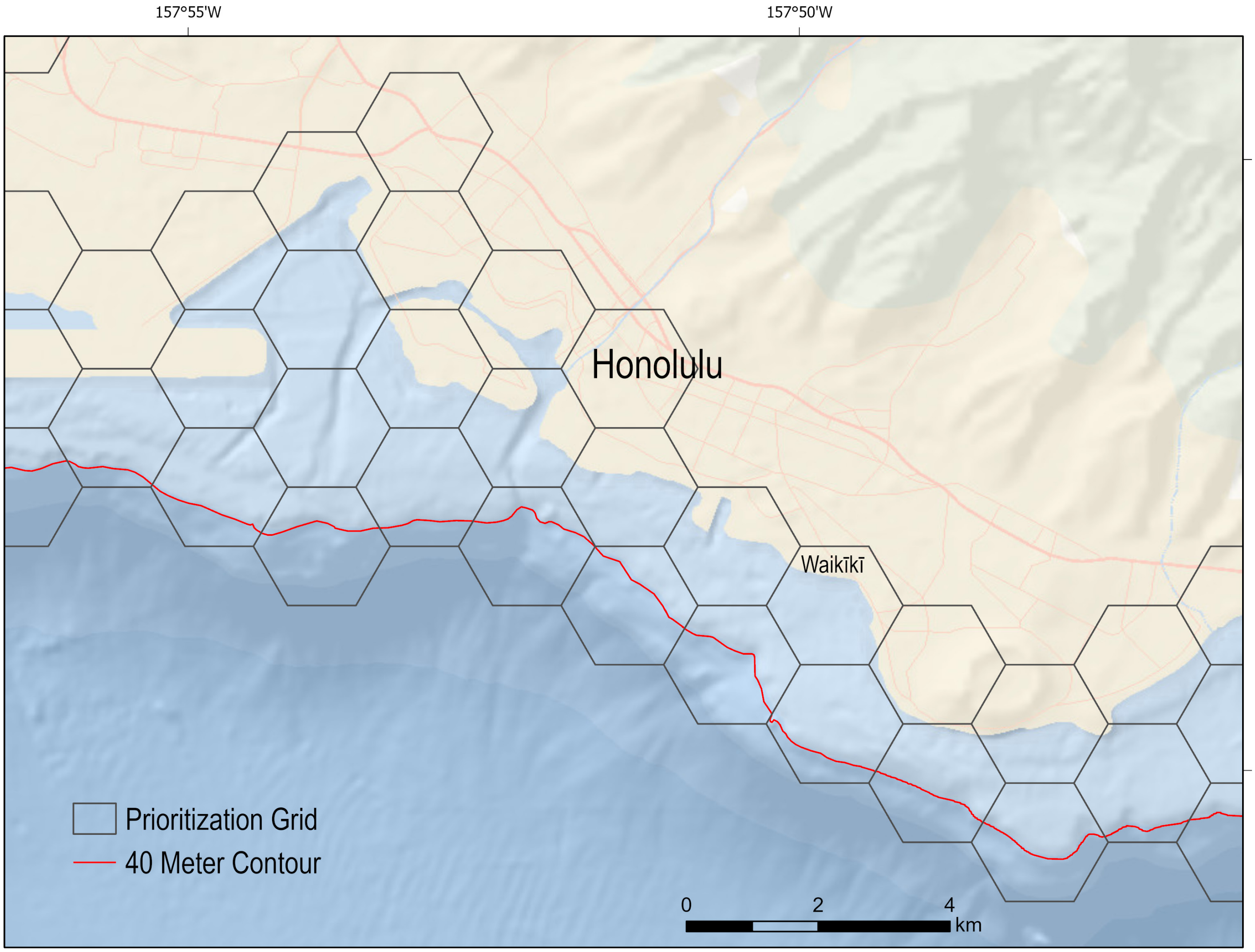


Figure 3. Example of the hexagonal grid (1 km per side with total area of 2.6 km^2) off the coast of Honolulu, O'ahu. The 40-m contour was used as the maximum depth for this prioritization effort.

2.2.3 Spatial Prioritization Application

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

Each participant was given 536 virtual coins, or 30% of the total number of grid cells (n = 1,786), to place in the prioritization grid to indicate the locations of their mapping needs. The application also did not allow more than 54 coins (or 10% of total number of coins) to be input into a single grid cell. Coin restrictions were designed to ensure that participants' needs were comparable (i.e., everyone "spent" the same number of coins), encourage a broad distribution of priorities, and increase the chance of overlap among participant needs.

The number of coins assigned to a cell translated to how urgently data were needed. 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, cells with 1–3% of coins indicated a need in the next 5–10 years, and cells with 0 coins indicated data were 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 nine 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 planned 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.

For each selected area, participants were also asked to describe specific data requirements. These were referred to as Map Product Requirements. For each cell receiving coins, participants could assign up to two (primary and secondary) requirements from a list of seven options (Table 3). This category was used to help determine the type of spatial scale, product resolution, and suggested platform needed to meet data needs. 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—and can be used to inform project planning and execution.

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

Management Use	*Definition*
1. Endangered Species Management	Including consultations, recovery planning, and implementation
2. Habitat Restoration	Restoration planning and implementation of coastal and marine habitats such as corals, submerged aquatic vegetation, etc.
3. Monitoring	Long-term biophysical monitoring, discrete management/ restoration assessments, or emergency/disaster response assessment
4. Coastal Vulnerability 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.

Table 3. List of Map Product Requirements and their associated recommendations for resolution, scale, and platform. ROV = remotely operated vehicle; DEM = digital elevation model; AUV = autonomous underwater vehicle.

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

2.3 Priority Summaries and Spatial Analysis

As participants entered and edited their selections, their responses were continuously saved to each participant's user-specific online data file. At the end of the data entry period, this information was downloaded, quality controlled, and analyzed to identify collective priorities within each coral reef jurisdiction. All quality control and data summaries were performed in R statistical software (version 4.1.0, RStudio Team, 2020).

2.3.1 Quality Control

This 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. It also ensured that all cells with coins had at least a primary Management Use and Map Product Requirement assigned. Once cells with coins passed this quality check, any Management Use and Map Product options assigned to cells with zero coins were removed. This situation typically occurred when a participant assigned coins to a cell, changed their mind, and returned the coins to allocate elsewhere.

Kona coast sunset, Hawai'i. Credit: Commander John Bortniak, NOAA Corps (ret.).

2.3.2 Data Analysis and Summary

To determine which Management Use and Map Product Requirement options were most commonly selected across the entire study area, the total number of coins were summed for each selection at the primary, secondary, and overall levels. The number of coins for each Map Product Requirement scale (regional, mesoscale, microscale) were also summed to understand the spatial scale at which data were needed. To understand how coins were allocated spatially, the number of coins from all participant groups were summed in each grid cell. The total number of coins allocated toward each Management Use and Mapping Product Requirement from each participant group was also summed in each grid cell. The number of groups allocating at least one coin, the number of different Management Uses, and the number of different Map Product Requirements were tallied in each grid cell. For each metric, the Top 10% of cells with coins were identified and highlighted using the quantile function in R.

2.3.3 Summary Rank and Focal Areas

A summary rank was calculated to understand areas of greater importance for multiple rationales. First, each cell was ranked by their total number of coins, number of participating groups, and number 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. The Top 10% of cells based on summary rank was calculated using the quantile function.

Focal areas were selected by identifying clusters of cells that were composed of more than five adjacent cells and in the highest summary rank category (Top 10%). These areas of five or more cells represented a manageable extent for mapping missions and improved efficiency of mission planning to meet multiple stakeholder needs (e.g., minimized transit time).

2.4 Project Timeline

In May 2022, participating groups were contacted via email and asked to confirm their participation and provide any additional contacts from their group. An introductory webinar was held on July 11, 2022, covering details on the project background, methods, outcomes, use of the web tool, and to answer questions. The data inventory was finalized prior to coin allocation. Participants were asked to input their priorities any time between July 11 and August 1. After the inputs were analyzed, participants were briefed on the preliminary results during a webinar on November 9, 2022, and were given the opportunity to comment on the results.

Chapter 3 Results

3.1 Management Use

The top Management Use selected by participants was *Monitoring*, making up 30% of the total coins allocated (Figure 4). The next most commonly selected options were *Fisheries Management* and *Spatial Protection and Management*, which were each selected for 15% of allocated coins. *Consultations and Permitting* was selected in 11% of coins overall and was selected exclusively as a primary Management Use. Fourteen out of 17 participating groups selected at least two different Management Uses (typically a primary and secondary), with one group (U.S. Fish and Wildlife Service – Pacific Island Fish and Wildlife Office) selecting seven different options (Figure 5). Eleven groups selected Monitoring as either their primary or secondary Management Use. Two groups (Hawai'i Pacific University and NOAA's National Coral Reef Monitoring Program) selected Monitoring as their only Management Use option (no secondary choice was selected), which may have had an influence on this option being the top Management Use overall. Coin distribution maps for each Management Use can be found in Appendix B.

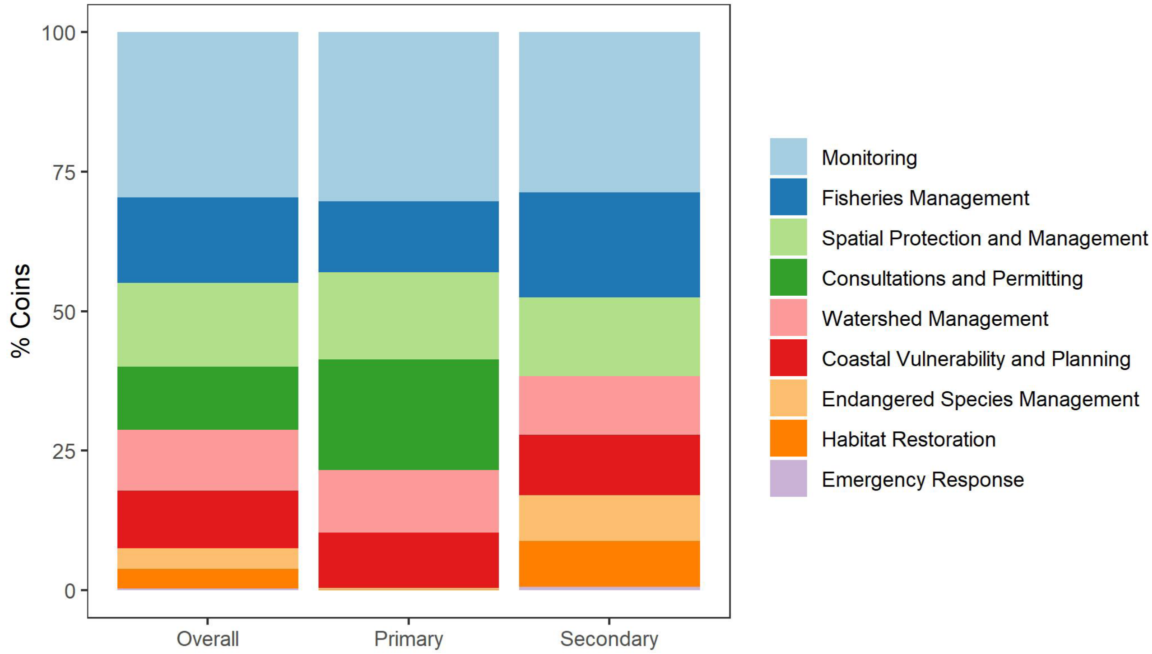


Figure 4. The percentage of coins for each Management Use selected at the overall, primary, and secondary levels.

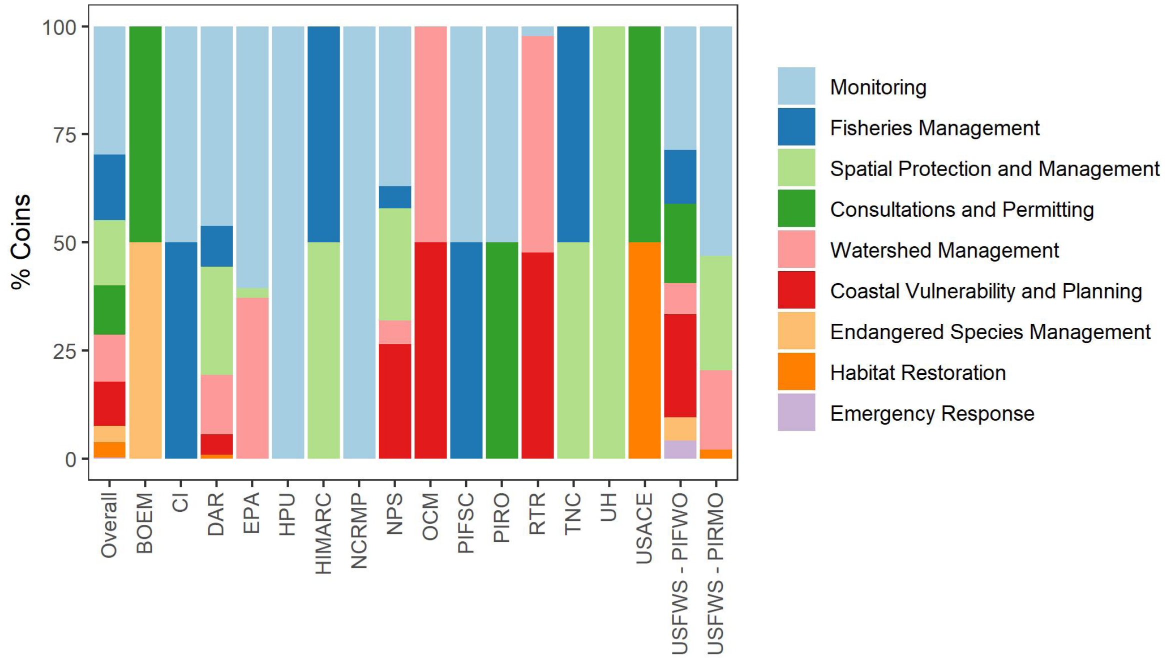


Figure 5. The percentage of coins for each Management Use selected per participant group at the primary and secondary levels.

3.2 Map Product Requirement

The proportion of coins that were assigned using the Map Product Requirement options at the primary and secondary levels revealed two top data requirements for coral management: *Substrate Types* and *Identification of Coral Species* (Figure 6). Of the seven options available, these two accounted for 54% of overall coins. *Density of Macrobiota* was the third most commonly selected option, totaling 15% of overall coins, and was most commonly selected as a secondary option. Of the 17 participating groups, 16 identified either *Substrate Types* or *Identification of Coral Species* as a data requirement for future management actions (Figure 7). Coin distribution maps for each Map Product Requirement can be found in Appendix C.

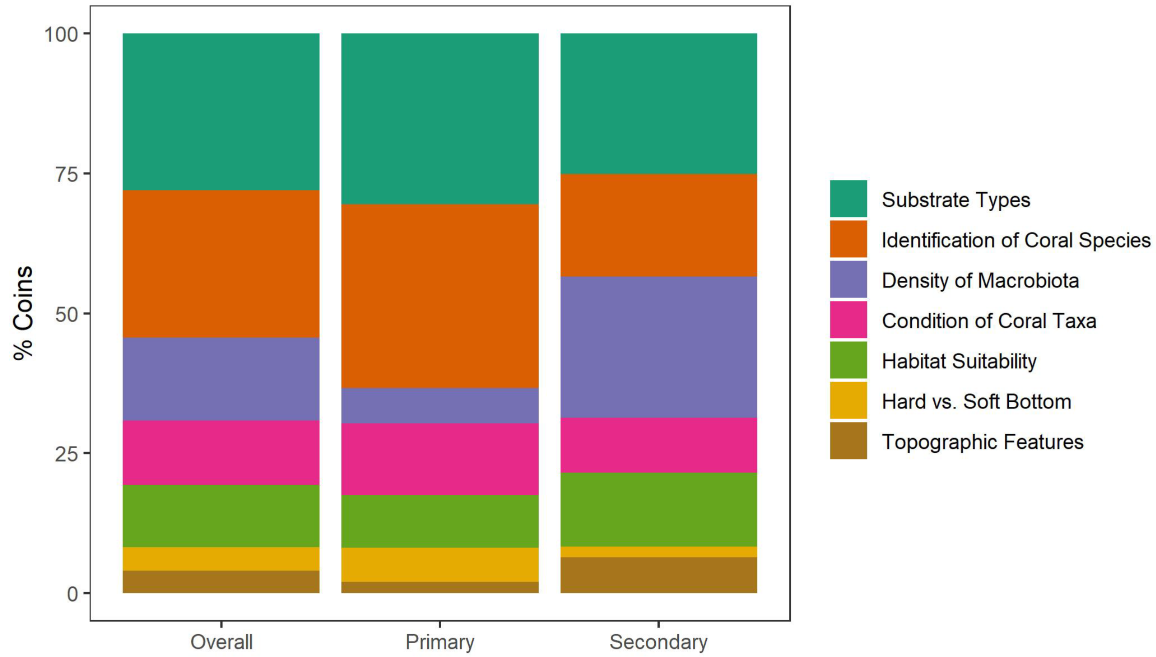


Figure 6. The percentage of coins for each Map Product Requirement selected at the overall, primary, and secondary levels.

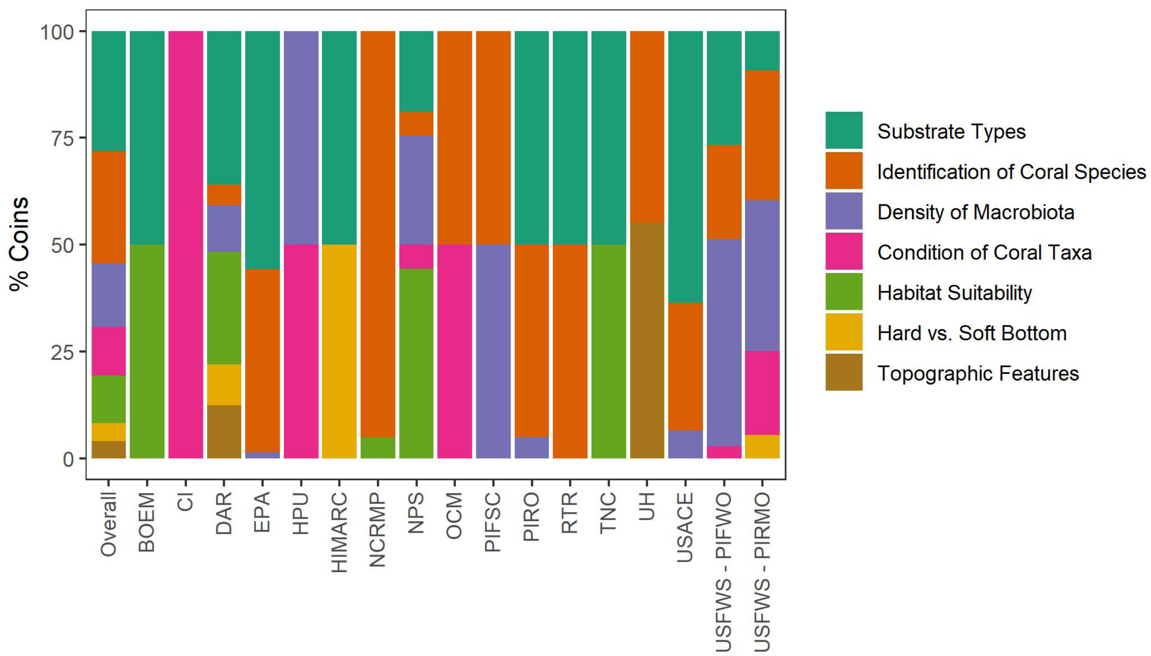


Figure 7. The percentage of coins for each Map Product Requirement selected per participant group at both the primary and secondary levels.

Additionally, the proportion of coins that were assigned using the Map Product Requirement options were summarized by the spatial scale at which data were collected (i.e., regional, mesoscale, or microscale; descriptions provided in Table 3). The proportion of coins overall revealed that data at the mesoscale were selected most often (42%), followed by microscale (37%) and regional scale (19%) data (Figure 8). However, mesoscale and regional scale were more commonly selected at the secondary level, while microscale was more commonly selected at the primary level. Coin distribution maps for each spatial scale can be found in Appendix C.

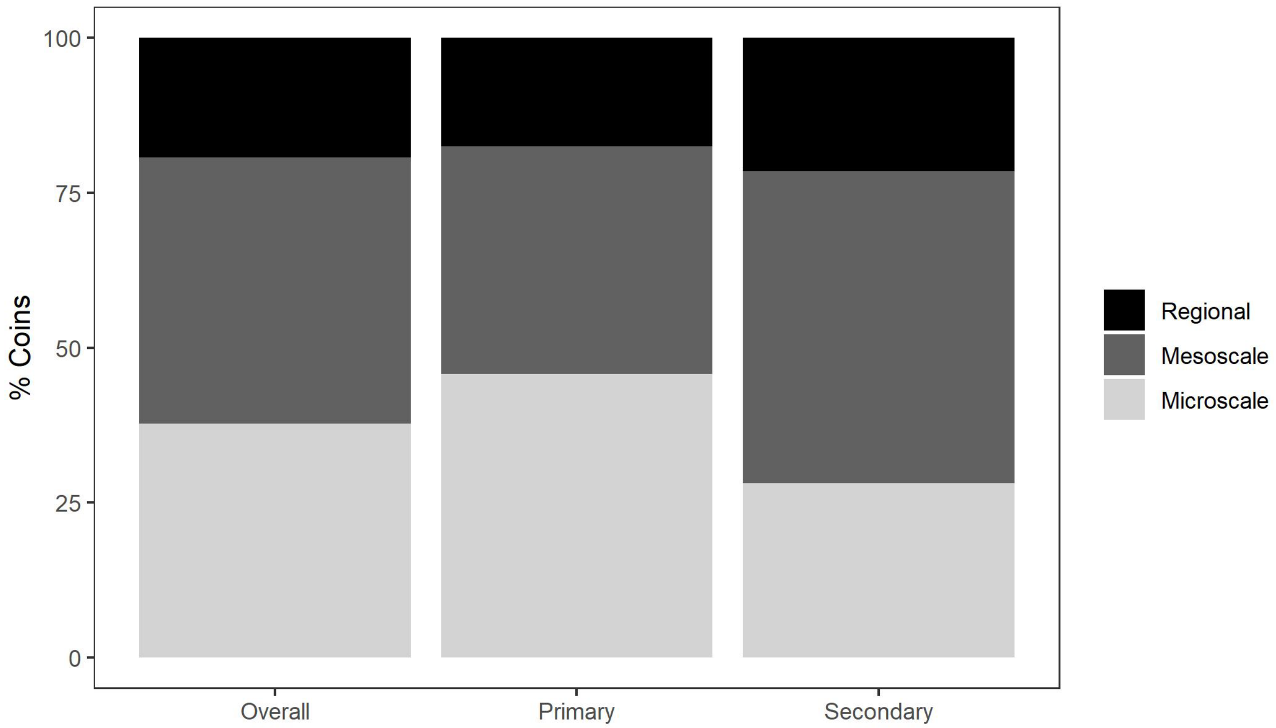


Figure 8. The percentage of coins for each Map Product Requirement spatial scale selected at the overall, primary, and secondary levels.

Humpback whale in Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS). Credit: J. Moore, NOAA under NOAA MMHSRP Permit 15240

3.3 Total Coins and Summary Rank

There were large clusters of adjacent cells (five or more) with the highest total number of coins (Top 10%) around the Island of Hawai‘i, Maui, Moloka‘i, O‘ahu, and Kaua‘i (Figure 9). Off the southwest coast of Hawai‘i, 17 cells in the Top 10% stretched from Papa Bay to Manuka Bay. Off the west coast of Maui, a large group of 16 cells in the Top 10% occurred off the coast of Kihei and included Mā‘alaea Bay. Farther west along the Maui coast, a group of nine cells occurred from Launiupoko to Olowalu. Several locations along the eastern shoreline of O‘ahu contained large groups of cells, including Honolulu (six cells), Maunalua Bay (10 cells), and Waimānalo Beach (nine cells). No cells in the Top 10% of total coins occurred around Lāna‘i, Kaho‘olawe, or Ni‘ihau. Cells containing the Top 10% of coins covered an area of 106 km^2.

Island of Hawai‘i coast. Credit: LCDR Eric Johnson, NOAA Corps.

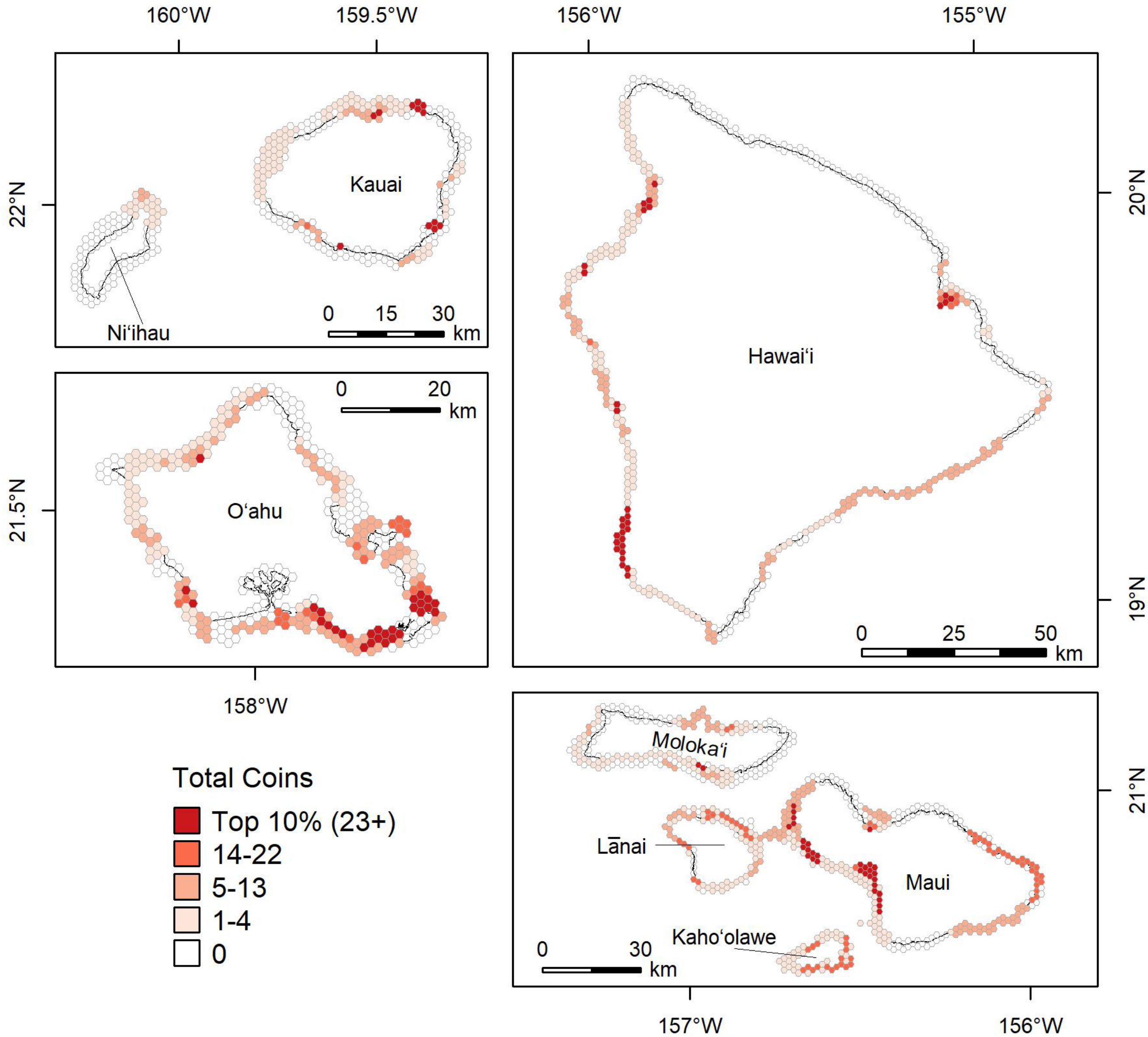


Figure 9. Map of total coins in the Main Hawaiian Islands.

The number of groups that allocated coins into each cell ranged from one to five participant groups per cell (Figure 10). Large clusters of cells in the Top 10% (three to five participant groups) occurred along the southwest coast of Hawai‘i from Papa Bay to Manuka Bay, northwest coast of Maui including Mā‘alaea Bay, Maunalua Bay (O‘ahu), and around Kaho‘olawe. Cells selected by multiple participants are an opportunity for collaboration and highlight where data collection would satisfy the needs of several groups.

Climate Change Team deploying diel suite instrument package in Papa Bay, Hawai‘i. Credit: NOAA Fisheries; Hawai‘i Marine Education & Research Center/Paul Cox

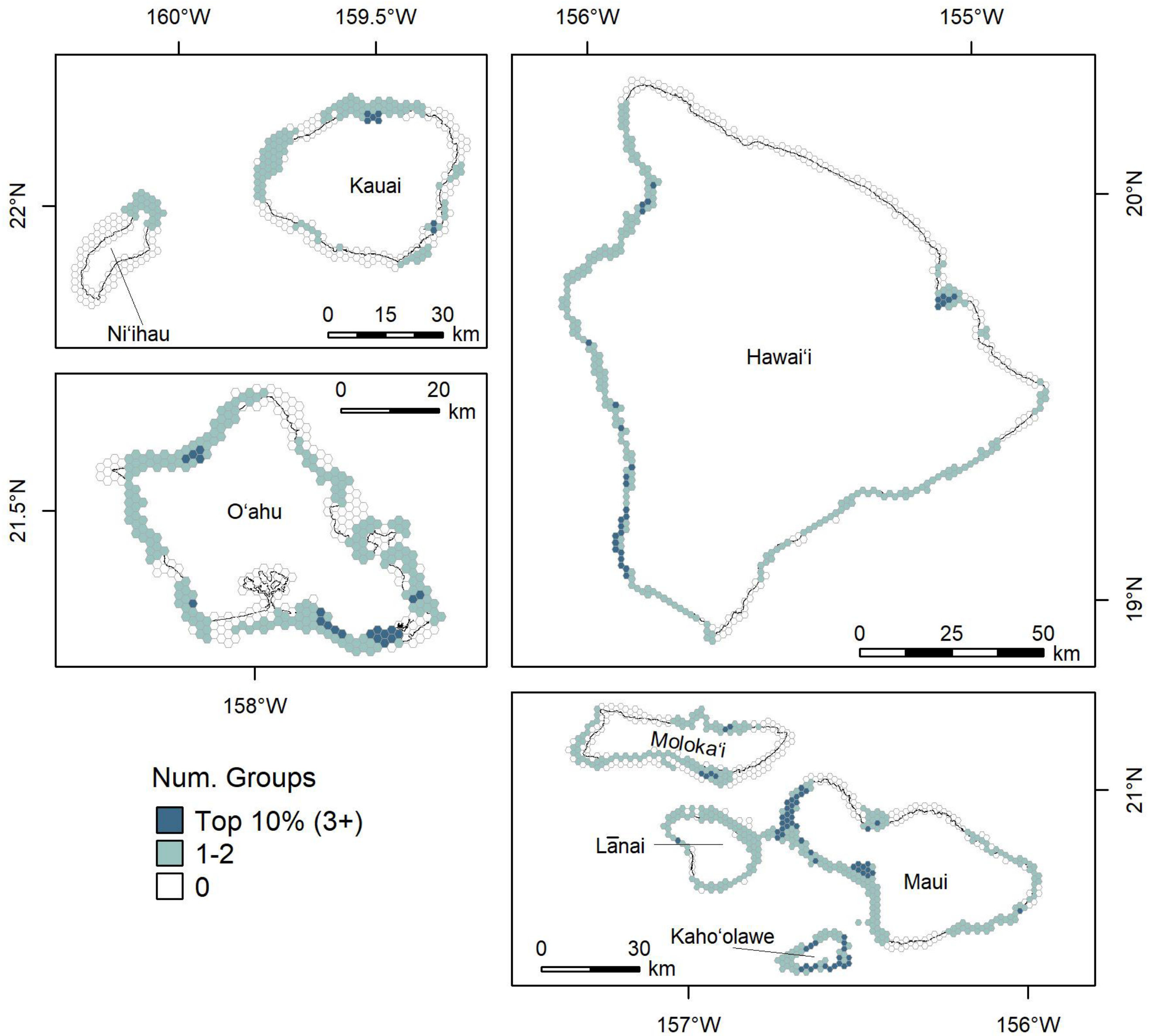


Figure 10. Number of groups who allocated at least one coin into each cell. A maximum of five participant groups input into a single cell.

Results

The number of Management Uses highlighted several unique areas where a variety of mandates and management actions would be served by collecting the required data (Figure 11). There were several large clusters of cells that contained three to six (Top 10%) different Management Uses selected by participants. Along the west coast of Maui, cells in the Top 10% category stretched from Māʻalaea Bay all the way north to Oneloa Bay and include many cells within the Auau Channel (connecting to Lānaʻi). Along the south shore of Oʻahu is a large group of cells in the Top 10% off the coast of Waikīkī in Māmala Bay. A couple locations along the north shore of Oʻahu contained a significantly high number of Management Uses selected, including Kāneʻohe Bay and off Kaiaka Point. Additionally, the north and south shores of Molokaʻi also had large clusters of cells in the Top 10%.


Green sea turtle, Oʻahu. Credit: NOAA NMFS PIFSC

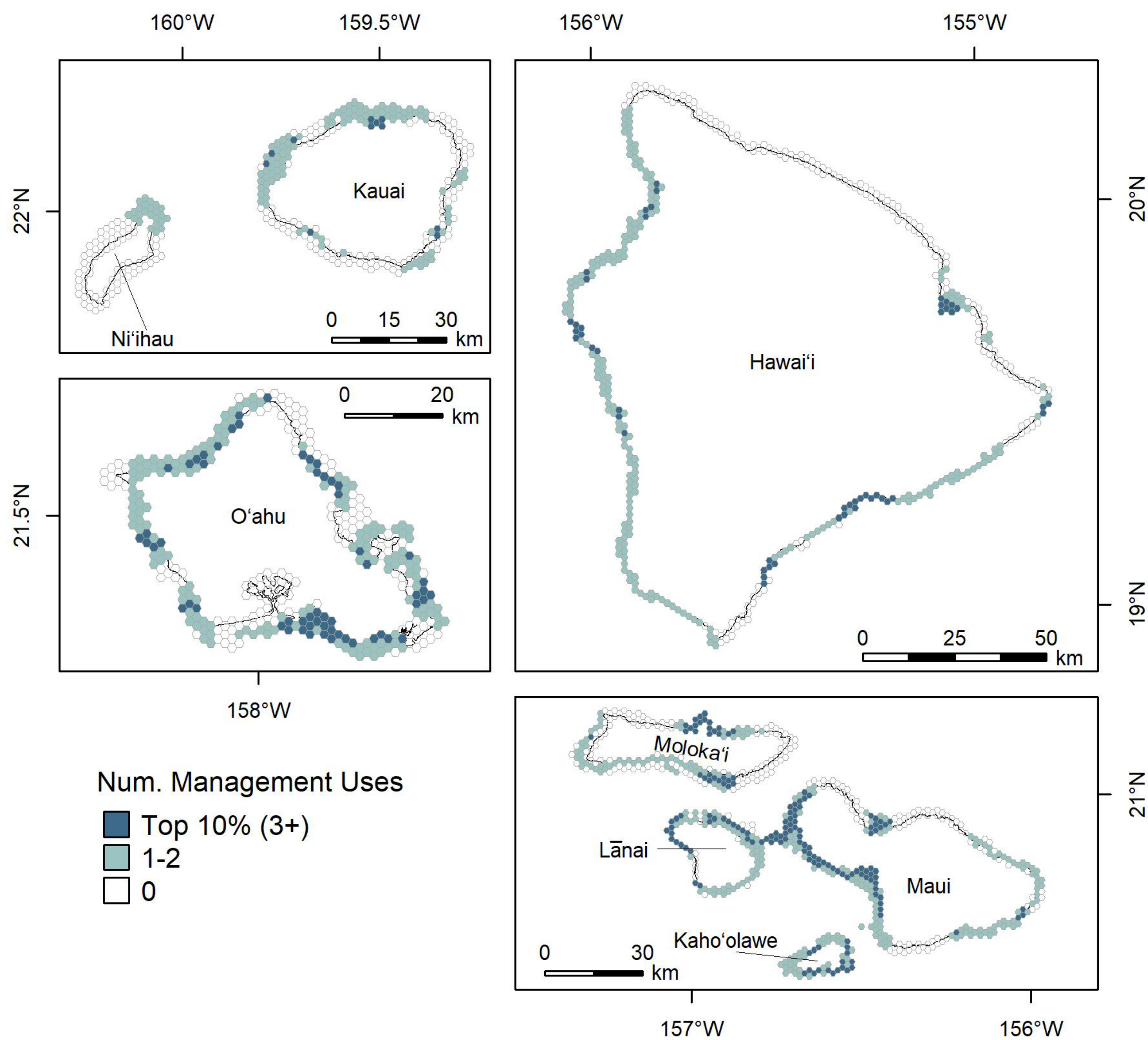
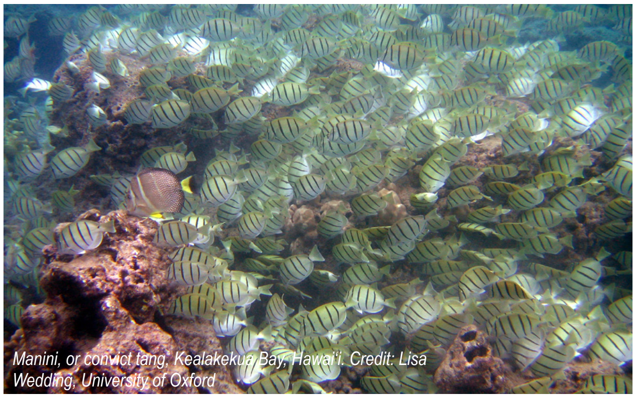


Figure 11. Number of different Management Use options that were selected in each cell.

The number of Map Product Requirements selected by participants is shown in Figure 12, and highlights areas where a significant number of different data needs were selected. Clusters of cells with values in the Top 10% indicate areas where a variety of data needs will be met. This would involve collaboration among managers and stakeholders to ensure the data collected can satisfy the diversity of data requirements in these areas. Areas of note that had four or more different Map Product Requirements selected were in Maunalua Bay and Waimānalo Beach in east Oʻahu, Auau Channel between Maui and Lānaʻi, and a stretch of coastal cells in along the western shore of the Island of Hawaiʻi from Pebbles Beach to Manukā Natural Area Reserve.



Manini, or convict tang, Kealakekua Bay, Hawaiʻi. Credit: Lisa Wedding, University of Oxford

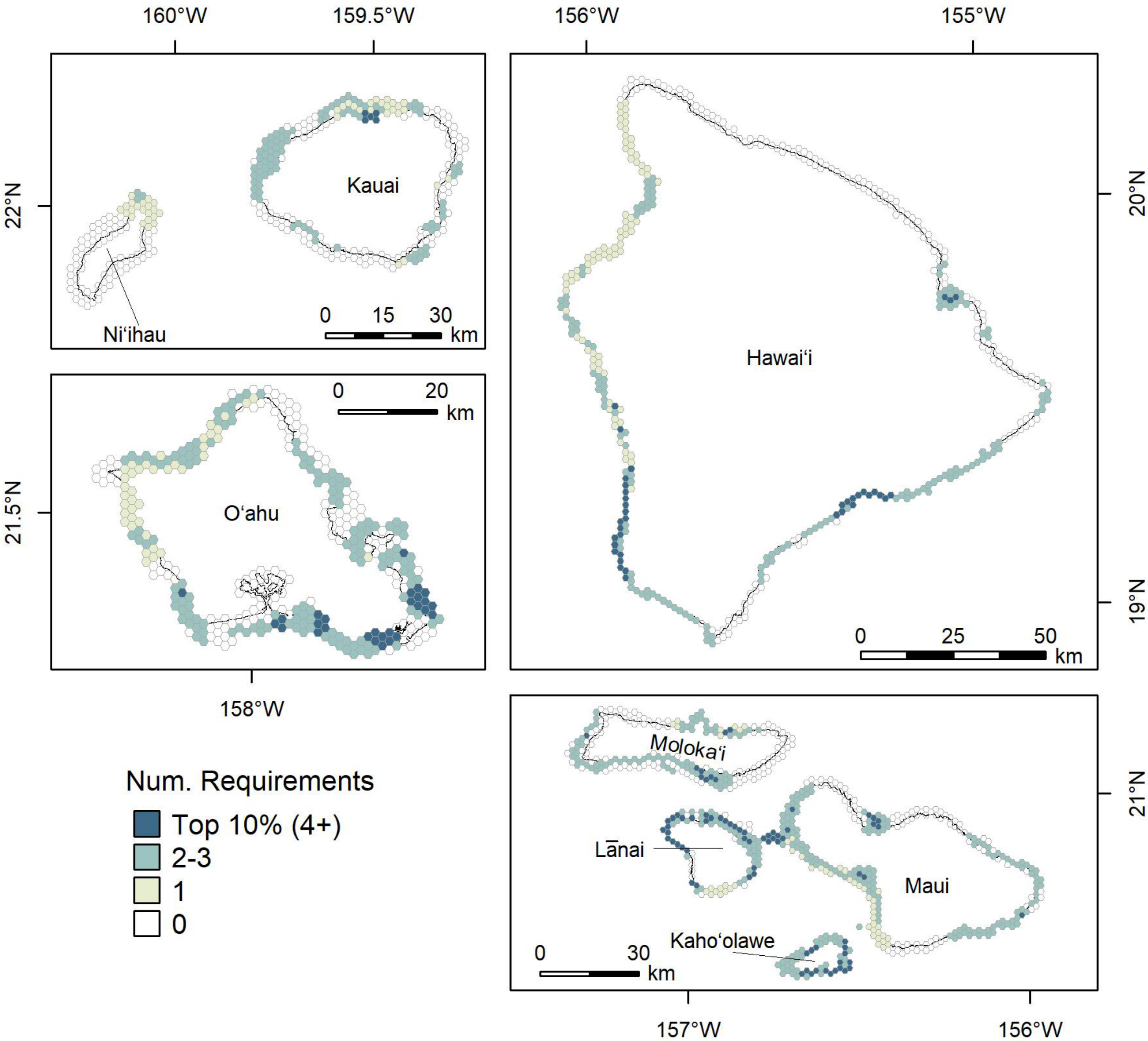


Figure 12. Number of different Map Product Requirement options that were selected in each cell.

By combining the total number of coins, number of participating groups, and number of Management Uses into a single layer, we were able to highlight cells that were of greater importance (Figure 13). A large cluster of 17 cells in the Top 10% summary rank category occurred around Māʻalaea Bay (west Maui). Additionally, a group of nine cells in the Top 10% occurred from Launiupoko to Olowalu, also in west Maui. Off the south coast of Oahu, seven cells off Waikīkī and an additional three cells in Maunalua Bay were in the Top 10%. These large clusters of cells are discussed in Section 3.4. Several smaller groups of highest-ranking cells also surrounded the island of Kahoʻolawe.

Waikīkī and Honolulu, Oʻahu. Credit: NOAA Teacher at Sea Program, NOAA Ship Hiʻilakai

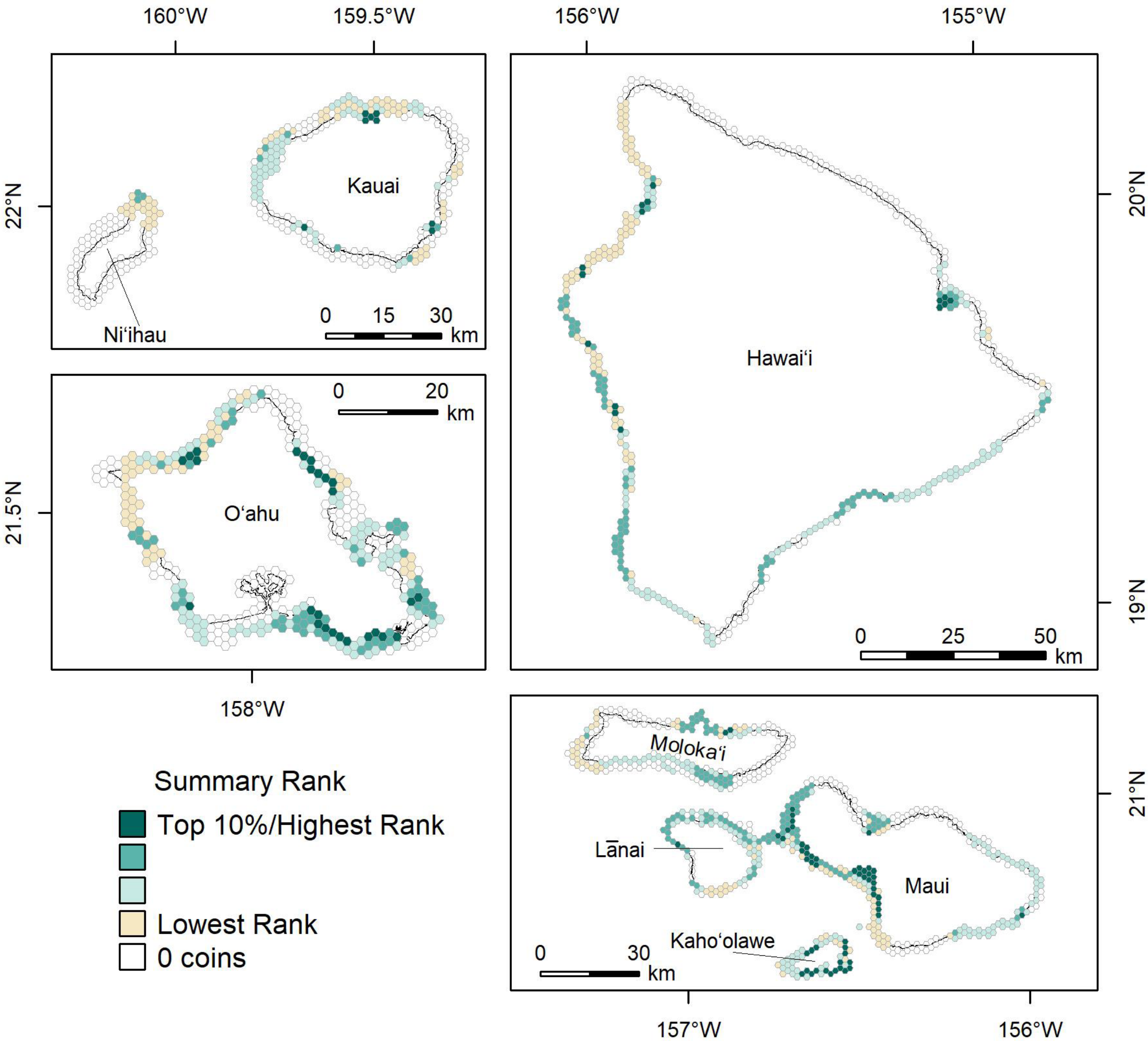


Figure 13. Summary rank based on total coins, number of participating groups, and diversity of Management Uses in each cell. Highest Rank identifies Top 10% of summary rank cells.

3.4 Gap Analysis and Focal Areas

Three focal areas are described in more detail below based on the results of this prioritization effort: 1) Olowalu and 2) Māʻalaea Bay in west Maui, and 3) Māmala and Maunalua Bay off the southeast coast of Oʻahu (Figure 14). These focal areas were identified because they contained numerous adjacent cells within the Top 10% of summary ranks and lacked existing or contemporary data.

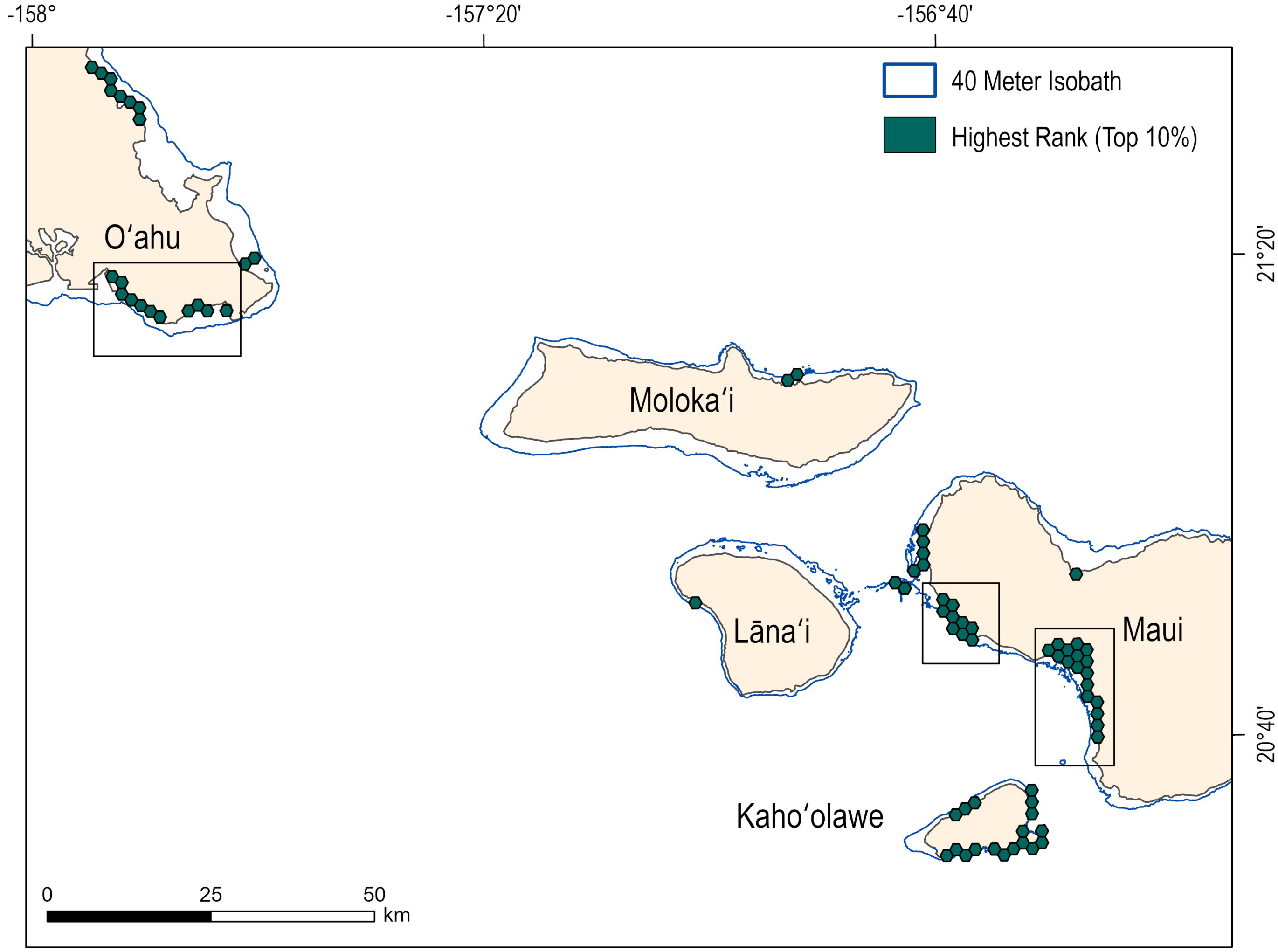


Figure 14. Overview of focal areas in the Main Hawaiian Islands identified using the highest summary rank (Top 10%).

3.4.1 Olowalu, West Maui

Off the coast of Olowalu in west Maui, nine hexagons (total area of 23 km^2) were selected by four participating groups (Figure 15). The top two Management Uses identified in this region were *Coastal Vulnerability* and *Watershed Management* (Table 4), which align with the recent management focus on climate change impacts and land-based sources of pollution (P. Maurin, pers. comm.). Coral reefs in this area have also been impacted by significant coral bleaching events in 2015 and again in 2019 (Coral Reef Watch, 2019), and bleaching events are expected to become more severe as climate change intensifies. Recently, Olowalu was identified as a focal area for restoration due to climate vulnerability and impacts from recent bleaching events (State of Hawaiʻi, 2023). Additionally, coastal erosion and rainfall have increased sedimentation into nearshore waters of west Maui (Stock and Corina, 2021), resulting in damaging conditions for coral ecosystems in the last 5–8 years (Hui O Ka Wai Ola, 2022).

Available 1-m resolution lidar data from NOAA and U.S. Army Corps of Engineers (USACE) (NOAA OCM, 2023) collected in 2013 cover a majority of the coastline down to a depth of approximately 40 m. Additional coverage exists from a bathymetry and backscatter synthesis grid of approximately 5-m resolution created by the School of Ocean and Earth Science and Technology (SOEST) (Smith, 2016), at the University of Hawai'i at Mānoa. This dataset contains depth data from multiple sources, and therefore the quality and age of the data vary. A large-scale, 2-m resolution mapping study of live coral cover surrounding the MHI, down to a 16-m depth, was conducted by Arizona State University's Global Airborne Observatory (GAO) (Asner et al., 2020, 2022). This effort used airborne imaging to create a bathymetric grid and distribution map of live coral cover in 2019 and 2020. This was key in documenting the relative condition of reefs and the effects of human-driven stressors, including marine heat waves.

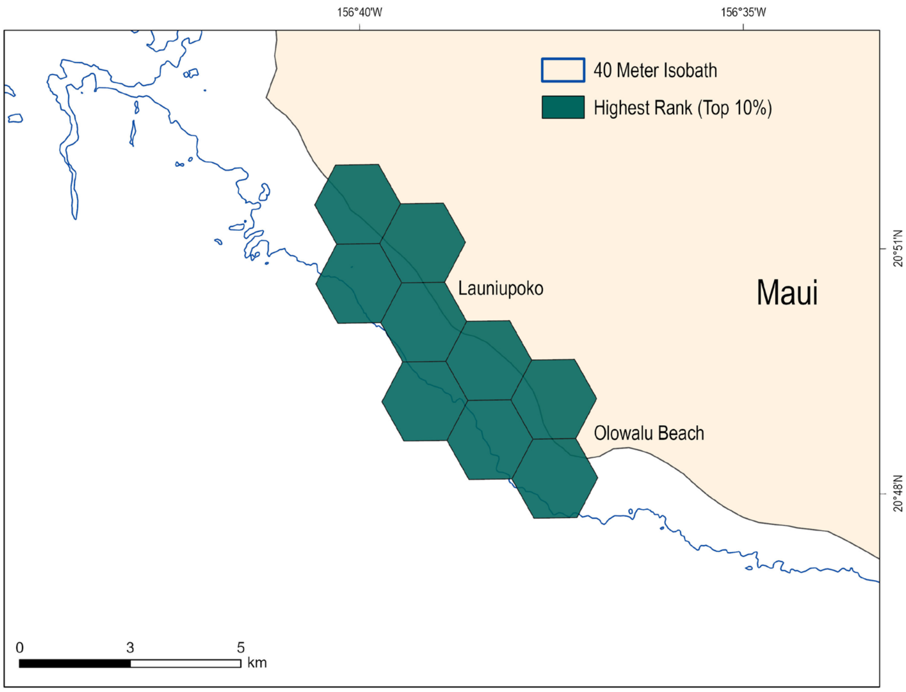
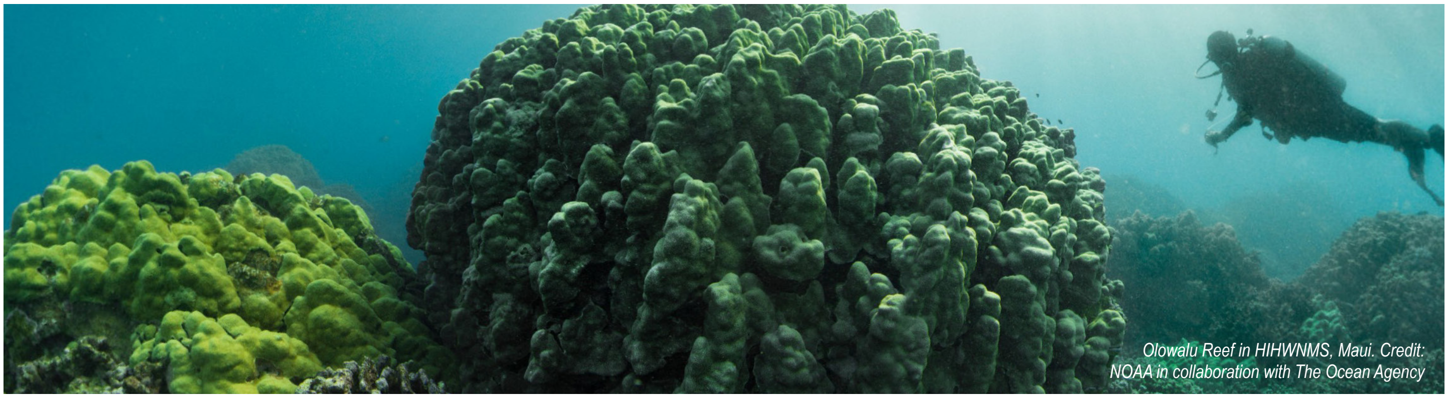


Figure 15. Highest-ranking cells offshore of Launiupoko and Olowalu Beach, located on the west coast of Maui.

Table 4. Data summary of participant input for the Launiupoko and Olowalu Beach priority 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% (9)	Top 10% (9)	4
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Coastal Vulnerability (48%)	Identification of Coral Species (51%)	Microscale (78%)
Watershed Management (48%)	Condition of Coral Taxa (28%)	Mesoscale (22%)
Consultations/Permitting (1%)	Substrate Type (22%)	Regional (0%)
Habitat Restoration (1%)		
Monitoring (1%)		

Within this focal area, 78% of allocated coins indicated microscale-level data were needed. These included fine-resolution data (<1 m) that could be used in the *Identification of Coral Species*, which was the top Map Product Requirement selected by participants. Although the 2013 USACE lidar dataset will likely meet this resolution need, these data are outdated when considering land-based changes, recent bleaching events, and climate change. Lidar data also lack backscatter information, which is crucial for identifying habitat characteristics and *Substrate Types* (Costa et al., 2009). The backscatter synthesis grid created by Smith (2016) may help meet the data needs of mesoscale level (2- to 10-m resolution); however, finer scale data products to identify coral species and condition would likely need 1-m or less resolution.



Olowalu Reef in HIHWNMS, Maui. Credit: NOAA in collaboration with The Ocean Agency

3.4.2 Māʻalaea Bay, West Maui

Off the west coast of Maui, in Māʻalaea Bay, 17 hexagons (total area of 44 km^2) were selected by seven participating groups (Figure 16). The top two Management Uses identified in this focal area were *Watershed Management* and *Coastal Vulnerability* (Table 5). Specifically, several sites were identified as potential targets for management actions that support coral reef resilience (Maynard et al., 2019). Māʻalaea Bay is also the focus of several other management activities including an oyster remediation trial (Maui Nui Marine Resource Council, n.d.), watershed management (Stock et al., 2021; Storlazzi et al., 2023), and a community effort to upgrade waste treatment facilities (Dobbyn, 2022). There is also a pressing need to understand the benefits that coral reefs can provide to coastal resilience (T. Callendar, pers. comm.).

One-meter resolution lidar data collected by USACE in 2013 cover a majority of the nearshore bathymetry down to a depth of 20 m (NOAA OCM, 2023). Additional coverage exists from the 5-m resolution SOEST multibeam and backscatter synthesis grids (Smith, 2016); however, several data gaps exist within the bay in depths greater than approximately 20 m. High-resolution 2-m coral cover and bathymetry data created by GAO (Asner et al., 2020, 2022) in 2019 and 2020 also cover the nearshore coastal area down to a depth of 16 m. Within this focal area, *Substrate Type* and *Identification of Coral Species* were the top Map Product Requirements. *Substrate Type* and *Density of Macrobiota* (third most selected) require *mesoscale* (2- to 10-m resolution) data, which may be covered partially by the 5-m bathymetry and backscatter mosaics created by Smith (2016). However, *Identification of Coral Species* often requires *microscale* (<1 m resolution) data, which are not represented in data collected after 2013. Live coral cover and bathymetry data provided by GAO may help with nearshore data needs; however, the depth limitations of 16 m leave a data gap in deeper water. Efforts to fill the data gaps within the deeper areas of Māʻalaea Bay (16 m or greater), specifically with multibeam data, will satisfy both bathymetry and backscatter data needs.

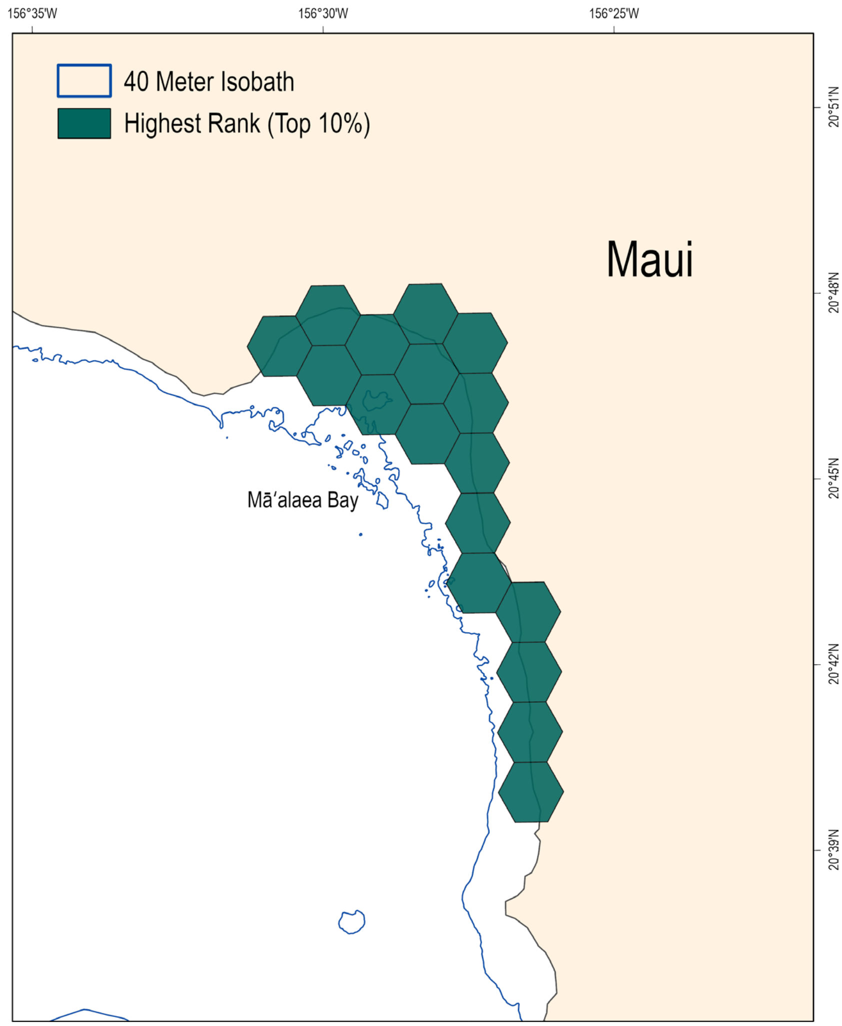


Figure 16. Highest-ranking cells (Top 10%) in Māʻalaea Bay.

Table 5. Data summary of participant input for Māʻalaea Bay focal area. Percent coins are calculated based on the Management Use, Product Requirement, and Spatial Scale coin totals within these 17 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% (16) High (1)	Highest Top 10% (17)	7
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Watershed Management (43%)	Substrate Type (49%)	Mesoscale (59%)
Coastal Vulnerability (31%)	Identification of Coral Species (39%)	Microscale (39%)
Monitoring (17%)	Density of Macrobiota (10%)	Regional (2%)
Consultations/Permitting (4%)	Hard vs. Soft Bottom (1%)	
Habitat Restoration (4%)	Topographic Features (1%)	
Fisheries Mgmt (1%)		

3.4.3 Māmala Bay and Maunalua Bay, South O‘ahu

On O‘ahu's south shore, a total of 11 hexagons (area of 29 km^2) were selected by eight participant groups in both Māmala Bay and Maunalua Bay (Figure 17). The top two Management Uses were *Monitoring* and *Consultations/Permitting* (Table 6), indicating a need for long-term assessment and planning in these two bay areas. Due to high climate vulnerability, human impacts, and major bleaching events, this region was selected as a priority area for coral restoration by local management groups. This region is also excellent for collaborative opportunities between Hawai‘i's Department of Land and Natural Resources – Division of Aquatic Resources (DLNR DAR), NOAA, Waikīkī Aquarium, and the University of Hawai‘i, among many others. Local community organizations have proposed Maunalua Bay be designated as a Fisheries Management Area, an effort that also falls under the goal of designating more marine managed areas in O‘ahu (DNLR DAR, 2022). Furthermore, DNLR DAR would use new mapping data to efficiently monitor Maunalua Bay and assist in this designation, as well as aid in the management of the fishery moving forward (P. Murakawa, pers. comm.).

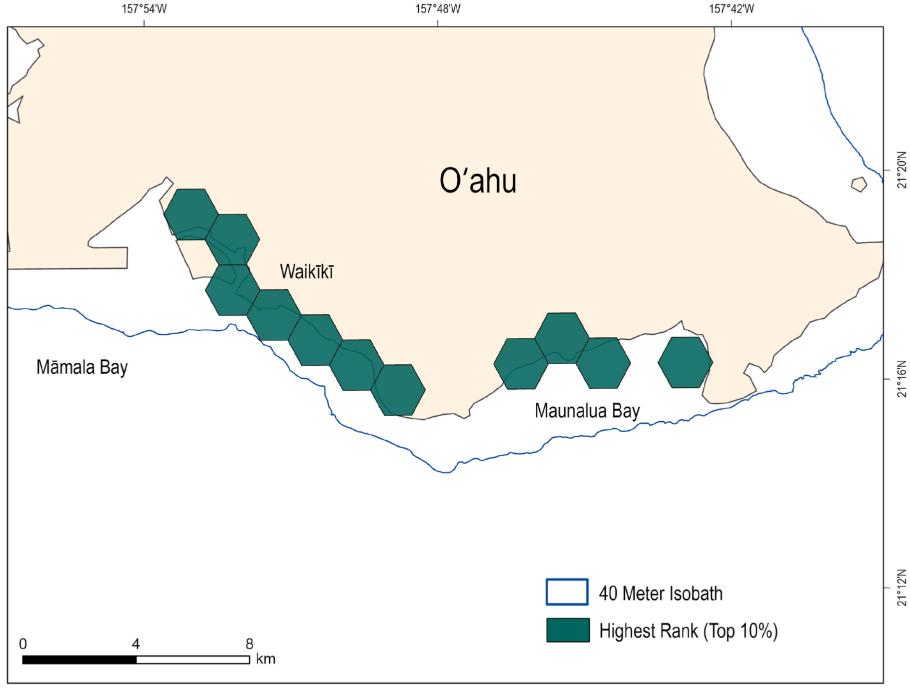


Figure 17. Highest-ranking cells (Top 10%) in Māmala Bay and Maunalua Bay in O‘ahu's south shore.

Table 6. Data summary of participant input for Māmala Bay and Maunalua Bay 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.

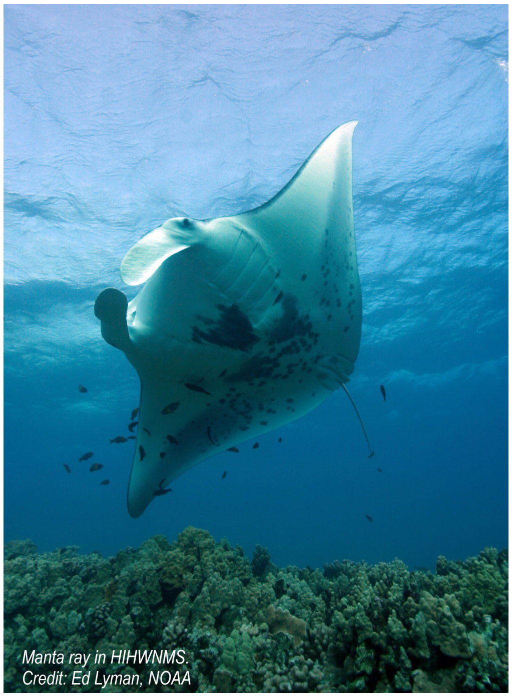
Total Coins (# hexagons):	**Rank** (# hexagons):	**Number of Groups:**
Top 10% (10) High (1)	Highest Top 10% (11)	8
Management Uses (% coins):	**Map Product Requirement (% coins):**	**Spatial Scale (% coins):**
Monitoring (46%)	Substrate Type (39%)	Mesoscale (54%)
Consultations/Permitting (26%)	Identification of Coral Species (28%)	Microscale (39%)
Spatial Protection/Mgmt (13%)	Density of Macrobiota (15%)	Regional (7%)
Habitat Restoration (9%)	Condition of Coral Taxa (11%)	
Coastal Vulnerability (3%)	Habitat Suitability (7%)	
Endangered Species Mgmt (2%)		
Emergency Response (1)		

Lidar data collected in 2013 by USACE (NOAA OCM, 2023) cover a majority of the coastal waters down to a depth of 40 m; however, they predate major bleaching events in 2015 and 2019 (Coral Reef Watch, 2019) and lack backscatter data used to classify habitats. Live coral cover provided by the GAO (Asner et al., 2020, 2022) collected in 2019 and 2020 also covers nearshore reefs in this focal area but is restricted to a depth of 16 m. Additional habitat classification maps from 2007 (NCCOS and University of Hawai‘i, 2007) exist in this region but are outdated when considering the aforementioned stress events within the last decade. *Substrate Types* and *Identification of Coral Species* were the top two Map Product Requirements, indicating both habitat-level (*mesoscale*) and species-level (*microscale*) data are needed. These data can be used to define seafloor habitat types and continue to monitor the condition of coral species.

Chapter 4 Conclusion

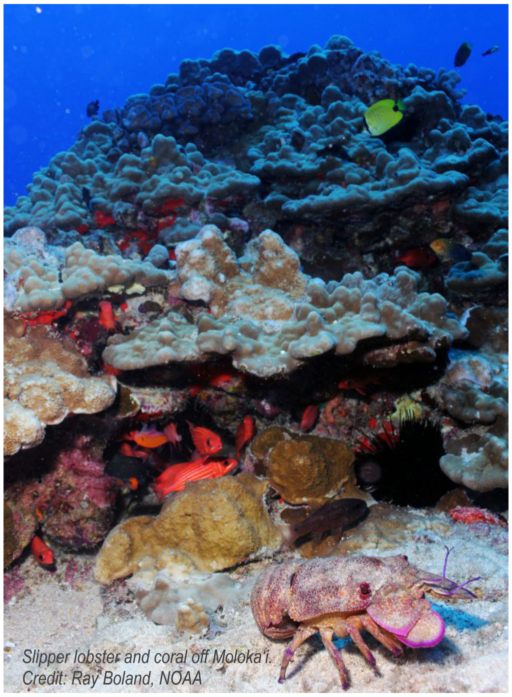
We used an online application to gather data needs from local experts in the MHI regarding their priorities for benthic mapping to support coral reef management. This system allowed participants to indicate where mapping data were needed, the urgency of the need, and the coral management actions and objectives the new data would meet. There are several areas that participants identified as a high priority for future mapping. These focal 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. Three focal areas were identified based on the Top 10% summary rank data: 1) Olowalu and 2) Māʻalaea Bay in west Maui, and 3) Māmala and Maunalua Bay in Oʻahu's south shore.

These three focal areas highlight some of the best opportunities for collaboration, with the potential to meet a variety of coral reef management goals. Around the entire MHI, major bleaching events in 2015, and most recently in 2019, have intensified the need for updated, fine-resolution data and continuous monitoring of coral ecosystems. According to Asner et al. (2022), approximately 6% of live coral cover was lost in west Maui following the 2019 marine heat wave, likely due to low coral resiliency resulting from land-based stressors. Two of the three focal areas were in west Maui, Olowalu and Māʻalaea Bay, and had significantly high participant interest as shown in the summary rank results. These two focal areas have been identified as candidates for several management actions due to land-based pollution (Campbell et al., 2022), sedimentation (Stock and Corina, 2021), and climate change (Maynard et al., 2019). Oʻahu's south shore was also identified as a focal area based on the summary rank (Top 10%). Notably, this region has been selected as a priority area for restoration due to bleaching events (State of Hawaiʻi, 2023). Excellent collaborative opportunities exist along Oʻahu's south shore between local state, federal, and academic institutions, providing more opportunity to coordinate new mapping and monitoring efforts. Across all focal areas, existing bathymetry data and habitat classification maps either predate the latest bleaching events, do not fully cover the depth range (i.e., gaps in >20 m), or do not meet the resolution requirements (1-m or finer) needed to monitor corals at the species level. Additionally, both lidar and multibeam convey depth and substrate hardness, but lidar reflectance information (i.e., substrate hardness) is generally less detailed and may not meet the high-resolution requirements needed to evaluate detailed reef features (Costa et al., 2009).



Manta ray in HIHWNMS.
Credit: Ed Lyman, NOAA

It is also important to recognize that some places were identified as high priority based on total coins, but for only one or two participating groups. For example, a group of nine cells off the coast of Waimānalo Beach (east Oʻahu) had values in the Top 10% for overall coins, but seven of these cells had input from only one or two participant groups. Two of these cells, however, were of interest to three or more different participating groups and were in the highest summary rank category. Thus, any mapping and data collection efforts in this area can focus on just these two cells in the highest summary rank. Another example is in Kīlauea Bay (north Kauaʻi), where a group of five cells were in the Top 10% for total coins but only received input from one participant group. The distribution and diversity of Management Use selection can also highlight important areas where a variety of goals can be met. For example, most of the grid cells along the west coast of Maui had three or more different Management Uses selected by participating groups. These cells also received a significant number of coins (in both the High and Top 10% categories) and were of interest to more than one participant group (many cells were in the Top 10% category). However, because this area covers such a large region, it might be difficult to collect data in the entire area, and thus survey efforts can be focused on just cells in the Top 10% of the summary rank.



Slipper lobster and coral off Molokaʻi.
Credit: Ray Boland, NOAA

Conclusion

For future mapping planning efforts, targeting cells within the highest summary ranks (Top 10%) will ensure that data collection will fulfill a variety of coral reef management purposes, address a need for several participating groups, and satisfy 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 differ depending on depth and water clarity. Benthic sonar and lidar mapping technologies are typically focused on gathering data over large geographic areas and features. Conversely, models of habitat suitability are often targeted at finer scale areas such as a specific reef feature. A cursory review of gaps in existing data and high-priority cells shows that some cells contain extensive survey data (i.e., lidar and/or multibeam); however, the data may be outdated, have too coarse of a resolution, be poor quality, or lack ancillary data such as backscatter. 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.

Corals at Kealakekua Bay, Hawai'i.
Credit: Lisa Wedding, University of Oxford

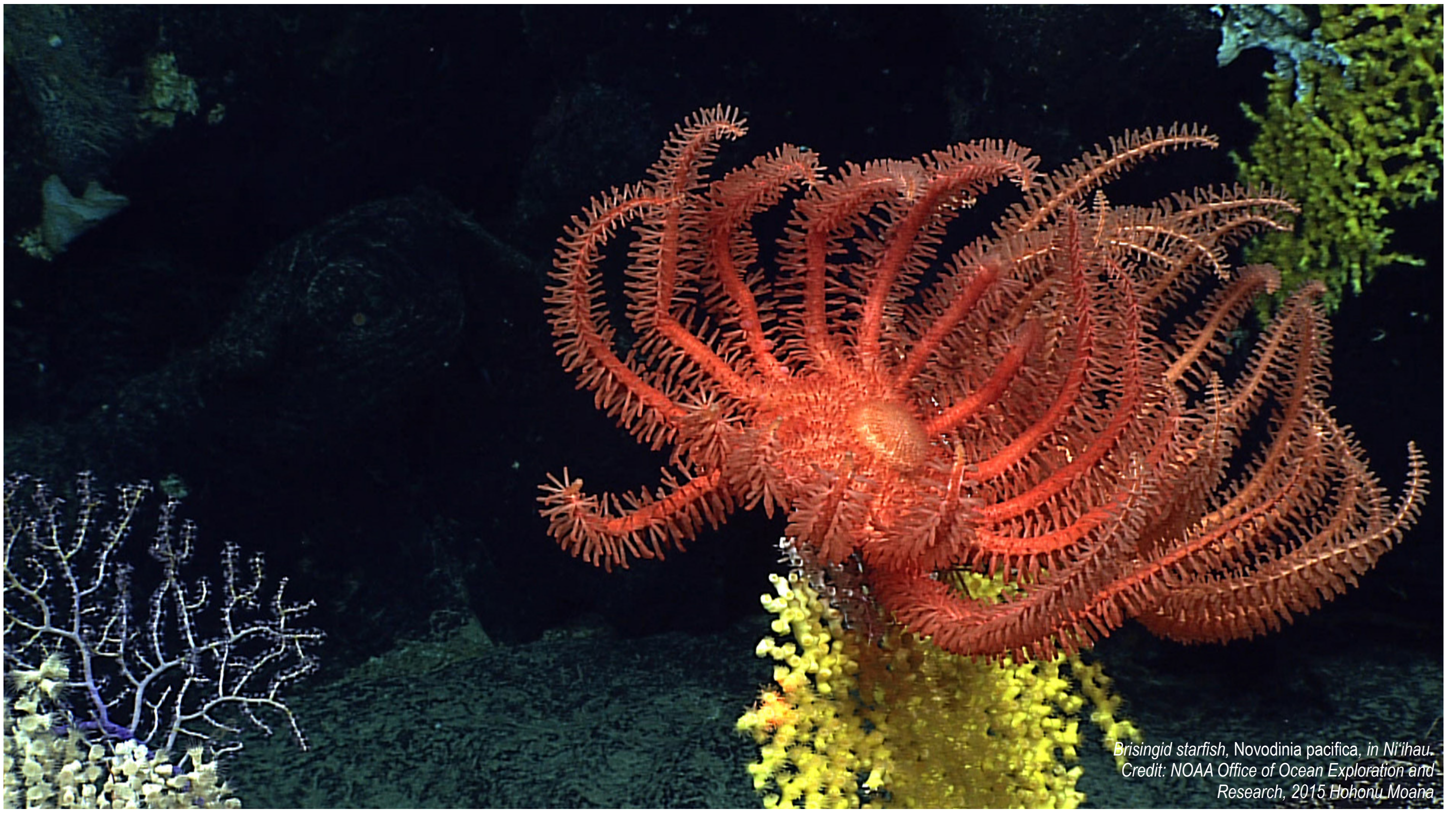
Melon-headed whales in Kauai.
Credit: Laura Morse, NOAA NMFS PIFSC

Chapter 5 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 published in NOAA's Integrated Ocean and Coastal Mapping – U.S. Mapping Coordination website (NOAA IOCM, 2023). See links below for access to reports, data viewers, and downloads.

Datasets, Data Web Services, and Metadata:

- 2023: NOAA NCCOS Assessment: Agency priorities for mapping coral reef ecosystems in Hawai'i, 2022-07-08 to 2022-08-01
    - Zenodo Accession (Kraus et al., 2023)
- 2022: Dashboard – Hawaiian Islands Coral Reef Mapping Prioritization Results
- 2021: Project Website – Coral Reef Prioritization | A Roadmap for Future Data Collection
- 2021: NCCOS Website – Defining Future Seafloor Mapping Priorities to Inform Shallow Coral Reef Management



Brisingid starfish, Novodinia pacifica, *in Ni'ihau.*
Credit: NOAA Office of Ocean Exploration and Research, 2015 Hohonu Moana

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Appendices

Appendix A: Data Inventory Reference Table

Table A.1. Data inventory for the Main Hawaiian Islands. Each web service within the data inventory shared with participants is listed below. Specific island coverage is also noted. Map service URLs accessed on March 1, 2023.

Category	Item Name (name of web service)	Hawai‘i	Kaho‘olawe	Maui	Lāna‘i	Moloka‘i	O‘ahu	Kaua‘i	Ni‘ihau	Description	Map Service URL
Multibeam	NCEI Bathymetric Mosaic Shaded Relief Visualization (Variable Resolution)	x	x	x	x	x	x			Color shaded relief visualization of high-resolution quality-controlled seafloor elevation from NOAA National Ocean Service (NOS) Hydrographic Survey Bathymetric Attributed Grids (BAGs) in U.S. coastal waters. Updated November 2022.	https://tiles.arcgis.com/tiles/C8EMgrsFcRFL6LrL/arcgis/rest/services/bag_hillshades/MapServer
	SOEST Multibeam Synthesis Grid (5-m resolution, 2016)	x	x	x	x	x	x	x	x	This layer originates from the School of Ocean and Earth Science and Technology's (SOEST) 2016 Main Hawaiian Islands Multibeam Backscatter and Bathymetry Synthesis. It has been clipped to 3 nmi of the Hawaiian coast line. https://www.soest.hawaii.edu/hmrg/multibeam/index.php	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/SOEST_MBES_synthesis__trimmed_3nm/FeatureServer
	Footprints of Multibeam Transit Surveys (Variable Resolution), Clipped to 3 nmi	x	x	x	x	x	x	x	x	This layer comprised of survey data simplified into polygon footprints. Data were collected by vessels equipped with acoustic systems as they transited in and out of local ports. The outlines of these "transit surveys" were trimmed to within 3 nmi from the coastline of the Main Hawaiian Islands (MHI). Data were downloaded from NOAA's National Centers for Environmental Information (NCEI) and accessed in 2022.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Multibeam_transit_surveys/FeatureServer
Lidar/Aerial	Ni'ihau Lidar Footprint (1-m resolution, 2022)								x	Footprint of topobathy lidar data collected in 2022. Bathymetric data are still in review and not yet public.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Niihau_Lidar/FeatureServer/214
	Global Airborne Observatory: Hawaiian Islands Bathymetry (2019, 2020)	x	x	x	x	x	x	x	x	This tiled layer displays bathymetry (depth) data for the MHI. Source: Arizona State University Global Airborne Observatory (GAO), 2019–2020. https://gdcs.asu.edu/programs/global-airborne-observatory	https://noaa.maps.arcgis.com/home/item.html?id=e8119a70e1a24b6c80a300a69afc511e
	USACE Bathymetric Lidar Footprint (1-m resolution, 2013)	x		x	x	x	x	x	x	Footprint of coastal lidar data collected in 2013 by US Army Corps of Engineers. Data are clipped to include aquatic areas only. Acoustic data are available for download from NCEI and provided as a 1-m resolution bathymetric grid.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Footprint_ALL_Lidar_1m_Hawaii_Coastline_Clip/FeatureServer
	USACE Bathymetric Lidar Footprint (3-m resolution, 2000)	x			x	x	x			Footprint of coastal lidar data collected by the USACE in 2000 around the MHI. Original data resolution at 3 m. Source download: https://www.fisheries.noaa.gov/inport/item/49740	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/USACE_Bathymetric_Lidar_2000/FeatureServer/154
Habitat Maps	Global Airborne Observatory: Hawaiian Islands Live Coral Cover (2019)	x	x	x	x	x	x	x	x	This tiled layer displays percent live cover of coral species across the MHI. Source: Arizona State University GAO, 2019.	https://tiles.arcgis.com/tiles/C8EMgrsFcRFL6LrL/arcgis/rest/services/ASU_GAO_Percent_live_cover_Tile_Project/MapServer
	NOAA NCCOS Habitat Maps (2003 and 2007)	x	x	x	x	x	x	x	x	The goal of the work was to map the coral reef habitats of the MHI by visual interpretation and manual delineation of IKONOS and Quick Bird satellite imagery. A two tiered habitat classification system was tested and implemented in this work. It integrates geomorphologic reef structure and biological cover into a single scheme and subsets each into detail. It also includes fourteen zones. http://coastalscience.noaa.gov/projects/detail?key=208	https://idpgis.ncep.noaa.gov/arcgis/rest/services/NOS_Biogeo_Biomapper/Hawaii_Dynamic/MapServer
	PIBHMC West Maui Habitat Map (2016)			x						Dominant benthic structure and biological cover habitat maps for west Maui. Biological cover derived from 5-m bathymetry synthesis grid. Data Source: https://www.soest.hawaii.edu/pibhmc/cms/data-by-location/main-hawaiian-islands/maui/maui-habitat/	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Maui_Benthic_Habitat/FeatureServer/211
	PIBHMC West Hawaii Habitat Map (2016)	x								Dominant benthic structure and biological cover habitat maps for west Hawai‘i. Data Source: https://www.soest.hawaii.edu/pibhmc/cms/data-by-location/main-hawaiian-islands/hawaii-big-island/hawaii-habitat/	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Hawaii_Substrate/FeatureServer/214

Table A.1. Hawaiʻi mapping inventory data table continued.

Category	Item Name (name of web service)	Hawaiʻi	Kahoʻolawe	Maui	Lānaʻi	Molokaʻi	Oʻahu	Kauaʻi	Niʻihau	Description	Map Service URL
Boundaries	Depth Contour (40 m)	x	x	x	x	x	x	x	x	An underwater contour that marks 40 m in depth surrounding the MHI.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Hawaii_40m_bathy/FeatureServer
Boundaries	Grid: Hawaii Prioritization	x	x	x	x	x	x	x	x	Empty grid cell for the 2022 Hawaii Mapping Prioritization. Each cell is 1 km in length per side.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/CRCP_HI2_cab/FeatureServer
Boundaries	Hawaiʻi Coastline	x	x	x	x	x	x	x	x	Coastline of the MHI. Produced by Hawaiʻi's Department of Planning and Sustainable Development.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Hawaii_Coastline/FeatureServer
Boundaries	Marine Managed Areas (DAR)	x	x	x	x	x	x	x	x	Marine Managed Areas (MMAs) in the MHI as of January, 2020. This is not a comprehensive layer/listing of all fishing regulations.	https://geodata.hawaii.gov/arcgis/rest/services/CoastalMarine/MapServer/39
Boundaries	NOAA's National Marine Sanctuary Program Boundaries (2021)	x		x	x	x	x	x		Data derived from NOAA's MPA Inventory and originally sourced from NOAA's Office of National Marine Sanctuaries. Updated August 2021.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/ONMS_2021_Boundaries/FeatureServer
Boundaries	USGS Watershed Boundary	x	x	x	x	x	x	x	x	Watershed boundary dataset downloaded from the U.S. Geodetic Survey website. The Watershed Boundary Dataset is used broadly in applications from scientific research to regulatory work. It is a companion dataset to the National Hydrography Dataset (NHD) and a component of the NHDPlus High Resolution (NHDPlus HR). Updated October 2022.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Hawaii_HUC10/FeatureServer
Boundaries	USFWS National Wildlife Refuges	x		x		x	x	x		This U.S. Fish and Wildlife Service feature layer depicts National Wildlife Refuges. Updated November 2022.	https://services.arcgis.com/QVENGdaPbd4LUkLV/arcgis/rest/services/National_Wildlife_Refuge_System_Boundaries/FeatureServer
Boundaries	U.S. National Park Service Lands	x		x		x	x			This layer displays the administrative boundaries of lands managed by the U.S. National Park Service. Updated May 2022.	https://services.arcgis.com/P3ePLMYs2RVChkJx/arcgis/rest/services/USA_National_Park_Service_Lands_20170930/FeatureServer
Boundaries	Designated Ocean Recreation Management Areas	x		x			x	x		Designated Ocean Recreation Management Areas (ORMAs) (Unverified): All designated ORMA zones as defined in Hawaii Administrative Rules (HAR) Ch. 256. This layer is "unverified." Boundaries were generated using the HAR rule descriptions and other Division of Boating and Ocean Recreation documents, but they have not been officially verified.	https://geodata.hawaii.gov/arcgis/rest/services/CoastalMarine/MapServer/10
Points	NOAA NCCOS Accuracy Assessment Sites (2007)	x		x	x	x	x			The geographic coordinate positions of the points in this thematic data were acquired by GPS using a Trimble GeoExplorer 3 with a customized data dictionary designed to reflect the NOAA Coral Classification Scheme for Benthic Habitats of the Pacific. All habitat determinations were made in the field, recorded in the GPS data logger, and seamlessly transferred to ArcView GIS using Trimble Path Finder Office Software.	https://products.coastalscience.noaa.gov/collections/benthic/e97hawaii/data2007.aspx; https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BenthicMapping_Hawaii_Dynamic/MapServer/1
Points	Pacific Islands Benthic Habitat Mapping Center Optical Validation (2005–2009)	x				x	x	x	x	The collection and analysis of photographic data to ground truth and interpret multibeam data layers with the goal of characterizing seafloor habitats. Optical validation was collected from 2005 to 2009. These data were downloaded from the Pacific Islands Benthic Habitat Mapping Center.	https://services2.arcgis.com/C8EMgrsFcRFL6LrL/arcgis/rest/services/Pacific_Islands_Benthic_Habitat_Mapping_Center_Optical_Validation/FeatureServer
Points	NOAA NCCOS Ground Validation Sites (2007)	x	x	x	x	x	x	x	x	The geographic coordinate positions of the points in these thematic data were acquired by GPS using a Trimble GeoExplorer 3 with a customized data dictionary designed to reflect the NOAA Coral Classification Scheme for Benthic Habitats of the Pacific.	https://products.coastalscience.noaa.gov/collections/benthic/e97hawaii/data2007.aspx; https://gis.ngdc.noaa.gov/arcgis/rest/services/nccos/BenthicMapping_Hawaii_Dynamic/MapServer/2
Other	Coastal Satellite Imagery	x		x	x	x	x	x	x	Benthic habitat maps of the MHI were created through visual interpretation of multispectral IKONOS and Quickbird imagery. Updated September 2020.	https://tiles.arcgis.com/tiles/C8EMgrsFcRFL6LrL/arcgis/rest/services/BenthicMapping_Hawaii_Imagery/MapServer

Appendix B: Individual Maps for Each Management Use

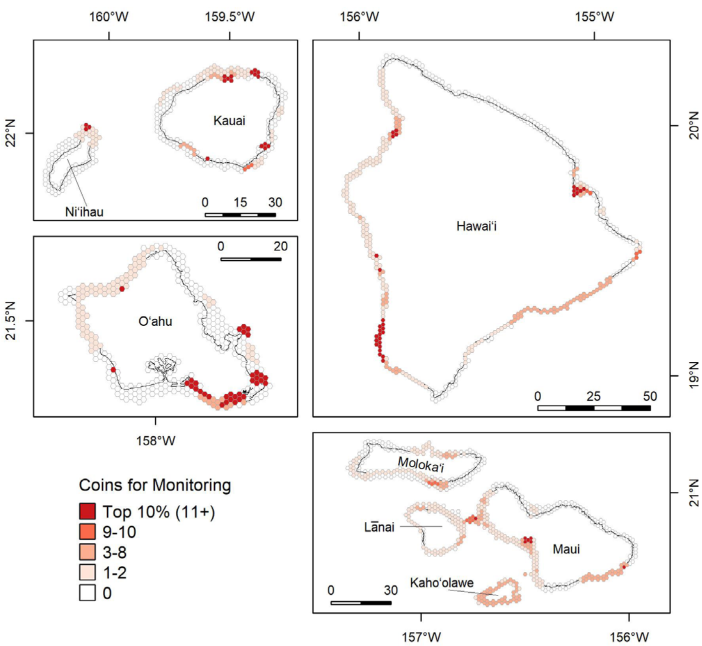

Figure B.1. Map of coins distributed for the Management Use *Monitoring*.

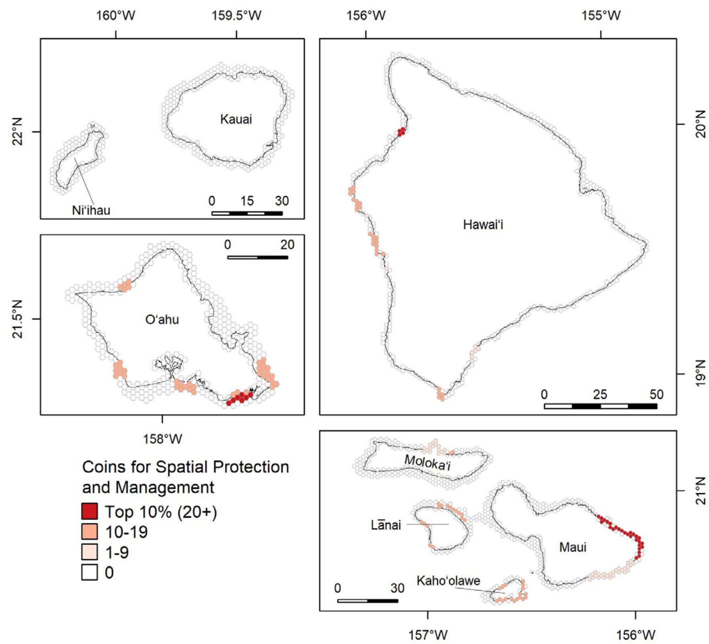

Figure B.2. Map of coins distributed for the Management Use *Spatial Protection and Management*.

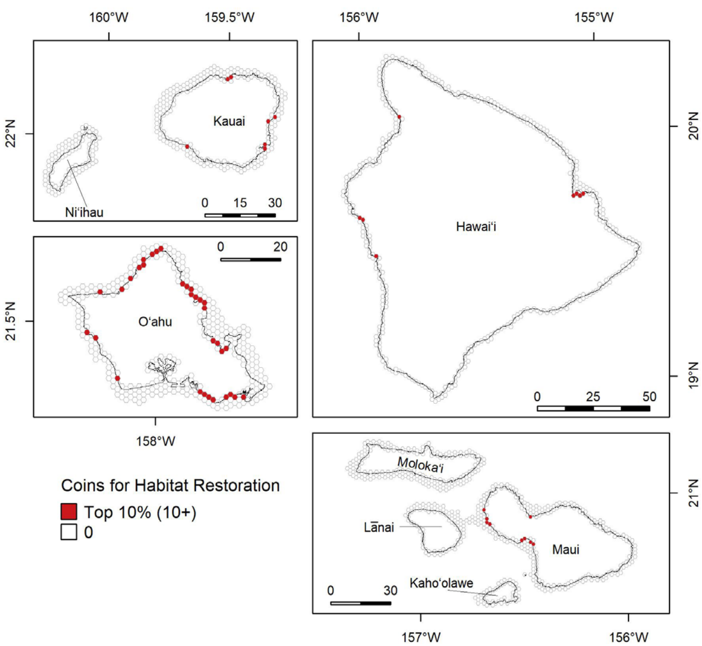

Figure B.3. Map of coins distributed for the Management Use *Habitat Restoration*.

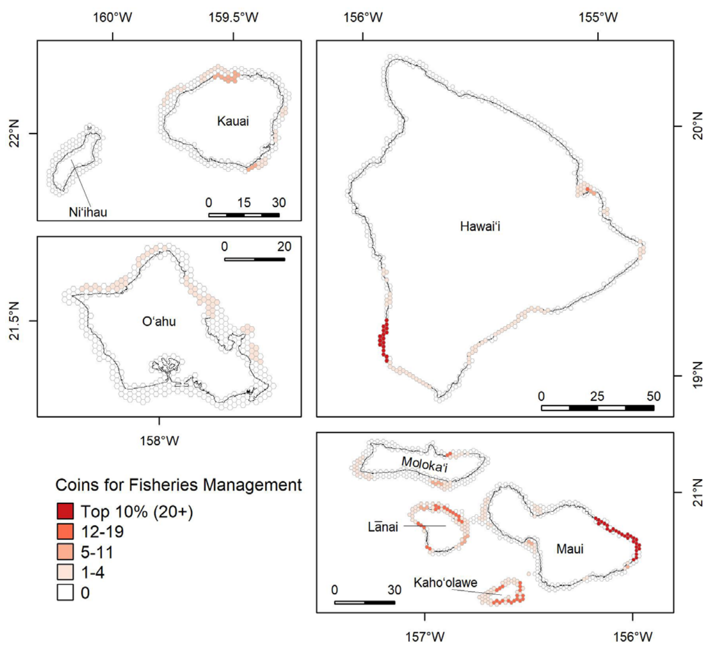

Figure B.4. Map of coins distributed for the Management Use *Fisheries Management*.

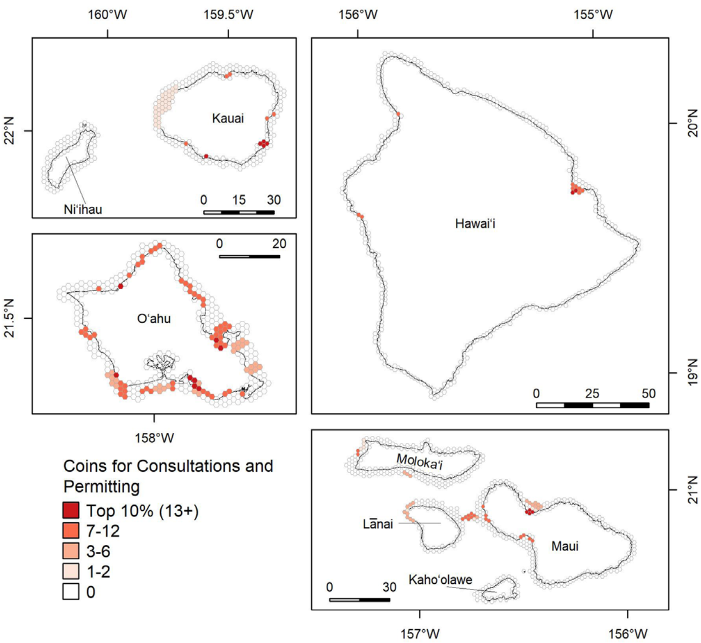

Figure B.5. Map of coins distributed for the Management Use *Consultations and Permitting*.

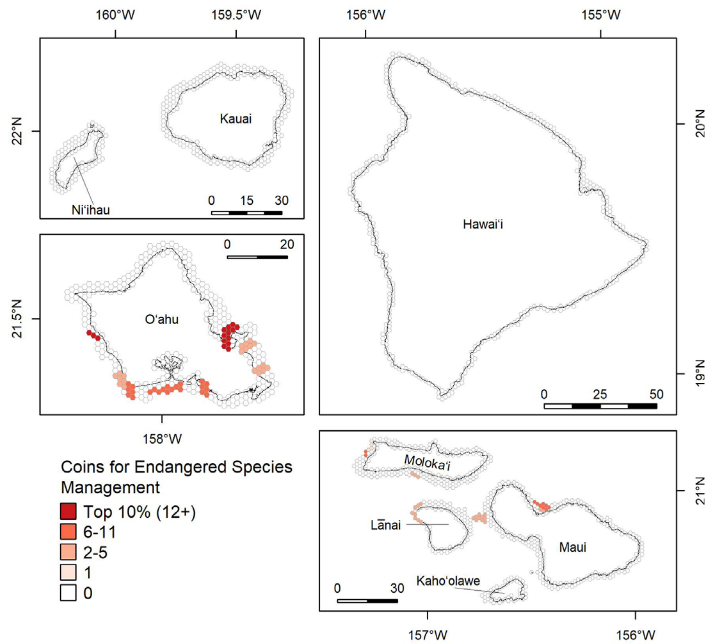

Figure B.6. Map of coins distributed for the Management Use *Endangered Species Management*.

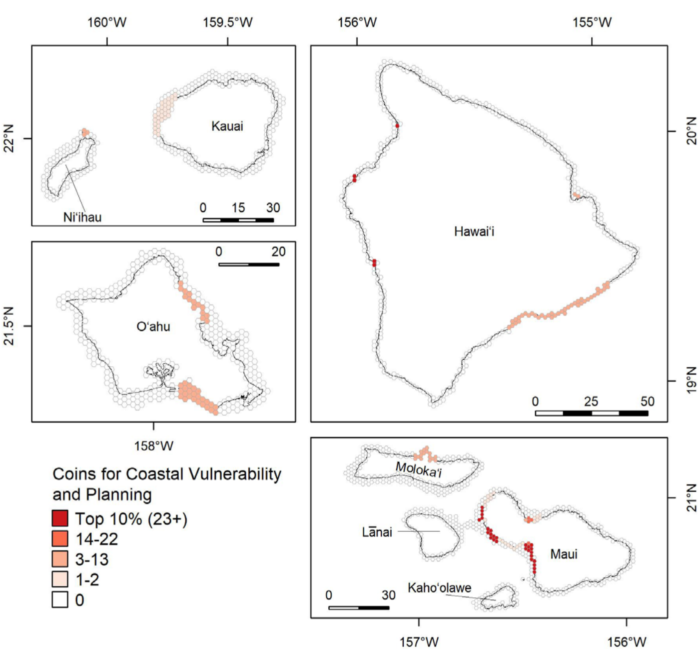

Figure B.7. Map of coins distributed for the Management Use *Coastal Vulnerability and Planning*.

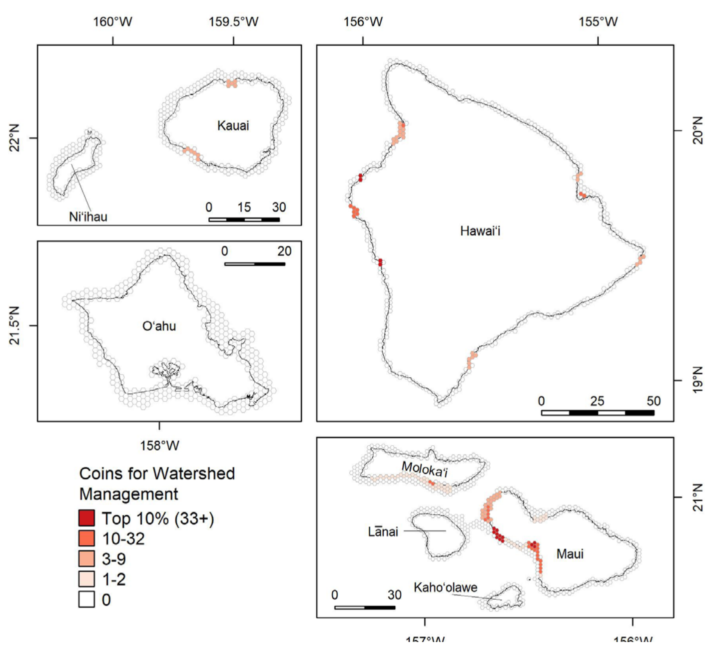

Figure B.8. Map of coins distributed for the Management Use *Watershed Management*.

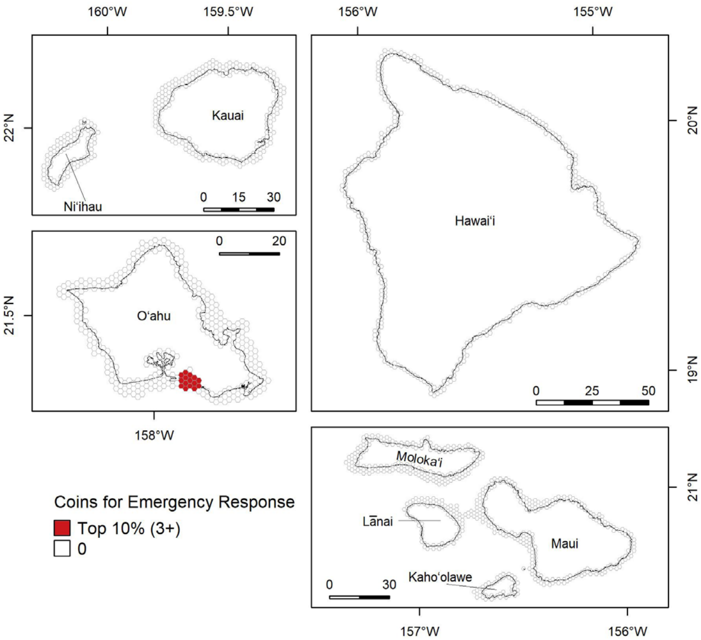

Figure B.9. Map of coins distributed for the Management Use *Emergency Response*.

Appendix C: Individual Maps for Each Product Requirement

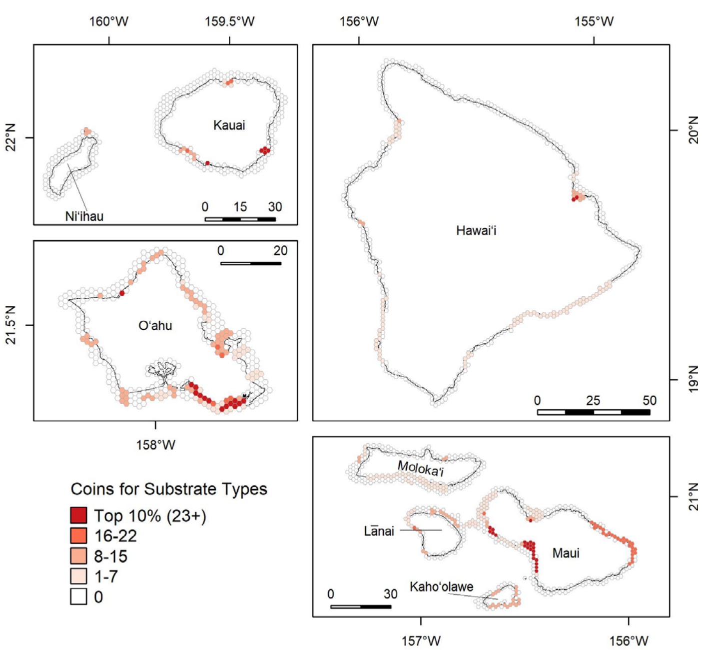

Figure C.1. Map of coins distributed for the Product Requirement *Substrate Types*.

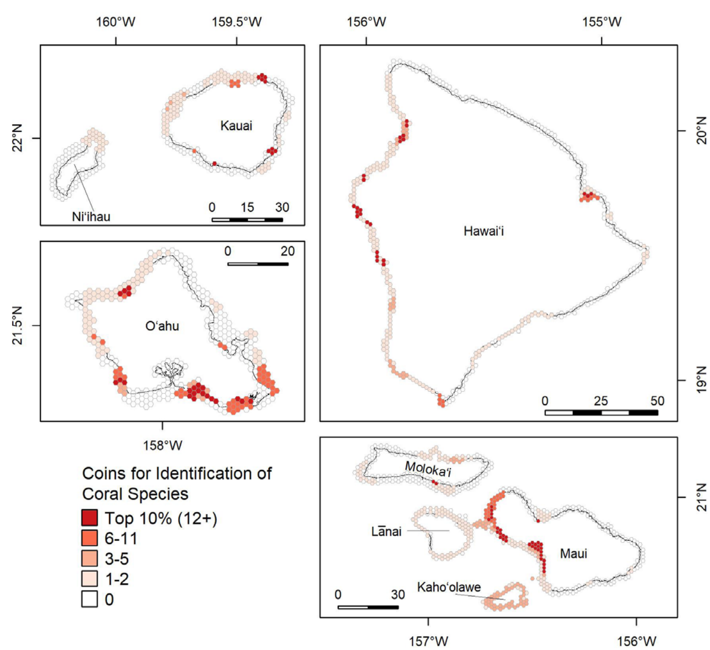

Figure C.2. Map of coins distributed for the Product Requirement *Identification of Coral Species*.

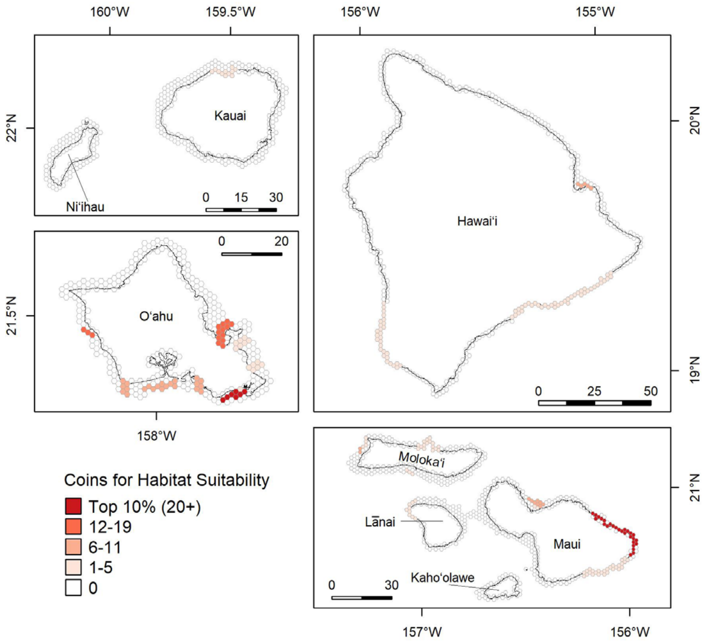

Figure C.3. Map of coins distributed for the Product Requirement *Habitat Suitability*.

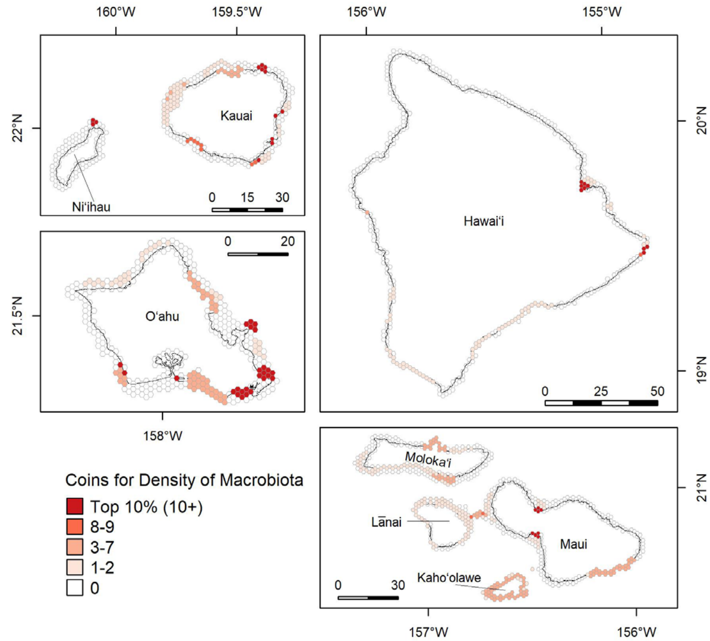

Figure C.4. Map of coins distributed for the Product Requirement *Density of Macrobiota*.

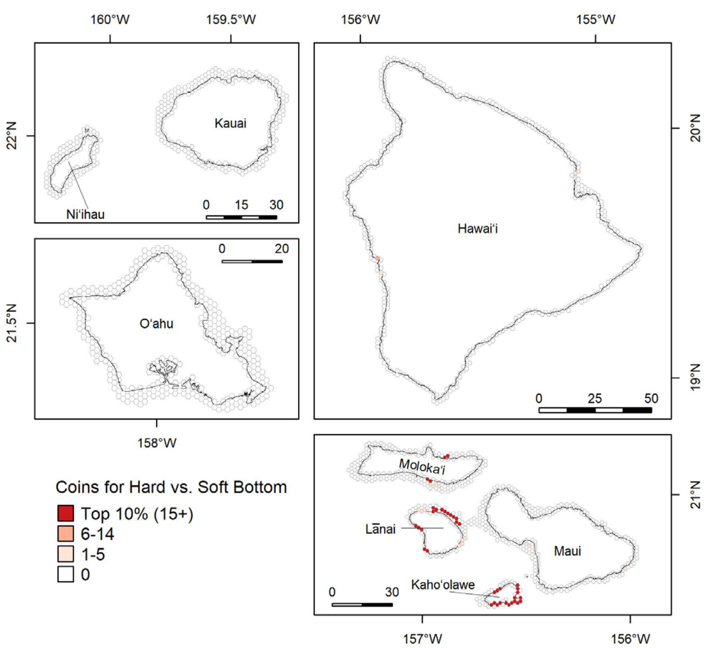

Figure C.5. Map of coins distributed for the Product Requirement *Hard vs. Soft Bottom*.

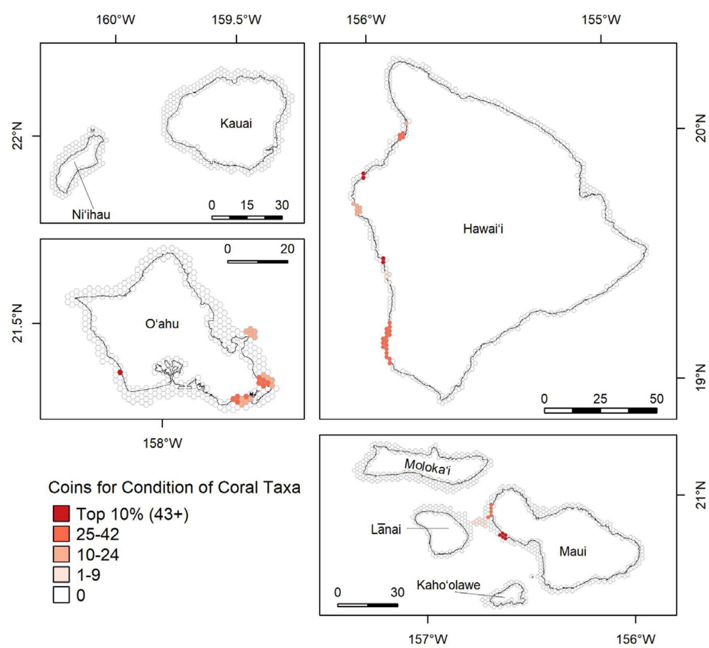

Figure C.6. Map of coins distributed for the Product Requirement *Condition of Coral Taxa*.

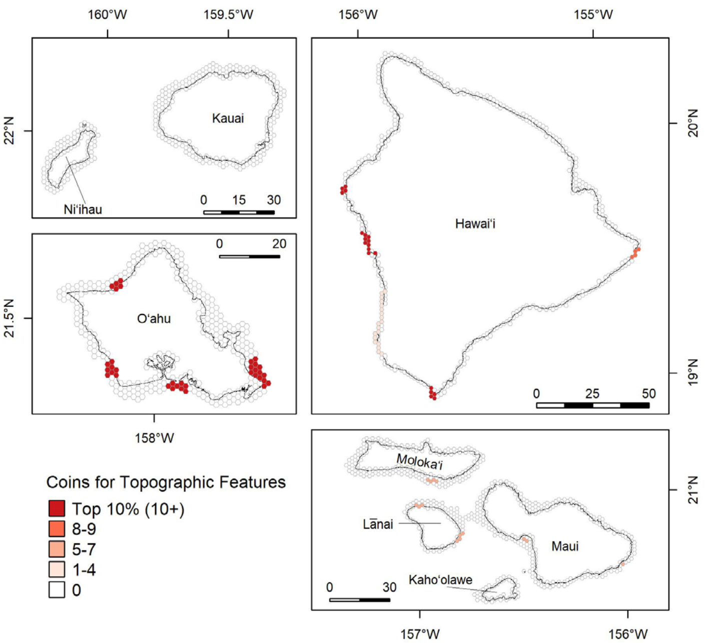

Figure C.7. Map of coins distributed for the Product Requirement *Topographic Features*.

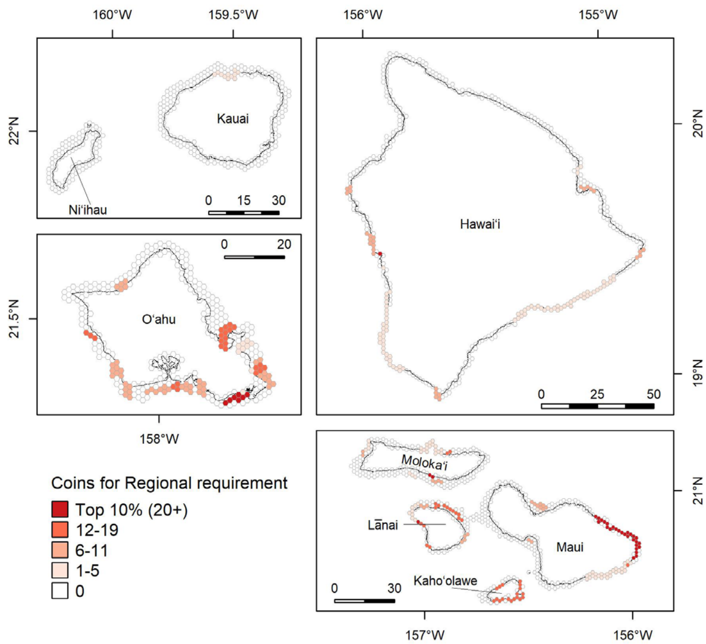

Figure C.8. Map of coins distributed for *Regional Scale* Product Requirements.

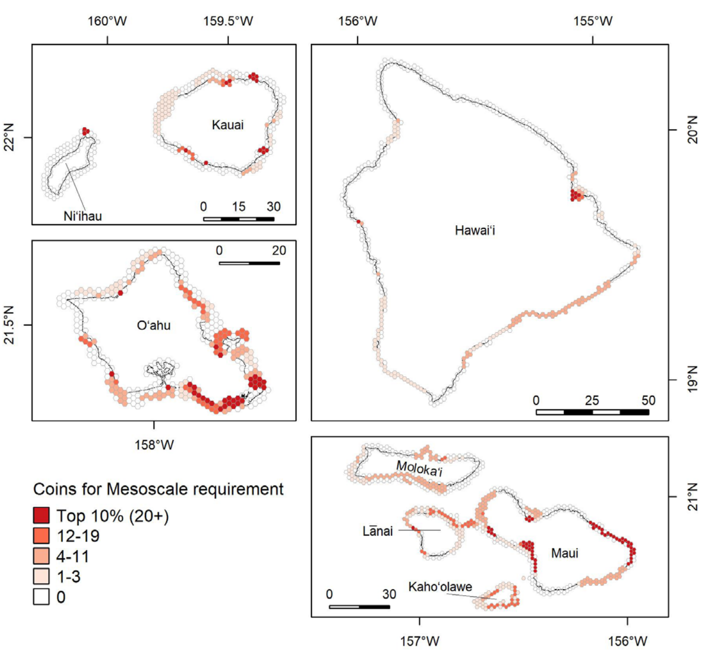

Figure C.9. Map of coins distributed for *Mesoscale* Product Requirements.

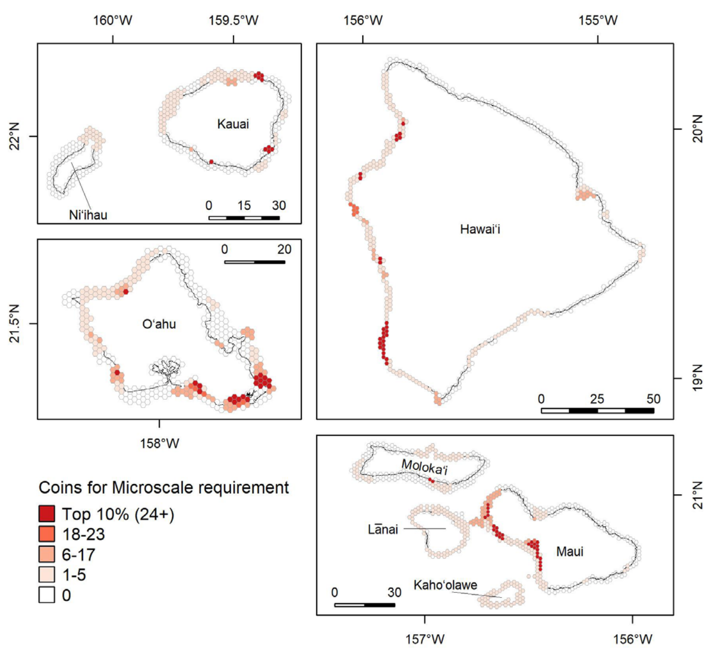

Figure C.10. Map of coins distributed for *Microscale* Product Requirements.

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