U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE/NOAA FISHERIES
Pacific Islands Fisheries Science Center
2570 Dole St. • Honolulu, Hawaii 96822-2396
(808) 983-5300 • Fax: (808) 983-2902

CRUISE REPORT[1]

VESSEL: NOAA Ship *Hi`ialakai*, Cruise HA-13-04, Legs I and II

CRUISE PERIOD: 1–23 August 2013

AREA OF OPERATION: Main Hawaiian Islands: Hawai`i Island, Maui Island, Lāna`i Island, Kaua`i Island, Ni`ihau Island, O`ahu Island, and Moloka`i Island

TYPE OF OPERATION: Personnel from the Coral Reef Ecosystem Division (CRED) of the NOAA Pacific Islands Fisheries Science Center, University of Hawai`i at Hilo, and San Diego State University, conducted interdisciplinary surveys of benthos, fishes, and climate in waters surrounding the main Hawaiian Islands as part of the National Coral Reef Monitoring Plan (NCRMP). All activities described in this report were covered by the following permits: Hawai`i Department of Land and Natural Resources, Division of Aquatic Resources Special Activity Permit No. 2014-6 (effective date: 19 July 2013, expiration date: 19 July 2014); U. S. Army Corps of Engineers Permit: USACE POH-2008-83 (OMB APPROVAL NO. 0710-0003) 30 April 2009.

ITINERARY:

Note: Daily field operations included Rapid Ecological Assessment (REA) benthic surveys and REA fish surveys,. Unless otherwise specified in the following daily summaries, these surveys occurred during each operational day.

1 August — Start of cruise; embarked all scientific personnel. Routine departure-day activities, including dive safety and operational briefings, dive gear checks, safety drills, etc. Departed Pearl Harbor fuel pier at 1730 en route to west Maui for first day of operations. Departure time was delayed by 4 hours from the original project instructions, owing to fueling operations and other ship-related activities.

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Issued 2 June 2014

2 August	Commenced field operations along West Maui; deployed and retrieved the following types of instruments: 4 Subsurface Temperature Recorders (STRs) and 1 Ecological Acoustic Recorder (EAR).
3 August	Conducted operations along NE Hawai`i Island, North Kohala-Hamakua. Deployed and retrieved the following types of instruments: 3 Autonomous Reef Monitoring Structures (ARMS), 10 Calcification Accretion Units (CAUs), 5 Bioerosion Monitoring Units (BMUs), and 3 STRs.
4 August	Conducted operations along SW Hawai`i Island, South Kona-Kau. Ship's main crane malfunction precluded 3 small boat launches. Deployed and retrieved the following types of instruments: 6 ARMS, 5 CAUs, 5BMUs, 4 STRs, 1 EAR, and 1 STR.
5 August	Conducted operations along E Hawai`i Island, Hilo Bay. Ship's main crane malfunction precluded 3 small boat launches. Deployed and retrieved the following types of instruments: 10 CAUs sites.
6 August	Conducted operations along SE Hawai`i Island, Puna. Deployed and retrieved the following types of instruments: 3 ARMS, 10 CAUs, 5BMUs, 4 STRs, and 1 EAR.
7 August	Conducted operations along South Hawai`i Island, Honuapo–South Point. Deployed and retrieved the following types of instruments: 6 ARMS, 10 CAUs, 5BMUs, and 4 STRs.
8 August	Conducted operations along NE Hawai`i Island, Kawaihae–Kiloho Bay. Deployed and retrieved the following types of instruments: 10 CAUs sites.
9 August	Conducted operations along E Maui Island, Hana Bay–Opana Point. Deployed and retrieved the following types of instruments: 5 CAUs and 3 STRs, and 3 ARMS.
10 August	Foul weather conditions prevented boat launches at planned location (North Maui); conducted operations along NE Maui Island, Honolua Bay–Ukumehame Beach Park. Recovered 1 STR.
11 August	Conducted operations along South Moloka`i. Field activities included 6 benthic REA surveys and 12 fish REA surveys. Deployed and retrieved the following types of instruments: 10 CAUs.
12 August	In-port at Pearl Harbor, Honolulu, Hawai`i. Refueling and dive rest day. Disembarked Kaylyn McKoy, Jacob Asher, Mark Manuel, and Louis Giuseffi; and embarked Ivor Williams, Marc Nadon, Brett Schumacher, Adel Heenan, and Kailea Carlson. Start of HA-13-04 Leg II.

13 August	Conducted operations along East Kaua`i. Foul weather limited small boat launches. Deployed and retrieved 2 STRs.
14 August	Conducted operations along East Ni`ihau. Deployed and retrieved the following types of instruments: 5 CAUs and 1 STR.
15 August	Conducted operations along West Kaua`i. Deployed and retrieved the following types of instruments: 1 EAR, 4 STRs, and 2 ARMS, 5 CAUs.
16 August	Conducted operations along West Ni`ihau. Deployed and retrieved the following types of instruments: 5 CAUs site 3 STRs.
17 August	Conducted operations along South Kaua`i. Deployed and retrieved the following types of instruments: 4 STRs and 5 CAUs
18 August	Conducted operations along N-NW O`ahu, Kahuku Point–Mokuleia. Deployed and retrieved the following types of instruments: 4 STRs, 5 CAUs, 5 BMUs, and 3 ARMS.
19 August	Conducted operations along West Moloka`i. Deployed and retrieved the following types of instruments: 5 STRs and 5 CAUs site and 3 STRs.
20 August	Conducted operations along North Moloka`i. Deployed and retrieved the following types of instruments: 10 CAUs and 3 STRs.
21 August	Conducted operations along North Lāna`i. Deployed and retrieved the following types of instruments: 10 CAUs and 3 STRs.
22 August	Conducted operations along South Lāna`i. Deployed and retrieved the following types of instruments: 3 STRs and 5 CAUs.
23 August	Conducted operations along East O`ahu, Makapu'u Point. Retrieved 3 ARMS. Transited to and arrived at Pearl Harbor, Honolulu, Hawai`i. Disembarked all scientific personnel. End of HA-13-04 Leg II.

OVERVIEW:

NOAA's Coral Reef Conservation Program (CRCP) has made the strategic decision to invest a portion of its annual operating budget in perpetuity to support a National Coral Reef Monitoring Plan (NCRMP) designed to provide a consistent flow of information to assess and report the status and trends of environmental conditions, living reef resources, and the people and processes that interact with coral reef ecosystems. The NCRMP builds upon a decade of CRCP-supported, nationwide coral reef monitoring and reporting efforts, such as the Pacific Reef Assessment and Monitoring Program (Pacific RAMP), a CRED-led research program, and *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States*, a NOAA Technical Memorandum compiled by the NOAA Center for Coastal Monitoring and Assessment. Although the scope of NCRMP is broad, it is intended to assess the status of coral reef ecosystems and their conditions throughout United States and its territories and provide a steady and comprehensive analytical context to gauge changes in conditions at the sub-jurisdictional scale of an island or atoll.

The NCRMP focuses on four priority themes: climate change and ocean acidification; benthic communities (especially corals); reef-associated fish communities; and socioeconomics. Biological monitoring for benthic and fish communities are conducted using a two-stage stratified random sampling design throughout shallow-water (0–30 m), hard-bottom coral reef habitats. Monitoring of climate change and ocean acidification is achieved by means of sustained, remotely sensed and in situ observations of ocean temperature; autonomous, discrete water sampling for analyses of carbonate chemistry; and distinct biological installations designed to provide integrated, ecosystem-wide response data (e.g., biodiversity, calcification, and bio-erosion) in the context of climate change. In the Pacific, biological (benthic and fish) and climate monitoring are conducted on a triennial basis. Socioeconomic monitoring is led by the CRCP at headquarters in Silver Spring, MD, and stands outside the scope of the NCRMP monitoring and assessment cruises; therefore, it is not addressed in this cruise report.

MISSIONS:

A. Conducted ecosystem monitoring for benthic cover (community structure), fish populations (species composition, abundance and size), coral populations (species composition, abundance, size distribution, and condition), and target invertebrates of the shallow-water (≤ 30 m) coral reef ecosystems of the main Hawaiian Islands.

B. Deployed and retrieved a suite of instruments and installations—including STRs, CTD sensor, ARMS, CAUs, BMUs, and EARs—to allow for remote, long-term monitoring of oceanographic, environmental, and ecological conditions of the coral reef ecosystems of the main Hawaiian Islands.

C. Conducted shallow-water CTD casts and collected water samples for dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, and microbial community analyses to depths ≤ 30 m to examine physical and biological linkages supporting and maintaining these island ecosystems.

D. Conducted shipboard oceanographic and meteorological observations to examine physical and biological linkages supporting and maintaining these island ecosystems, using CTD casts deployed to a depth of 500 m with concurrent water samples taken at select locations and depths, collecting continuous ADCP, SST, and salinity, ecosystems and fundamental meteorological data, such as air temperature, wind speed and direction, barometric pressure, and relative humidity.

E. Collected a small number of shallow-water coral cores to examine calcification (growth) rates in recent decades and assess potential early impacts of ocean acidification.

F. Collected a small number of shallow-water rubble samples to examine the microbes.

G. Determined the existence of threats to the health of these coral reef resources from anthropogenic sources, including marine debris.

RESULTS:

This section provides tallies of research activities (Table 1), a list of data collected during cruise HA-13-04, and a summary of important observations. For more information pertaining to the methods employed, detailed information on data acquired, and a list of samples collected at the islands visited, see Appendices A–I.

Table 1. Statistics for the Pacific RAMP 2013 cruise to the main Hawaiian Islands (cruise HA-13-04), including the islands of Hawai`i (HAW), Kaua`i (KAU), Lāna`i (LAN), Maui (MAI), Moloka`i (MOL), Ni`ihau (NII), and O`ahu (OAH). The numbers for REA sites include sites where REA benthic or fish surveys were conducted. The totals for scuba dives include all dives carried out for all activities at each island.

Research Activity	HAW	KAU	LAN	MAI	MOL	NII	OAH	TOTAL
Scuba dives	276	149	128	143	164	120	60	1040
Biological Surveys								
REA Sites: Benthic	24	14	14	8	21	17	6	104
REA Sites: Fish	58	37	29	34	39	26	14	237
Biological Sample Collections								
Microbial Water Samples	14	6	6	6	6	4	2	44
Microbial Benthic Samples	0	0	0	0	3	1	0	4
Biological Monitoring Installations								
ARMS Retrieved	6	6	0	3	0	0	3	18
ARMS Deployed	9	0	0	0	0	0	3	12
CAUs Deployed	50	10	15	5	25	10	5	120
BMUs Deployed	25	0	0	0	0	0	5	30
EARs Retrieved	2	1	0	1	0	0	0	4
Oceanographic Moored Instruments								
STRs Retrieved	6	2	2	5	2	2	1	20
STRs Deployed	9	8	2	3	6	3	3	34
Hydrographic Surveys								
Shallow-water CTD Casts	29	8	7	11	8	8	4	74
Deepwater CTD Casts: Total	25	9	11	6	5	11	6	73
Total Length (km) of ADCP Transects	74.25	28.33	37.11	21.50	16.34	37.46	19.89	234.88
Water-quality Sampling								
Shallow-water Salinity Water Samples	33	10	8	9	14	8	5	87
Shallow-water DIC Water Samples	33	10	8	9	14	8	5	87
Deep-water chl-*a* Water Samples	115	45	40	30	10	55	30	325

The coral reef ecosystems of the main Hawaiian Islands have been surveyed biennially since 2005 and triennially starting in 2010 through CRED's Pacific RAMP. The cruise HA-13-04 marked this program's fifth expedition around the islands of Hawai`i, Maui, Lāna`i, O`ahu, Kaua`i, Ni`ihau-Lehua, and Moloka`i, including the implementation of a stratified random design for benthic REA surveys, leading to the quantification shallow (0–6 m) and deep (18–30 m) coral reef habitats not previously surveyed. Herein, we present highlights, by island, from our observations during this latest expedition.

Hawai`i Island

- The majority of benthic surveys revealed reef conditions similar to those found during surveys in previous years. Belt-transect surveys did not indicate any major increases in coral disease prevalence at the REA benthic sites visited.

- Notable fish sightings include a single gray reef shark (*Carcharhinus amblyrhynchos*) seen on the southeast coast and a pair of Tinker's butterflyfish (*Chaetodon tinkeri*) was seen at a deep site on the east side of the island.

Kaua`i Island

- Reef coral development at most REA benthic sites surveyed around Kaua`i Island was poor. Surge-soured bottoms and runoff appeared to be major factors limiting coral community development in many areas around this island.

- A 140-cm white-tip reef shark (*Trienodon obesus*) was seen off the northern coast of the island by a fish survey diver.

Lāna`i Island

- The majority of benthic surveys revealed reef conditions similar to those conditions found during surveys in previous years. Belt-transect surveys did not indicate any major increases in coral disease prevalence at the REA benthic sites visited.

- Many of the hard substrate habitats in the deep category (18–20 m) around the Island were covered by *Halimeda* meadows.

- Thick carpets of the green alga *Caulerpa filicoides* were observed overgrowing moderately deep (15–18 m) coral communities off north Lāna`i.

- Several barred jacks (*Carangoides ferdau*) were seen at two sites on the northern coast of Lanai during fish surveys and a large (200 cm) manta ray (*Manta birostris*) was seen on the northwest coast.

Maui Island

- Fairly obvious signs of sedimentation stress and elevated levels disease were observed at site MAI-1449 off south Kihei.

- A single kawakawa or mackerel tuna (*Euthynnus affin*is) was seen on the north-east coast of Maui during an REA fish survey.

Moloka`i Island

- The majority of benthic surveys revealed reef conditions similar to those conditions found during surveys in previous years. Belt-transect surveys did not indicate any major increases in coral disease prevalence at the REA benthic sites visited.

- Several sites along the north shore of Moloka`i were surveyed for fish and benthic communities, and oceanography. High winds and surge generally impede small boat access to these marine habitats.

- Notable sightings by the fish team include a 200-cm manta ray (*Manta birostris*) and a great barracuda (*Sphyraena barracuda*) on the western coast, a large school of more than 40 barred jacks (*Carangoides ferdau*) on the southern coast, and on the northern coast, the Hawaiian morwong (*Goniistius vittatus*), a fish rarely seen shallower than 30 m in the main Hawaiian Islands.

Ni`ihau Island and Lehua Rock

- The majority of benthic surveys revealed reef conditions similar to the conditions seen during surveys in previous years. Belt-transect surveys did not indicate any major increases in coral disease prevalence at the REA benthic sites visited.

- Most hard-bottom benthic communities surveyed around Ni`ihau Island were coral poor. Surge-scoured hard-bottoms and runoff appeared to be major factors limiting coral community development in this area.

- A 180-cm manta ray (*Manta birostris*) was seen on the west coast of Ni'ihau.

O`ahu Island

- The majority of benthic surveys revealed reef conditions similar to the conditions found during surveys in previous years. Belt-transect surveys did not indicate any major increases in coral disease prevalence at the REA benthic sites visited.

- Several cases of the coral cyanobacterial tissue loss disease, recently reported at Hanalei Bay, Kaua`i were observed at site OAH-1558 off Haleiwa Beach Park.

The following data and samples were collected during this expedition:

Climate and Ocean Acidification Monitoring
Oceanographic Instrumentation and Biological Installations:

- Seawater temperature at depths of 1, 5, 15, 25 m
- Assessment of taxonomic diversity of coral reef species by collection of invertebrate specimens from retrieved ARMS
- Installation of CAUs to allow for future assessment of calcification rates once they are retrieved in about 3 years
- Installation of BMUs to allow for future assessment of bio-erosion rates once they are retrieved in about 3 years

Nearshore Oceanography from Small Boats:

- Shallow-water CTD profiles to depths ≤ 30 m, including all sites where CAUs were installed and selected benthic REA sites
- Water samples for salinity, DIC, and TA collected in concert with shallow-water (≤ 30 m) CTD casts

Shipboard Oceanography:

- CTD profiles to a depth of 300 m
- Nutrient and chl-*a* concentrations from water samples collected at variable depths
- Dissolved oxygen, turbidity, fluorescence, and pH measurements recorded by CTD sensor
- Transects of profiles of ocean current velocity and direction collected using a shipboard ADCP unit
- Solar radiation, air temperature, barometric pressure, and wind speed and direction
- Surface seawater temperature and salinity measurements from real-time flow through shipboard instrumentation

Biological Monitoring

REA Benthic Surveys:

- Digital still photographs of overall site character and typical benthos
- Digital still photographs of the benthos along transect lines
- Number, species or genus, size, and condition of all coral colonies observed within belt transects of known area
- Digital still photographs of diseased corals and coralline algae
- Water samples and benthic rubble grabs at select REA sites for microbial analyses

REA Fish Surveys:

- Number, species, and estimated sizes of all fishes observed within visually estimated cylinders, each with a 7.5-m radius, during stationary-point-count surveys
- Visual estimates of benthic cover, habitat type, and habitat complexity
- Digital still photographs of the benthos along transect lines
- Digital still photographs of rare or interesting fish species
- Species presence checklists for estimates of fish community diversity

SCIENTIFIC PERSONNEL:

Bernardo Vargas-Ángel, Chief Scientist, Benthic REA Diver, University of Hawai`i (UH)-Joint Institute for Marine and Atmospheric Research (JIMAR), Pacific Islands Fisheries Science Center (PIFSC)-Coral Reef Ecosystems Division (CRED)
Jacob Asher, Fish REA Diver, UH-JIMAR, PIFSC-CRED
Paula Ayotte, Fish REA Diver, UH-JIMAR, PIFSC-CRED
Hatsue Bailey, Benthic REA Diver, UH-JIMAR, PIFSC-CRED
Kaile`a Carlson CTD Specialist, UH Hilo
Matthew Dunlap, Benthic REA Diver, UH-JIMAR, PIFSC-CRED
Emma George, Microbial Diver, San Diego State University
Andrew Gray, Fish REA Diver, UH-JIMAR, PIFSC-CRED
Louis Giuseffi CTD Specialist, PISFC
Adel Heenan, Fish REA Diver, UH-JIMAR, PIFSC-CRED
Kevin Lino, Fish REA Diver, UH-JIMAR, PIFSC-CRED
Mark Manuel, Fish REA Diver, UH-JIMAR, PIFSC-CRED
Kaylyn McKoy, Fish REA Diver, UH-JIMAR, PIFSC-CRED
Marc Nadon, Fish REA Diver, UH-JIMAR, PIFSC-CRED
Noah Pomeroy, Instrumentation Diver, UH-JIMAR, PIFSC-CRED
Kerry Reardon, Instrumentation Diver, UH-JIMAR, PIFSC-CRED
Russell Reardon, Operations Lead /Instrumentation Diver, UH-JIMAR, PIFSC-CRED
Brett Schumacher, Benthic REA Diver, UH-JIMAR, PISFC-CRED
Dione Swanson, Benthic REA Diver, UH-JIMAR, PISFC-CRED
Molly Timmers, Instrumentation Diver, UH-JIMAR, PISFC-CRED
Kevin Trick, Data Manager, UH-JIMAR, PISFC-CRED
Oliver Vetter, Instrumentation Diver, UH-JIMAR, PISFC-CRED
Ivor Williams, Fish REA Diver, PISFC-CRED
Charles Young, Instrumentation Diver, UH-JIMAR, PISFC-CRED
Jill Zamzow, Fish REA Diver, UH-JIMAR, PISFC-CRED

Submitted by: _____
Bernardo Vargas-Ángel
Chief Scientist

Approved by: _____
John Christensen
Program Manager
NOAA Coral Reef Conservation Program

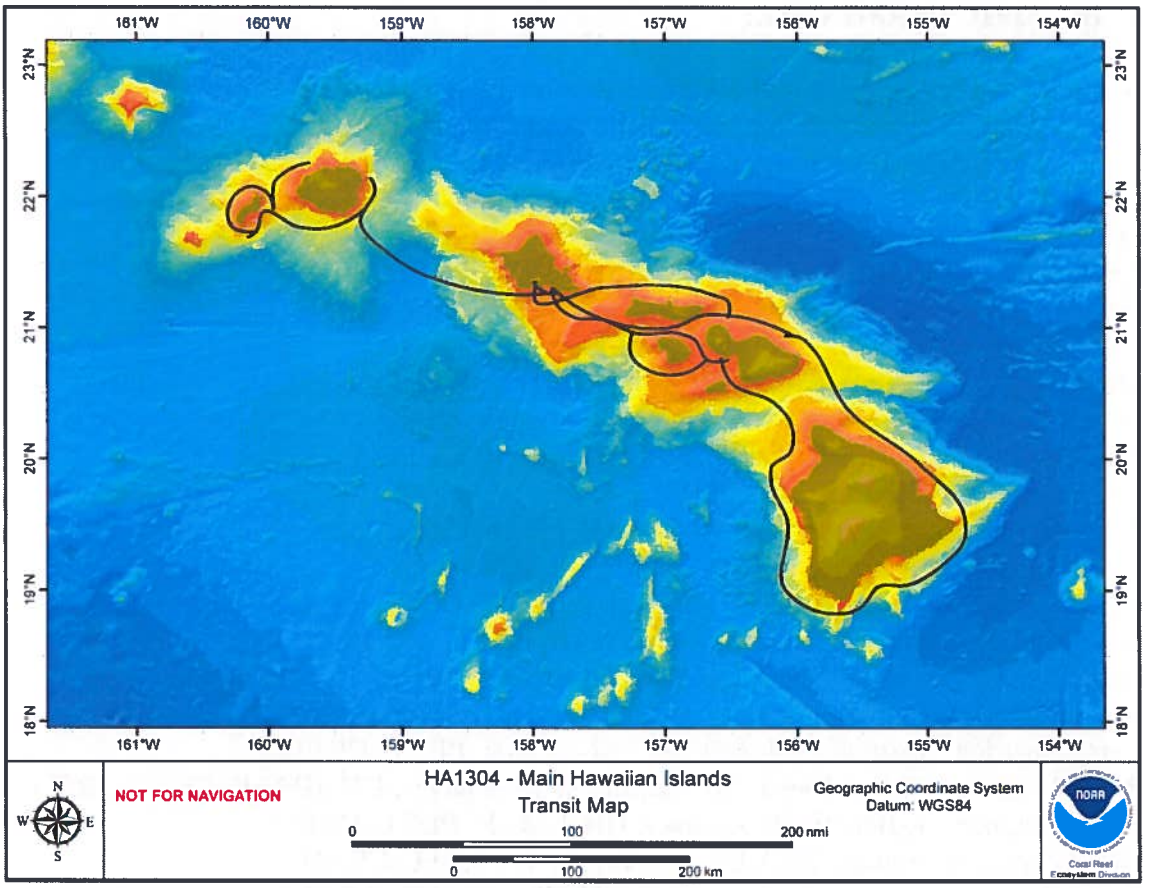

Figure 1.--Track of the NOAA Ship *Hi`ialakai* for the cruise HA-13-04, August 1–23, 2013, with Hawai`i Island, Maui Island, Lāna`i Island, Kaua`i Island, Ni`ihau Island, Lehua Rock, O`ahu Island, and Moloka`i Island surveyed. Satellite image: SIO, NOAA, U.S. Navy, NGA, GEBCO (Becker, 2009; Smith and Sandwell, 1997) © 2008 The Regents of the University of California.

APPENDIX A: METHODS

This appendix describes the methods and procedures used by the Coral Reef Ecosystem Division (CRED) of the NOAA Pacific Islands Fisheries Science Center during its Pacific Reef Assessment and Monitoring Program (Pacific RAMP) cruise HA-13-04 on the NOAA Ship *Hi`ialakai* during the August 1–23, 2013, period.

A.1. Climate and Ocean Acidification Monitoring: Instrumentation, Biological Installations, and Water Quality

(Noah Pomeroy, Kerry Reardon, Russell Reardon, Molly Timmers, Oliver Vetter, and Chip Young)

For main activities were conducted for the monitoring of climate and ocean change: (1) nearshore oceanographic and water-quality surveys; (2) deployment and retrieval of an array of subsurface moored instrumentation and installations to provide continuous, high-resolution time-series of physical observations or integrated, ecosystem-wide biological process data; (3) offshore oceanographic surveys characterizing physical, biological, and chemical water properties, and ocean currents around these islands; and (4) shipboard meteorological observations, including wind speed and direction, relative humidity, air temperature, and barometric pressure. In addition, previously deployed instrumentation such as Ecological Acoustic Recorders (EARs), which monitor the sounds of marine animals and vessel traffic around the islands, were also retrieved.

Climate and ocean acidification monitoring efforts at each survey site fall into four different levels of increasing scientific investigative effort. These are intended to document the island-scale, water chemistry, spatial and temporal variability of reef water thermal structure across a depth gradient, and the integrated biological responses of the reef community to the prevailing chemical and physical conditions.

1- Class 0 sites: Only discrete water samples are collected and analyzed for dissolved inorganic carbon (DIC) and total alkalinity (TA).

2- Class 1 sites: Only subsurface temperature recorders (STRs), SBE 56 temperature loggers (Sea-Bird Electronics, Inc., Bellevue, Wash.), are deployed.

3- Class 2 sites: Include collection of discrete water samples for DIC and TZ, and STR deployments, in addition to benthic surveys and still photographic records of the benthos. Biological installations, including Calcification Accretion Units (CAUs), Bioerosion Monitoring Units (BMUs), Autonomous Reef Monitoring Structures (ARMS), and coral coring are added.

4- Class 3 sites: A MAPpCO2 buoy system is added to the Class 2 site set-up.

Most of the CRED's efforts focus on establishing Class 0 and Class 2 sites at select locations distributed along the four cardinal directions around each island surveyed. For

"Class 2 sites" and above, thermal structure measurements are obtained based on the deployment of subsurface temperature recorders (STRs; SBE 56) along a perpendicular forereef transect at depths of 1, 5, 15, and 25 m; each SBE 56 records the near-reef water temperature at the same time, on a 5-min interval, for the duration of the instrument's deployment. Within this context, a permanent water-quality, temperature, and biological survey/sampling site, designated as *NCRMP Monitoring Station*, is established at the 15-m depth STR location, at select areas. In addition to the SBE 56 the NCRMP Monitoring Station includes: deployment of 3 ARMS units, 5 CAUs, and 5 BMUs; collection of 3 carbonate chemistry water samples (with associated CTD casts); acquisition of still photographic benthic imagery to document benthic cover and composition; and rugosity measurements of benthic topographic complexity.

A.1.1. Moored Instruments for Time-series Observations

CRED accomplishes long-term oceanographic assessment and monitoring through the deployment and retrieval of a variety of platforms, which either electronically record *in-situ* measurements (temperature, currents, and waves) or by facilitating biological recruitment/growth on fabricated structures. The following types of oceanographic instruments and biological installations were retrieved or deployed during this cruise.

Subsurface Temperature Recorder (STR): provides high-resolution temperature data (SBE 39 or SBE 56). Data are internally recorded at 5-min intervals. This type of subsurface instrument is deployed at depths of 0.5–40 m. All loggers retrieved were of the type SBE 39; all loggers deployed were of the type SBE 56.

Wave-and-tide Recorder (WTR): Provides high-resolution wave and tide records (SBE 26*plus* Seagauge recorder, accuracy of 0.01% in pressure). Data are internally recorded and sample intervals vary depending on duration of deployment. This type of subsurface instrument typically is deployed at depths of 10–25 m.

Calcification Accretion Unit (CAU): are used to detect changes in calcification rates and net accretion of crustose coralline algae and other benthic sessile calcifiers.

Bioerosion Monitoring Unit (BMU): provides proxy for an integrated signal of net reef bioerosion.

Autonomous Reef Monitoring Structure (ARMS): provides an assessment of cryptic taxonomic diversity of coral reef associated species.

A.1.2. Hydrographic Surveys

Detailed oceanographic and water-quality surveys were conducted using the following sampling techniques and equipment.

Shallow-water (Nearshore) Conductivity, Temperature, and Depth Casts: a CTD profiler deployed from a small boat provided water column data on temperature, conductivity (which is related to salinity) and pressure, which is related to depth (SBE 19*plus* SeaCAT Profiler). A transmissometer (C-Star, WET Labs, Philomath, Oregon)

provided profiles of beam transmittance, which is related to turbidity. A dissolved oxygen sensor (SBE 43, accuracy of 2% of saturation) also was attached and measurements were made in concert with CTD measurements. A CTD cast was performed at each location where a water sample was collected. The CTD is lowered by hand, off a small boat at descent rates of ~ 0.5–0.75 m s^{-1} to depths up to 30 m.

Deep-water (Shipboard) CTD Casts: a ship-based CTD profiler provided high-resolution conductivity, temperature, and pressure data (SBE 911*plus*CTD, accuracy of 0.003 S m-1 in conductivity, 0.001°C in temperature, and 0.015% in pressure). Measurements of dissolved oxygen (SBE 43) and fluorescence and turbidity (ECO FLNTU, WET Labs, accuracy of 0.01 μg l-1 in fluorescence and 0.01 NTU in turbidity) were performed in concert with CTD measurements. Data were collected at depths up to 300 m.

Shipboard Acoustic Doppler Current Profiler (ADCP): a ship-based sensor provided transects of directional ocean current data (75-kHz Ocean Surveyor, Teledyne RD Instruments Inc., Poway, California). The system was configured with an 8-m pulse length, 16-m depth bins starting at 25 m and extending typically to 600 m (range depended on density and abundance of scatterers), and 15-min averaged ensembles.

Water Chemistry: water samples for analyses of concentrations of chlorophyll-*a* (chl-*a*), dissolved inorganic carbon (DIC), and Total Alkalinity (TA), were collected at select locales concurrently with CTD casts.

A.2. Biological Monitoring: Benthic Surveys and Microbial Sampling

(Hatsue Bailey, Emma George, Matthew Dunlap, Brett Schumacher, Dione Swanson, and Bernardo Vargas-Ángel)

A two-stage stratified random sampling design was employed to survey the Rapid Ecological Assessment (REA) sites in the main Hawaiian Islands. The survey domain encompassed 99.6% of the mapped area of reef and hard bottom habitats and was divided into strata based on island, habitat structure type, and depth. The broad habitat structure types included simple, complex, and coral-rich. Depth categories of shallow (0–6 m), moderate (> 6–18 m) and deep (>18–30 m) were also incorporated into the stratification scheme. Allocation of sampling effort was proportional to strata area. Sites were randomly selected within each stratum.

A.2.1. Benthic composition and coral demographics

Surveys at each site were conducted within two 18 meter belt transects. Adult coral colonies (≥ 5 cm) were surveyed within four (1.0 × 2.5 m) segments in the following manner: 0–2.5 m (segment 1); 5.0–7.5 m (segment 3); 10–12.5 m (segment 5); and 15–17.5 m (segment 7). All colonies whose center fell within 0.5 m on either side of each transect line were identified to lowest taxonomic level possible (species or genus), measured for size (maximum diameter to nearest cm), and morphology was noted. In

addition, partial mortality and condition of each colony was assessed. Partial mortality was estimated as percent of the colony in terms of old dead and recent dead and the cause of recent mortality was identified if possible. The condition of each colony, including disease and bleaching, was noted along with the extent (percent of colony affected) and level of severity (range from moderate to acute).

Juvenile coral colonies (< 5 cm) were surveyed within three (1.0 × 1.0 m) segments along the same two transects: 0–1.0 m (segment 1); 5.0–6.0 m (segment 3); and 10.0–11.0 m (segment 5). Juvenile colonies were distinguished in the field by a distinct tissue and skeletal boundary (not a fragment of larger colony). Each juvenile colony was identified to lowest taxonomic level (genus or species) and measured for size by recording both the maximum and perpendicular diameter to the nearest 2 mm.

Still photographs were collected to record the benthos at predetermined points along the same 2 transect lines with a high-resolution digital camera mounted on a pole. Photographs were taken every 1 m, starting at the 1-m mark and ending at the 15-m mark. This work generates 30 photographs per site. Those benthic photos are later analyzed by CRED staff and partners with the computer program Coral Point Count with Excel extensions (CPCe) as the basis to estimate the benthic cover and composition at each site (benthic habitat photographs taken at sites surveyed by the fish team are also to be analyzed).

A.2.2. Microbial Communities

Microbes are a fundamental aspect of all marine ecosystems. Trophic-level interactions within the marine microbial food web can have a big effect on global nutrient and carbon cycling. Within a reef system, the amount of energy from primary production that is re-mineralized by the microbial fraction determines the amount of energy available for the entire food web. Shifts in the abundance and community composition of the microbial community in a reef system have also been linked to declines in coral health.

It is well known that bacteriophages (bacterial viruses) are the most abundant form of life in the ocean, ranging from 1×10^6 virus-like particles (VLPs) per mL of seawater in the open ocean to 1×10^8 VLPs per mL in more productive coastal waters. The number of microbial cells in seawater is typically 1×10^6 cells per mL. Microbial and viral loading and the dominance of heterotrophic bacteria in reef water are linked to coral disease. One of the most direct methods for assessing and monitoring changes in abundance of these microbiological components is by fluorescent microscopy using nucleic acid staining.

A direct parallel exists between microbial and viral loading, increasing human disturbance, and reef health. Microbial communities in more degraded coral reef systems support a high abundance of potential coral pathogens and heterotrophic microbes (a heterotrophic organism obtains food only from organic material, such as carbon and nitrogen, and is unable to use inorganic matter to form proteins and carbohydrates). In contrast, near-pristine reefs support microbial communities that are balanced between

heterotrophs and autotrophs and contain very few potential pathogens (an autotrophic organism can synthesize food from inorganic material).

Spatial assessment of microbial and viral components with respect to levels of dissolved organic carbon (DOC), nutrients (NO_2; NO_3; ammonium, NH_4; and PO_4^{3-}), and particulate organic carbon (POC) within coral reef ecosystems may identify important predictors of coral reef ecosystem degradation. For example, in addition to microbial abundance, bacterial growth efficiency (BGE) may also play a role in reef system health. BGE is affected greatly by DOC:Nitrogen (NO_x+NH_4) ratios in the water column. Water column stoichiometry (C:N:P ratios) directly affect microbial growth rates.

In summary, no long-term data on the dynamics of natural bacterial assemblages in reef systems (let alone other ecotypes) are currently available. Building a pan-Pacific microbial data set is an extremely important step towards greater understanding of the overall health of the reef system. The majority of reefs on the planet are affected and analyses are confounded by the inability to attribute differences in reef system dynamics to variation in resource availability caused by oceanography or human activity. The region monitored through Pacific RAMP includes reefs experiencing various combinations of human activity and resource availability. The hope is that new patterns in the microbial data sets will emerge at regional or pan-Pacific scales and that this information can be used to understand the mechanisms underlying reef system decline.

Collection of Microbial Water Samples: As part of the ongoing effort to understand the microbial community, two types of water samples were collected. The first type included two diver-deployable Niskin bottles that were used to collect water at each moderately deep REA site. The Niskin bottles (two 2-L replicates) were filled with "reef water" collected from < 1 m above the benthos. These water samples were returned to the ship and processed for DOC, particulate organic matter (POM), nutrients, microbial (bacteria and archaea) and viral counts (fluorescent microscopy), fluorescence-activated cell sorting (FACS, heterotrophs vs autotrophs), and microbial and viral community composition (coarse analysis: 16s rRNA).

The other type of water collection was for metagenomic analysis of the microbial and viral community associated with reef benthos. Only one sample per island was procured. This collection involved carboys (four 20-L replicates) that were also filled with "reef water" collected from < 1 m above the benthos. The samples were collected using a flexible, plastic hose with a carboy bottle attachment. The carboys were filled using a small, lightweight pump attached to the other end of the hose. All microbial collections were done at select REA sites (locations with supporting fish or benthic data).

The following data items were collected daily at each moderately deep REA site (for reef- and pore-water samples):

- DOC: 2 replicates
- POM: 2 replicates
- Nutrients: 2 replicates

- Microbial (bacteria and archaea) and viral abundance: 2 replicates (0.02-μm filters, stained using SYBR Gold, Molecular Probes Inc., Eugene, Oregon)
- Microbial (bacteria and archaea) size structure : 2 replicates (0.2-μm filters, stained using 4', 6-Diamidino-2-phenylindole (DAPI))
- Microbial community composition (FACS, heterotrophs/autotrophs): 6 replicates
- Microbial community composition (16s rRNA): 1 (0.22-μm filters)

The following data items were collected once per island at REA sites:

- Microbial community composition (metagenome): 1 sample, (3–6 filters of 0.45 μm)
- Viral community composition (metagenome): 1 sample, (3–6 vials)
- Coral rubble or sediment: 6 replicate bags

Processing of Water Samples: This section describes the techniques used to process the water samples.

Enumeration of microbes and viruses. Samples of 1-mL from each Niskin were fixed using paraformaldehyde and stained using the general nucleic acid stain SYBR Gold. The samples were filtered through 0.02-μm Anodisc filters and mounted on a microscope slide. Direct counts of microbes and VLPs will be completed using fluorescent microscopy and Image Pro software.

Microbial biomass. Samples of 1-mL from each Niskin were fixed using glutaraldehyde and filtered through 0.2-μm filters. These filters were stained with DAPI, a general nucleic acid stain for staining double-stranded DNA (dsDNA) that allows length and width data to be obtained for individual microbes. These filters were then mounted on a microscope slide for analysis using fluorescent microscopy and Image Pro software. Slide analysis will be performed at San Diego State University (SDSU). All filters were stored at – 20° C for archival purposes.

Enumeration of autotrophic vs. heterotrophic microbes. Flow cytometry will be used to assess the ratio of autotrophic to heterotrophic microbes in the water column. This technique also will provide complementary data for microbial abundance, microbial community structure, and levels of chl-*a*.

Six 1-mL samples of water from each REA site were pushed through a 20-μm filter. This filtrate was dispensed into cryovials (6 × 1 mL) and fixed with glutaraldehyde. Vials were inverted to mix. Glutaraldehyde-preserved samples were flash frozen in liquid nitrogen contained in a dry shipper to prevent damage to microbial cells. These samples will be shipped on dry ice to SDSU for flow cytometry analysis.

Water Chemistry (DOC/POC). 30 mL of seawater were filtered through a 47-mm pre-combusted glass fiber filters from each of the 2 Niskin bottles, and the filtrate was collected in pre-combusted plastic bottles. The bottles were stored at – 20°C. To assess POC, 500 mL of seawater were filtered through a 47-mm pre-combusted glass fiber filter

(2 replicates), and the filters were stored at – 20°C. Stable isotopes of carbon and nitrogen also will be analyzed from the filters via standard protocols at SDSU.

Collection of DNA for metagenomics. The community structure of the microbes and viruses associated with the water column was assessed by metagenomic analysis. Metagenomics is a powerful tool for studying environmental populations as < 1% of all environmental microbial diversity is currently cultivable. The steps for analysis of microbial community diversity and function involve collection of environmental DNA followed by 16S rRNA gene sequencing. Approximately 1.5–2 L of reef water was filtered through a 0.22-μm sterivex filter. DNA isolation and metagenomic analysis will be completed at SDSU.

At one REA site per island, four 20-L collapsible carboys of water were filled with water from reef crevices or reef benthos using a manual bilge pump. Upon return to the ship, this water sample was pre-filtered through 100-μm mesh and concentrated using tangential flow filtration (TFF). TFF concentrates the bacteria and viruses in the water, bringing the initial 70–80 L of water to a final volume of ~ 500 mL. This concentrate was then filtered through 0.45-μm filters to capture microbes (bacteria and archaea). These filters were frozen at – 20°C. The DNA of the entire community will be extracted and sequenced at SDSU, and the diversity and function of the microbial communities associated with the reef benthos will be analyzed. The filtrate from this sample contains concentrated viruses. Chloroform was added to this filtrate to kill any small microbes that passed through the 0.45-μm filter, and the sample was stored at 4°C. Once shipped to SDSU, viruses will be isolated from the viral concentrate, and community DNA will be extracted and sequenced. This extracted and sequenced DNA will then be analyzed for viral community diversity and function.

Collection of Benthic Samples (if time permits): This section describes samples, or benthic grabs, collected if time permitted.

Collection of benthic microbial DNA. In addition to changes in the microbial community associated with the water column, we are also interested in whether or not community shifts in microbes associated with the benthos are a useful indicator of reef health. When time permits, six "fistfuls" of coral rubble or sediment and six pieces of the most dominant algal-type will be collected in Ziploc bags. Both the algal and rubble/sediment samples were frozen at – 20°C. These samples stayed on the ship until it returned to Honolulu. The bacterial 16s rRNA genes associated with these samples will be sequenced to characterize the microbial communities associated with the benthos (rubble and algae).

A.3. Biological Monitoring: Surveys of Reef Fishes

(Jacob Asher, Paula Ayotte, Andrew Gray, Adel Heenan, Kevin Lino, Mark Manuel, Kaylyn McCoy, Marc Nadon, Ivor Williams, Jill Zamzow)

Divers conducted REA fish surveys using the stationary-point-count (SPC) method at preselected REA sites. Two separate teams performed these surveys. Each team consisted

of 2 divers, and conducted 1 SPC survey per site. All fish REA sites visited were selected using a stratified random sampling design in shallow (0–6 m), moderate (6–18 m), or deep (18–30 m) depth strata, in forereef, backreef, and lagoon habitat strata, when applicable. Surveys were performed using a 30-m transect line set along a single depth contour. The REA sites selected for fish surveys typically differ in location from the REA sites where benthic surveys were conducted.

Once a transect line was deployed, the 2 divers moved to the 7.5-m and 22.5-m marks on this transect line to start their SPC surveys. Each of these marks or points, with 1 diver at each, served as the center of a visually estimated cylindrical survey area with a radius of 7.5 m. During the first 5 min, divers only recorded the presence of species within their respective cylinders. Afterwards, divers went down their respective species lists, which were created from their work during the initial 5 min of a survey, sizing and counting all individuals within their cylinder, one species at a time. Cryptic species missed during the initial 5 min of a survey could still be counted, sized, and added to the original species list. Fish species observed at a REA site but not recorded during the SPCs were recorded for presence data.

After a survey was completed, divers recorded benthic habitat information within their respective cylindrical survey areas. Divers visually estimated habitat complexity, habitat type, and percentage of cover for hard corals, macroalgae, crustose coralline red algae, turf algae, and sand. Urchin densities were also estimated. Every meter along the transect line, still photographs were taken of the benthos to the right side of the line. Like the photographs taken along transect lines during surveys at REA benthic sites, these images will be analyzed later.

APPENDIX B: TUTUILA ISLAND AND SOUTH BANK

APPENDIX B: HAWAI`I ISLAND

The island of Hawai`i, also known as the Big Island, is located at 19.60° N, 155.50° W in the north Pacific and is the largest island of the main Hawaiian Island chain. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: Methods.

B.1. Climate and Ocean Acidification Monitoring: Instrumentation, Biological Installations, and Water Quality

Oceanographic operations during the cruise HA-13-04 at Hawai`i Island entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), autonomous reef monitoring structures (ARMS), bioerosion monitoring units (BMU), nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select *NCRMP* sites, and shipboard water sampling and CTD casts offshore to a depth of 300 m, and acoustic Doppler current profiler (ADCP) transects.

Twenty-nine shallow-water CTD casts were performed at each location where water samples were collected, this included sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Thirty-three shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 6 STRs were retrieved and 9 STRs were deployed. Six ARMS were recovered and processed for taxonomic analysis and 12 ARMS were deployed. Fifty CAUs were deployed at 10 locations around the island and 25 BMUs were collocated at the CAU sites which were directly a part of the NCRMP monitoring stations. Two environmental acoustic recorder (EAR) moorings were also retrieved (Fig. B.1.1and Table B.1.1).

From the NOAA Ship *Hi`ialakai*, ~ 74.3 km of ADCP transect lines were run in the 4 cardinal directions (N, S, E, W) away from this island during night operations. On the reciprocal course, shipboard CTD casts were conducted to a depth of 300 m per transect line every 2 km for a total of 25 deep-water CTD casts. Water samples were collected concurrently at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. Near Hawai`i Island, 115 chl-*a* shipboard water samples were collected. Additionally, 3 CTD cast were conducted for a collaborative project with PIFSC's Ecosystems and Oceanography Division to a depth of 1200 m (Fig. B.1.2).

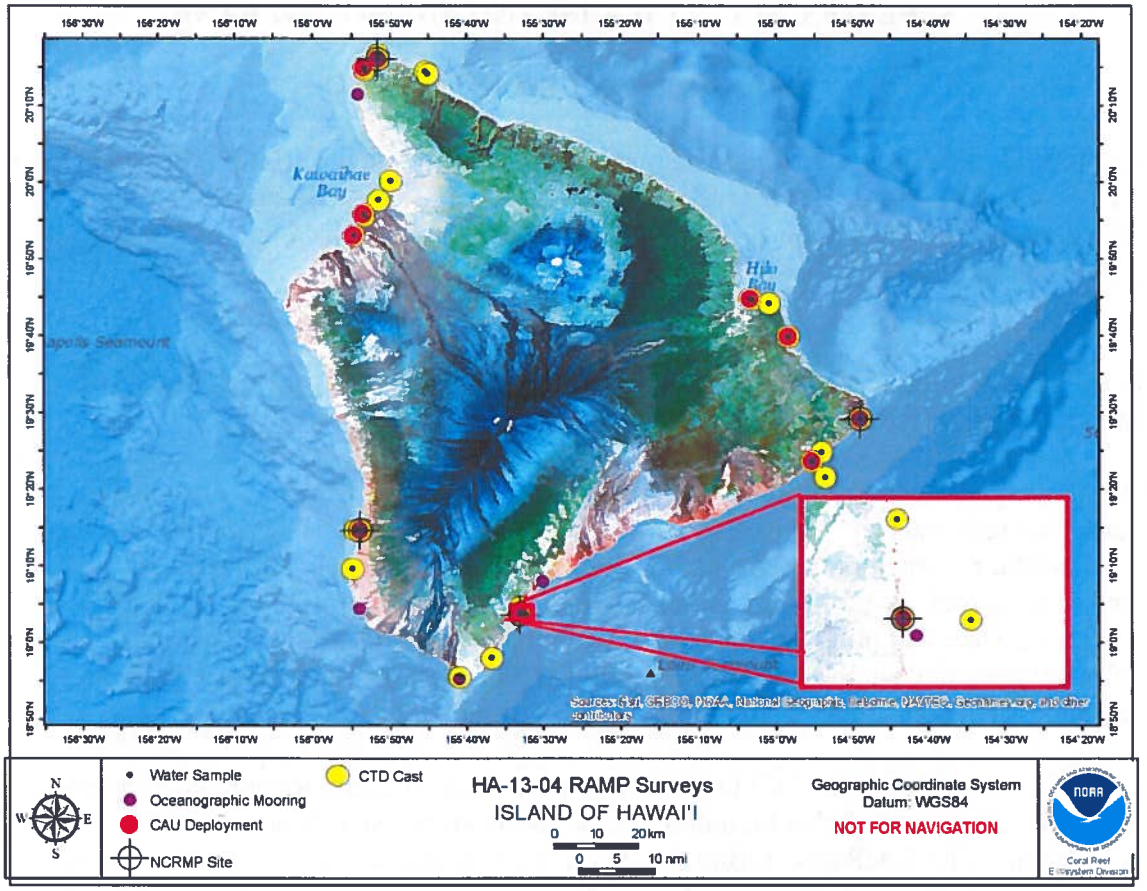

Figure B.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of nearshore CTD casts and water sampling performed at Hawai`i Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table B.1.1.-- Geographic coordinates and depths of the moored oceanographic instruments (STR and EAR) and biological installations (CAU, ARMS, and BMUs), that were retrieved or deployed at Hawai`i Island during cruise HA-13-04.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
HAW_007	3-Aug	STR	20.26828	−155.8604	14.0	–	1
HAW_008	3-Aug	STR	20.27025	−155.86103	25.3	–	1
HAW-41	3-Aug	ARMS	20.26828	−155.8604	13.1	–	3
HAW-41	3-Aug	BMU	20.26828	−155.8604	13.1	–	5
HAW-41	3-Aug	CAU	20.26828	−155.8604	13.1	–	5
HAW-42	3-Aug	BMU	20.24913	−155.89095	13.4	–	5
HAW-42	3-Aug	CAU	20.24913	−155.89095	13.4	–	5
HAW_006	4-Aug	EAR	19.07380	−155.90163	17.1	1	–
HAW_006	4-Aug	STR	19.07380	−155.90163	17.1	1	–
HAW_009	4-Aug	STR	19.24432	−155.90024	14.6	–	1
HAW_010	4-Aug	STR	19.24421	−155.90043	23.8	–	1
HAW_011	4-Aug	STR	19.24447	−155.89971	4.6	–	1
HAW-24	4-Aug	ARMS	19.03822	−155.88255	14.0	3	–
HAW-43	4-Aug	ARMS	19.24432	−155.90024	14.6	–	3
HAW-43	4-Aug	BMU	19.24432	−155.90024	14.6	–	5
HAW-43	4-Aug	CAU	19.24432	−155.90024	14.6	–	5
HAW-44	5-Aug	CAU	19.74696	−155.05803	12.8	–	5
HAW-45	5-Aug	CAU	19.66471	−154.97473	13.1	–	5
HAW_002	6-Aug	STR	19.48639	−154.81761	12.2	1	1
HAW_005	6-Aug	EAR	19.39415	−154.92422	17.1	1	–
HAW_005	6-Aug	STR	19.39415	−154.92422	17.1	1	–
HAW_012	6-Aug	STR	19.48623	−154.81678	24.1	–	1
HAW-46	6-Aug	ARMS	19.48642	−154.8176	12.2	–	3
HAW-46	6-Aug	BMU	19.48642	−154.8176	12.2	–	5
HAW-46	6-Aug	CAU	19.48642	−154.8176	12.2	–	5
HAW-47	6-Aug	CAU	19.39416	−154.92445	13.7	–	5
HAW_003	7-Aug	STR	18.92254	−155.68432	14.0	1	–
HAW_004	7-Aug	STR	19.13291	−155.50222	14.3	1	–
HAW_013	7-Aug	STR	19.06075	−155.55231	13.7	–	1
HAW_014	7-Aug	STR	19.05797	−155.55019	25.0	–	1
HAW-22	7-Aug	ARMS	18.96860	−155.73073	15.2	3	–
HAW_001	8-Aug	STR	20.19143	−155.90369	10.1	1	–
HAW-48	8-Aug	BMU	19.06075	−155.55231	13.7	–	5
HAW-48	8-Aug	ARMS	19.06075	−155.55231	13.7	–	3
HAW-48	8-Aug	CAU	19.06075	−155.55231	13.7	–	5
HAW-49	8-Aug	CAU	19.93093	−155.89203	14.9	–	5
HAW-731	8-Aug	CAU	19.88457	−155.91391	14.0	–	5

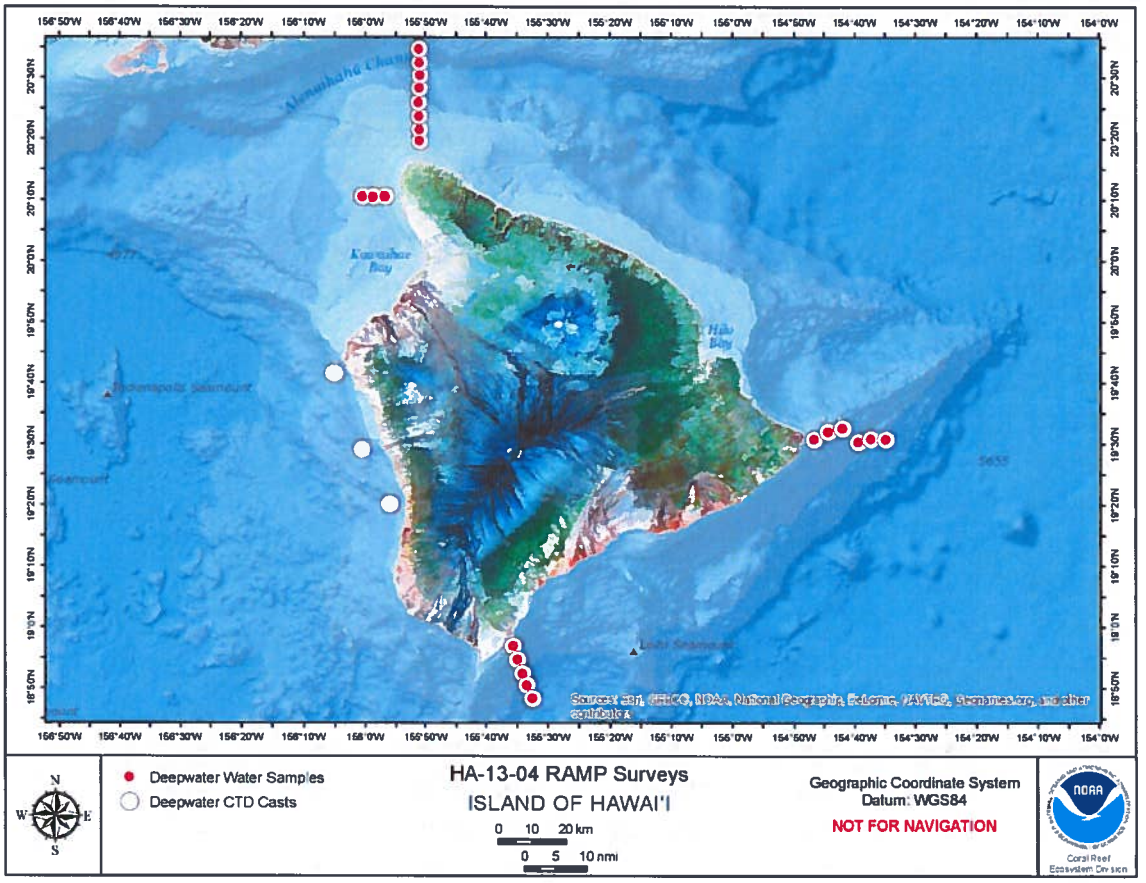

Figure B.1.2.--Locations of deep-water CTD casts and water sampling performed at Hawai`i Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

B.2. Biological Monitoring: Benthic Surveys and Microbial Sampling

Rapid Ecological Assessment (REA) benthic sampling utilized a two-stage stratified random sampling design that incorporated both broad categories of reef structure and depth to define habitat strata. Belt-transect surveys were conducted and photographs were taken along transect lines at 24 REA sites around Hawai`i Island to assess benthic composition, coral community structure, and coral and algal disease; water samples for microbial analyses were collected at 14 REA sites (Fig. B.2.1 and Table B.2.1). For more information about collections made at REA sites, see Table I.1.1 in Appendix I: Biological Collections.

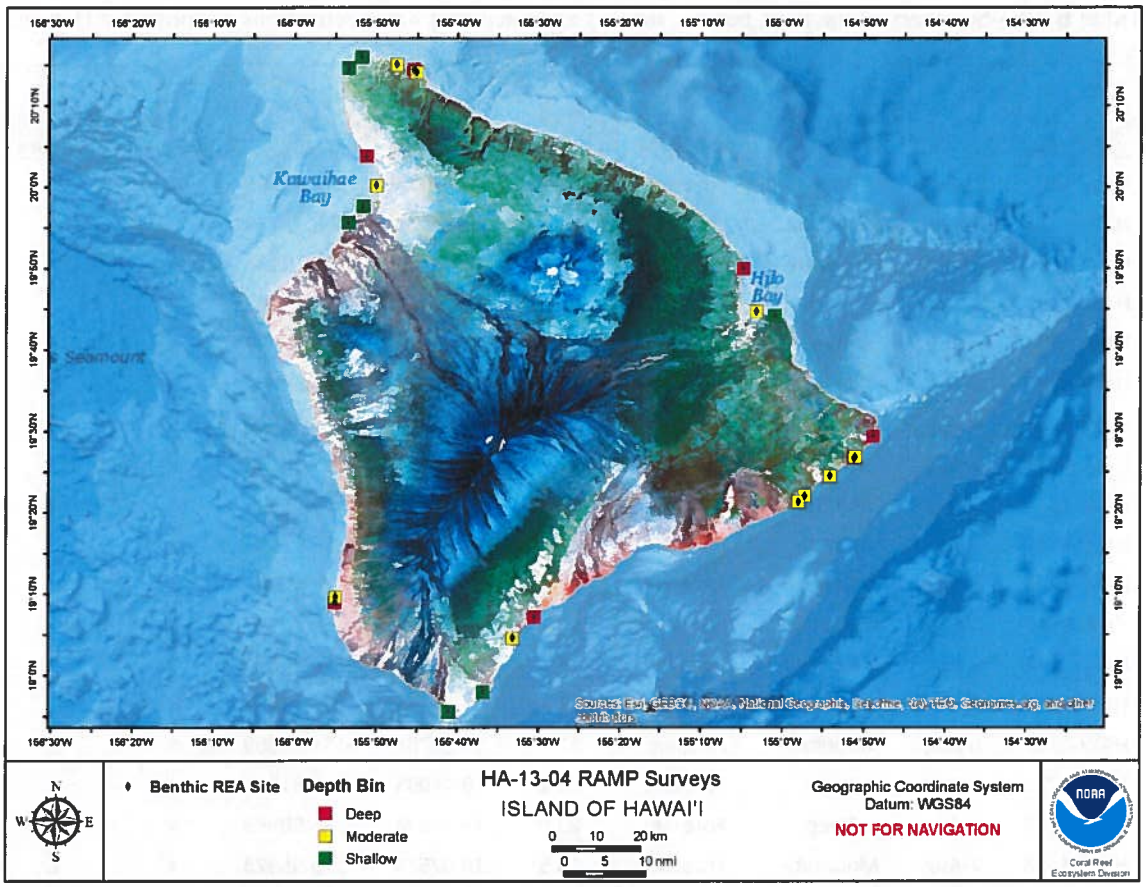

Figure B.2.1.--Locations of REA benthic and CAU sites surveyed at Hawai`i Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table B.2.1.--Summary of the REA benthic surveys and microbial water collections performed at Hawai`i Island during cruise HA-13-04.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude	REA Coral Survey	Microbial Samples
HAW-1402	3-Aug	Deep	Forereef	22.1	20.2405	−155.75785	x	
HAW-1411	3-Aug	Moderate	Forereef	12.7	20.23514	−155.75179	x	2
HAW-1448	3-Aug	Moderate	Forereef	13.6	20.25086	−155.79184	x	
HAW-1468	3-Aug	Shallow	Forereef	6.4	20.24428	−155.89005	x	
HAW-1476	3-Aug	Shallow	Forereef	6.1	20.26738	−155.86297	x	
HAW-1487	4-Aug	Deep	Forereef	23.3	19.14996	−155.9173	x	
HAW-1566	4-Aug	Moderate	Forereef	13.3	19.16066	−155.91548	x	2
HAW-1631	5-Aug	Deep	Forereef	24.2	19.83253	−155.08038	x	
HAW-1643	5-Aug	Moderate	Forereef	13.3	19.74482	−155.05386	x	2
HAW-1748	5-Aug	Shallow	Forereef	6.7	19.73666	−155.01568	x	
HAW-1625	6-Aug	Deep	Forereef	23.6	19.4442	−154.8548	x	
HAW-1648	6-Aug	Moderate	Forereef	15.2	19.40823	−154.90147	x	2
HAW-1743	6-Aug	Moderate	Forereef	15.2	19.3557	−154.96618	x	2
HAW-1750	6-Aug	Moderate	Forereef	13.0	19.44598	−154.85287	x	
HAW-1757	6-Aug	Moderate	Forereef	17.3	19.36768	−154.95369	x	
HAW-1759	6-Aug	Deep	Forereef	21.2	19.49005	−154.81417	x	
HAW-1677	7-Aug	Deep	Forereef	23.0	19.11874	−155.50833	x	
HAW-1693	7-Aug	Moderate	Forereef	14.5	19.07674	−155.55323	x	2
HAW-1733	7-Aug	Shallow	Forereef	6.1	18.96681	−155.61356	x	
HAW-1766	7-Aug	Shallow	Forereef	8.2	18.92599	−155.68288	x	
HAW-1488	8-Aug	Deep	Forereef	20.3	20.06308	−155.85329	x	
HAW-1540	8-Aug	Moderate	Forereef	15.5	20.00324	−155.83318	x	2
HAW-1540	8-Aug	Moderate	Forereef	15.8	20.00324	−155.83318	x	1
HAW-1579	8-Aug	Shallow	Forereef	5.2	19.96097	−155.85952	x	
HAW-1619	8-Aug	Shallow	Forereef	5.2	19.92726	−155.88949	x	

B.3. Biological Monitoring: Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 58 REA sites at Hawai`i Island over three different habitat strata: deep, moderate, and shallow forereef (Fig. B.3.1 and Table B.3.1). No fishes were collected during these surveys.

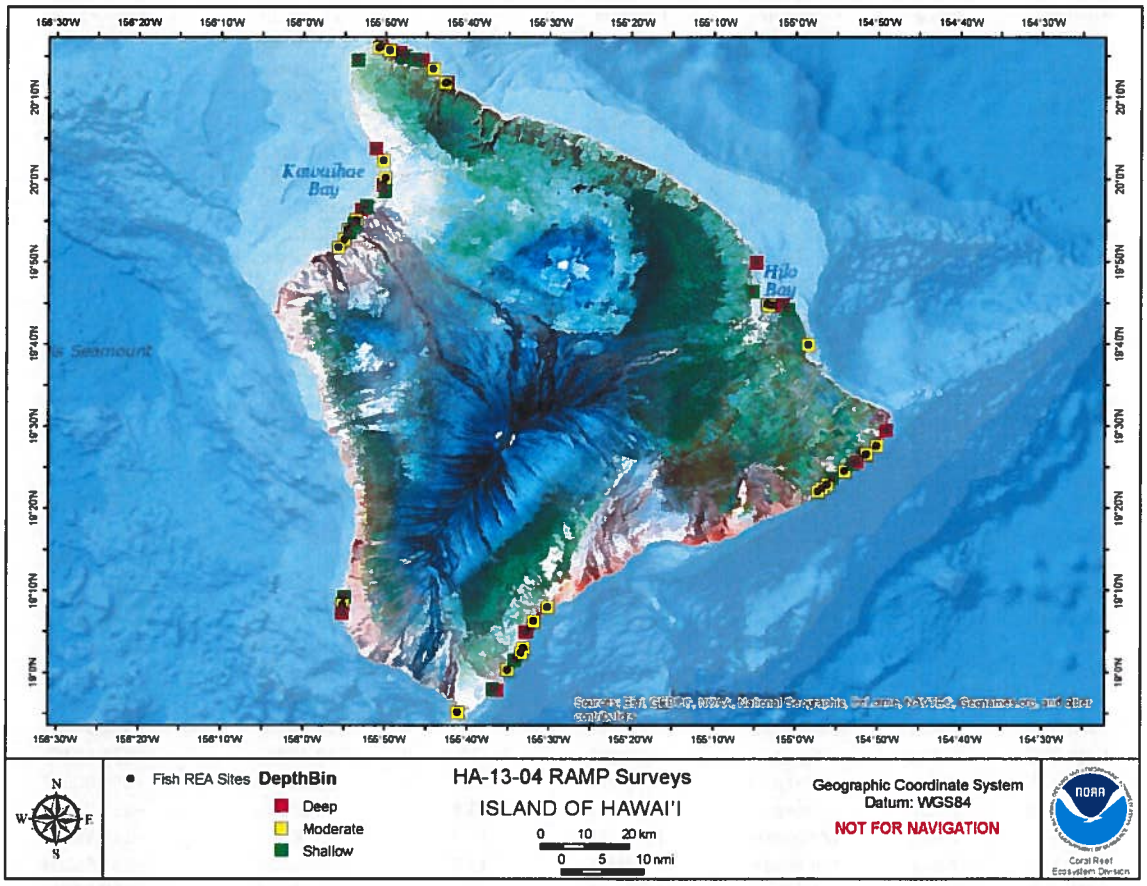

Figure B.3.1.--Locations of REA fish sites surveyed at Hawai`i Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table B.3.1.--Summary of sites where REA fish surveys were conducted at Hawai`i Island during cruise HA-13-04.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
HAW-395	3-Aug	Deep	Forereef	26	20.25749	−155.80384
HAW-397	3-Aug	Deep	Forereef	22.6	20.19750	−155.70913
HAW-398	3-Aug	Deep	Forereef	24.5	20.27030	−155.84219
HAW-402	3-Aug	Deep	Forereef	28.5	20.24327	−155.75887
HAW-407	3-Aug	Moderate	Forereef	15.2	20.26760	−155.84732
HAW-416	3-Aug	Moderate	Forereef	10.3	20.22456	−155.73706
HAW-431	3-Aug	Moderate	Forereef	12	20.19613	−155.71175
HAW-433	3-Aug	Moderate	Forereef	13.6	20.26169	−155.8247
HAW-448	3-Aug	Moderate	Forereef	13.3	20.25060	−155.79246
HAW-460	3-Aug	Shallow	Forereef	5.8	20.24362	−155.8899
HAW-468	3-Aug	Shallow	Forereef	5.5	20.24934	−155.79703
HAW-469	3-Aug	Shallow	Forereef	5.2	20.24433	−155.77398
HAW-487	4-Aug	Shallow	Forereef	5.5	19.15302	−155.91551
HAW-506	4-Aug	Moderate	Forereef	18	19.13675	−155.91902
HAW-765	4-Aug	Deep	Forereef	27.3	19.12053	−155.92019
HAW-629	5-Aug	Deep	Forereef	23.3	19.74557	−155.02553
HAW-631	5-Aug	Deep	Forereef	23.6	19.83253	−155.08038
HAW-632	5-Aug	Deep	Forereef	22.7	19.74419	−155.0468
HAW-640	5-Aug	Moderate	Forereef	11.2	19.74691	−155.05798
HAW-643	5-Aug	Moderate	Forereef	11.3	19.74482	−155.05386
HAW-649	5-Aug	Moderate	Forereef	12.7	19.66451	−154.97485
HAW-664	5-Aug	Shallow	Forereef	5	19.77316	−155.08776
HAW-748	5-Aug	Shallow	Forereef	3.3	19.73666	−155.01568
HAW-625	6-Aug	Deep	Forereef	21.8	19.44146	−154.8574
HAW-642	6-Aug	Moderate	Forereef	14.6	19.46009	−154.8348
HAW-648	6-Aug	Moderate	Forereef	11.8	19.40857	−154.90093
HAW-662	6-Aug	Shallow	Forereef	6.1	19.39416	−154.92583
HAW-663	6-Aug	Shallow	Forereef	5.5	19.42318	−154.88391
HAW-750	6-Aug	Moderate	Forereef	14.8	19.44336	−154.85563
HAW-751	6-Aug	Deep	Forereef	23	19.42718	−154.87537
HAW-754	6-Aug	Moderate	Forereef	14.5	19.38145	−154.93578
HAW-755	6-Aug	Moderate	Forereef	12.1	19.37340	−154.9464
HAW-757	6-Aug	Moderate	Forereef	12	19.36724	−154.95484
HAW-759	6-Aug	Deep	Forereef	23	19.49032	−154.81463
HAW-675	7-Aug	Deep	Forereef	23.8	18.96360	−155.60637
HAW-679	7-Aug	Deep	Forereef	23.8	19.08246	−155.54523
HAW-687	7-Aug	Moderate	Forereef	15.2	19.00462	−155.58382
HAW-697	7-Aug	Moderate	Forereef	13.6	19.04886	−155.55204
HAW-700	7-Aug	Deep	Forereef	23	19.08268	−155.54811
HAW-705	7-Aug	Moderate	Forereef	13	19.13277	−155.5024
HAW-719	7-Aug	Moderate	Forereef	10	19.10353	−155.53123
HAW-721	7-Aug	Shallow	Forereef	6	19.02497	−155.56913
HAW-732	7-Aug	Moderate	Forereef	11.2	18.91923	−155.68496
HAW-733	7-Aug	Shallow	Forereef	4.3	18.96727	−155.61379
HAW-735	7-Aug	Moderate	Forereef	13.3	19.03912	−155.55667
HAW-486	8-Aug	Deep	Forereef	19.7	19.98997	−155.83813
HAW-488	8-Aug	Deep	Forereef	23	20.06300	−155.85326
HAW-492	8-Aug	Deep	Forereef	19	19.93910	−155.88289
HAW-526	8-Aug	Moderate	Forereef	7.6	19.89859	−155.90916
HAW-532	8-Aug	Moderate	Forereef	9.4	20.03786	−155.83679
HAW-535	8-Aug	Moderate	Forereef	8.8	19.87847	−155.91609
HAW-540	8-Aug	Moderate	Forereef	15.8	20.00345	−155.8333
HAW-549	8-Aug	Moderate	Forereef	6.9	19.91792	−155.89317
HAW-582	8-Aug	Shallow	Forereef	4.3	19.97724	−155.83395
HAW-583	8-Aug	Shallow	Forereef	2.4	19.91123	−155.89698
HAW-591	8-Aug	Shallow	Forereef	1.7	19.94641	−155.87149
HAW-617	8-Aug	Shallow	Forereef	5.2	19.89316	−155.90632
HAW-623	8-Aug	Moderate	Forereef	13	19.86210	−155.92813

APPENDIX C: KAUA`I ISLAND

The island of Kaua`i is located at 22.09° N, 159.53° W in the north Pacific and is part of the main Hawaiian Island chain. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: Methods.

C.1. Climate and Ocean Acidification Monitoring: Instrumentation, Biological Installations, and Water Quality

Oceanographic operations during the cruise HA-13-04 at Kaua`i Island entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), autonomous reef monitoring structures (ARMS), bioerosion monitoring units (BMU), nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select National Coral Reef Monitoring Plan (NCRMP) sites, and shipboard water sampling and CTD casts offshore to a depth of 300 m, and acoustic Doppler current profiler (ADCP) transects.

At nearshore locations around Kaua`i Island, 8 shallow-water CTD casts were performed at each location where water samples were collected, this includes sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Ten shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 2 STRs were retrieved and 8 STRs were deployed. Six ARMS were recovered and processed for taxonomic analysis; none deployed. Ten CAUs were deployed at 2 locations around the island. One environmental acoustic recorder (EAR) mooring was retrieved (Fig. C.1.1 Table C.1.1).

From the NOAA Ship *Hi`ialakai*, ~ 28 km of ADCP transect lines were run in the 4 cardinal directions (N, S, E, W) away from this island during night operations. On the reciprocal course, shipboard CTD casts were conducted to a depth of 300 m per transect line every 2 km for a total of 9 deep-water CTD casts. Water samples were collected concurrently at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. Near Kaua`i Island, 45 chl-*a* shipboard water samples were collected (Fig. C.1.2).

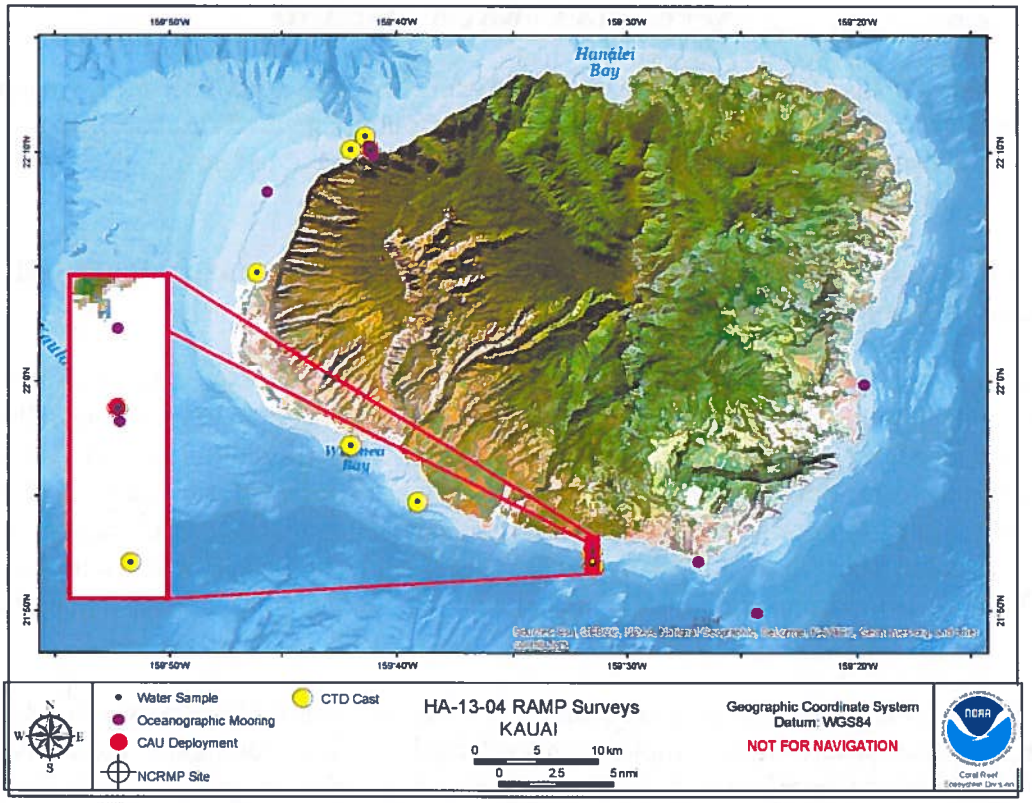

Figure C.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of nearshore CTD casts and water sampling performed at Kaua`i Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table C.1.1.-- Geographic coordinates and depths of the moored oceanographic instruments (STR and EAR) and biological installations(CAU, ARMS, and BMUs), that were retrieved or deployed at Kaua`i Island during cruise HA-13-04.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
KAU-008	13-Aug	STR	21.99793	−159.32823	24.7	–	1
KAU-009	13-Aug	STR	21.83206	−159.40542	14.6	–	1
KAU-02	13-Aug	ARMS	22.16408	−159.29892	13.0	2	–
KAU-007	15-Aug	EAR	22.13804	−159.76127	17.7	1	–
KAU-007	15-Aug	STR	22.13804	−159.76127	17.7	1	–
KAU-010	15-Aug	STR	22.16841	−159.68567	14.9	–	1
KAU-011	15-Aug	STR	22.17149	−159.68708	25.6	–	1
KAU-012	15-Aug	STR	22.16451	−159.68329	5.2	–	1
KAU-08	15-Aug	ARMS	22.16687	−159.68022	13.0	2	–
KAU-21	15-Aug	CAU	22.16841	−159.68567	14.9	–	5
KAU-002	17-Aug	STR	21.86887	−159.44755	6.1	1	–
KAU-013	17-Aug	STR	21.87665	−159.52551	14.3	–	1
KAU-014	17-Aug	STR	21.87570	−159.52536	25.6	–	1
KAU-015	17-Aug	STR	21.88225	−159.52549	5.2	–	1
KAU-06	17-Aug	ARMS	21.88967	−159.60902	12.0	2	–
KAU-22	17-Aug	CAU	21.87665	−159.52551	14.3	–	5

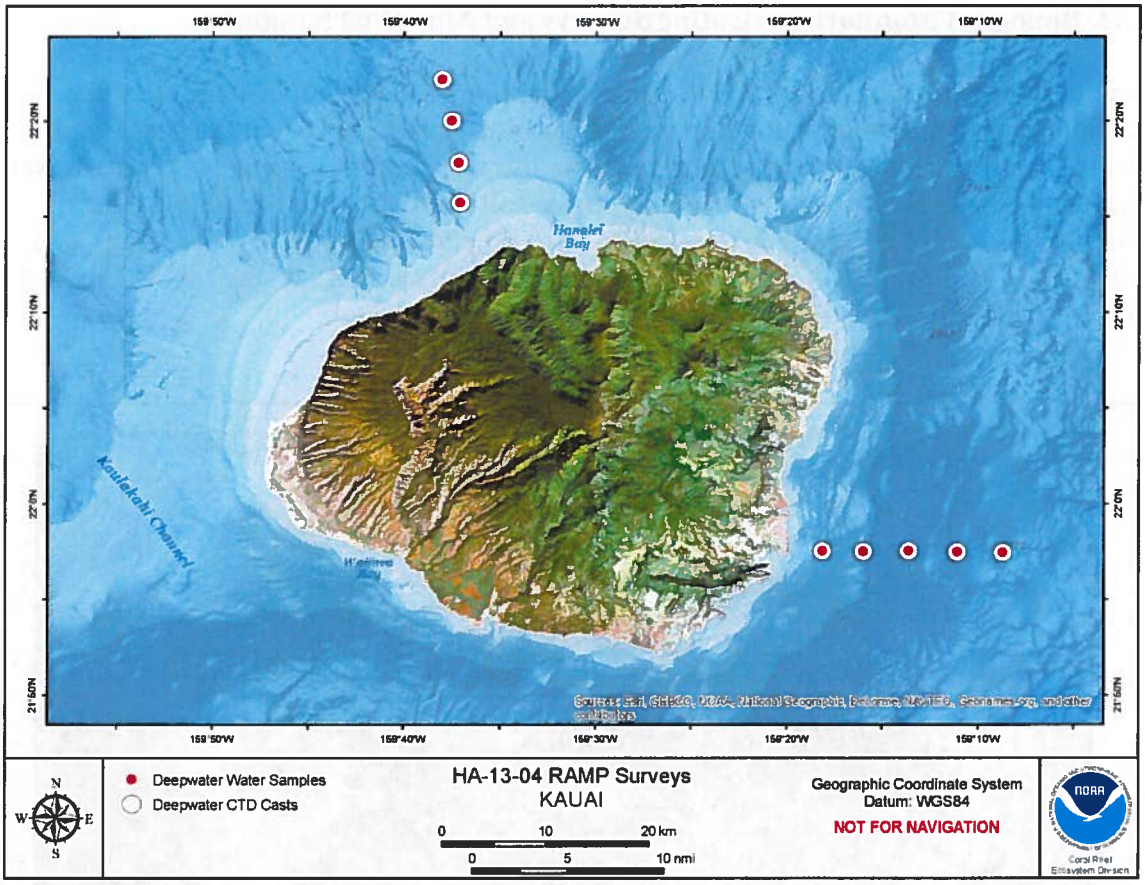

Figure C.1.2.--Locations of deep-water CTD casts and water sampling performed at Kaua`i Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

C.2. Biological Monitoring: Benthic Surveys and Microbial Sampling

Rapid Ecological Assessment (REA) benthic sampling utilized a two-stage stratified random sampling design that incorporated both broad categories of reef structure and depth to define habitat strata. Belt-transect surveys were conducted and photographs were taken along transect lines at 14 randomly located sites on Kaua`i Island. Six water samples for microbial analyses were collected at 3 benthic REA survey sites (Fig C.2.1; Table C.2.1). For more information about collections made at REA sites, see Table I.1.1 in Appendix I: Biological Collections.

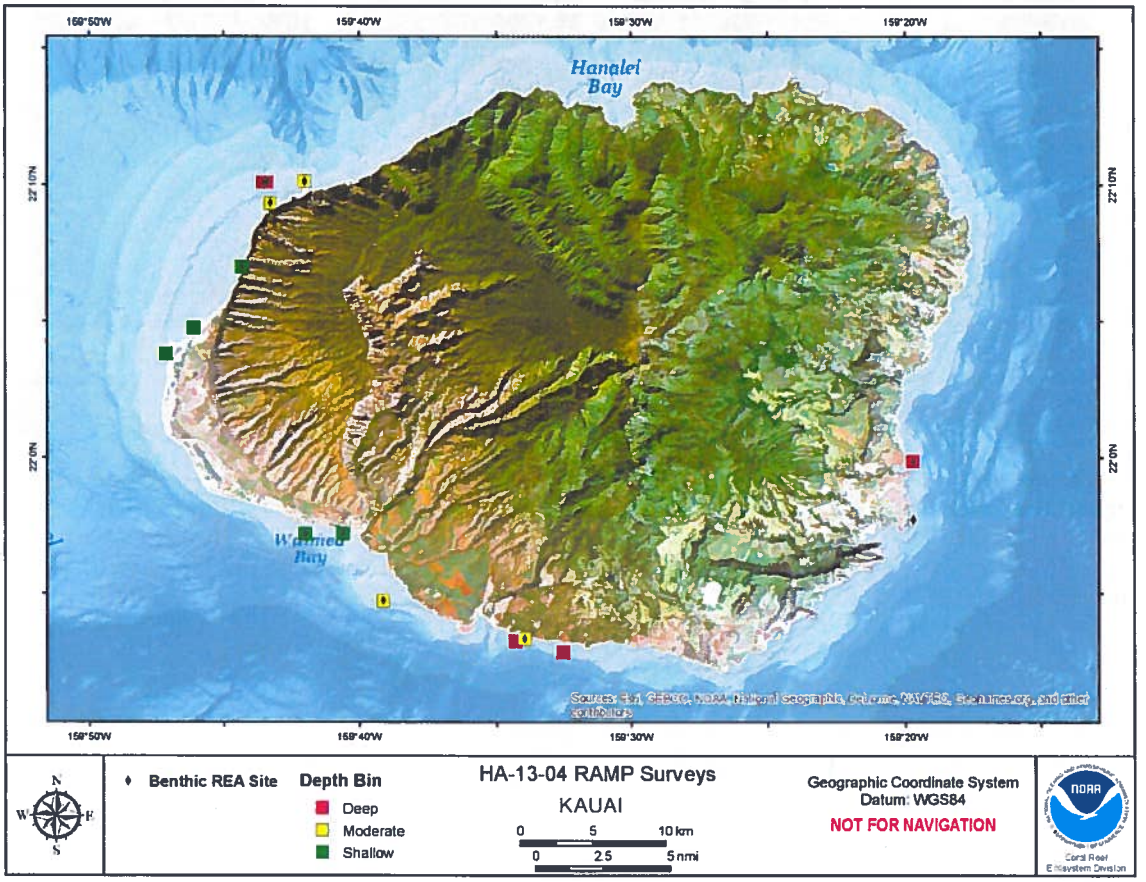

Figure C.2.1.--Locations of REA benthic sites surveyed at Kaua`i Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table C.2.1.--Summary of REA benthic surveys and microbial water collections performed at Kaua`i Island during cruise HA-13-04.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude	REA Coral Survey	Microbial Samples
KAU-1231	13-Aug	Deep	Forereef	18.2	21.99781	−159.32869	x	
KAU-1246	13-Aug	Moderate	Forereef	13.6	21.96207	−159.32846		2
KAU-1312	15-Aug	Deep	Forereef	24.8	22.16807	−159.72578	x	
KAU-1339	15-Aug	Shallow	Forereef	3.9	22.11616	−159.73879	x	
KAU-1340	15-Aug	Deep	Forereef	21.2	22.16817	−159.72261	x	
KAU-1352	15-Aug	Shallow	Forereef	4.8	22.06375	−159.78543	x	
KAU-1361	15-Aug	Moderate	Forereef	12.7	22.15537	−159.72099	x	
KAU-1363	15-Aug	Moderate	Forereef	12.7	22.16861	−159.70004	x	2
KAU-1366	15-Aug	Shallow	Forereef	3.9	22.07906	−159.76887	x	
KAU-1217	17-Aug	Deep	Forereef	23.6	21.88729	−159.57158	x	
KAU-1238	17-Aug	Deep	Forereef	22.4	21.88105	−159.54254	x	
KAU-1252	17-Aug	Moderate	Forereef	14.2	21.88927	−159.56625	x	
KAU-1263	17-Aug	Moderate	Forereef	16.4	21.91232	−159.65221	x	3
KAU-1291	17-Aug	Shallow	Forereef	5.8	21.9533	−159.69987	x	
KAU-1293	17-Aug	Shallow	Forereef	3.0	21.9534	−159.67645	x	

C.3. Biological Monitoring: Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 37 REA sites at Kaua`i Island over three different habitat strata: deep, moderate, and shallow forereef (Fig. C.3.1 and Table C.3.1). No fishes were collected during these surveys.

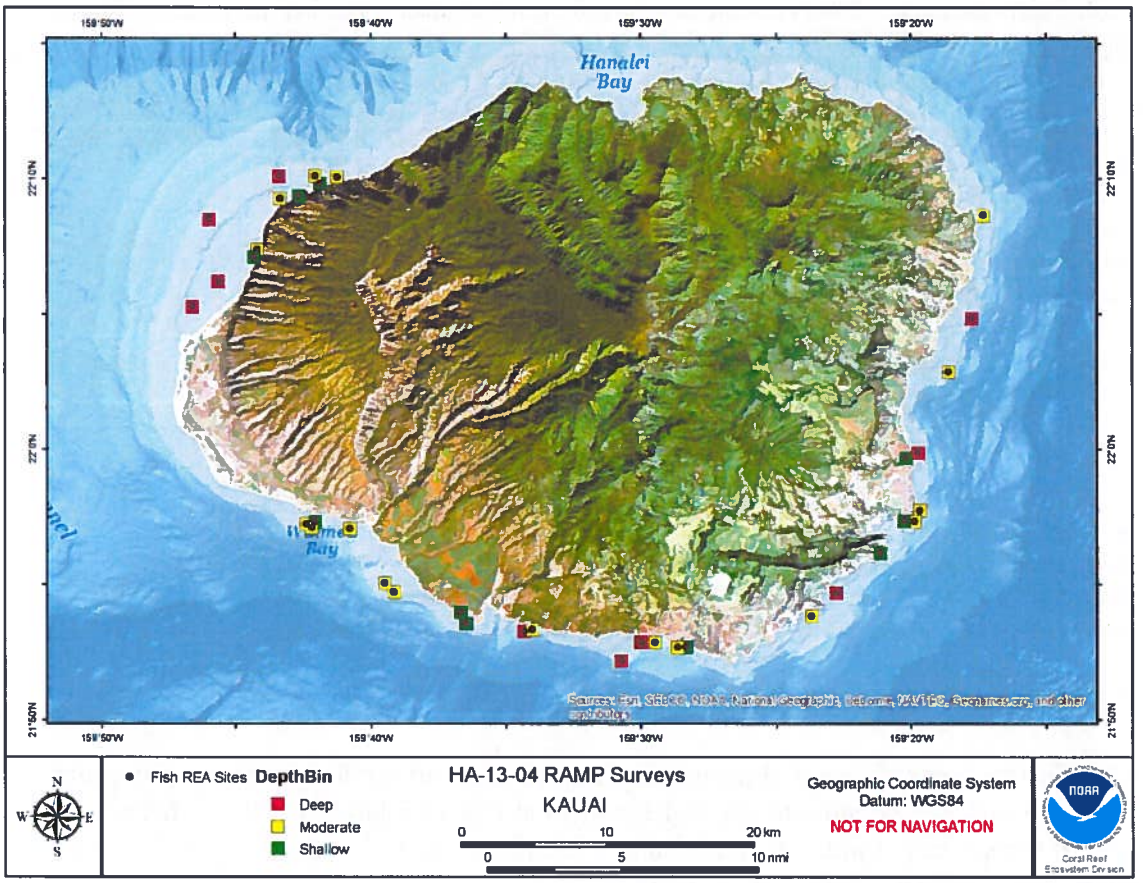

Figure C.3.1.--Locations of REA fish sites surveyed at Kaua`i Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table C.3.1.--Summary of sites where REA fish surveys were conducted at Kaua`i Island during cruise HA-13-04.

REA-Site	Date	DepthBin	Reef-Zone	Depth-(m)	Latitude	Longitude
KAU-227	13-Aug	Deep	Forereef	18.8	21.91130	−159.37993
KAU-228	13-Aug	Deep	Forereef	19.7	22.08074	−159.29588
KAU-231	13-Aug	Deep	Forereef	20.0	21.99785	−159.32879
KAU-246	13-Aug	Moderate	Forereef	11.5	21.96228	−159.32777
KAU-248	13-Aug	Moderate	Forereef	16.7	22.04769	−159.31018
KAU-253	13-Aug	Moderate	Forereef	14.2	22.14425	−159.28875
KAU-262	13-Aug	Moderate	Forereef	15.5	21.95563	−159.33087
KAU-276	13-Aug	Shallow	Forereef	4.0	21.95617	−159.33746
KAU-286	13-Aug	Moderate	Forereef	16.1	21.89740	−159.39515
KAU-294	13-Aug	Shallow	Forereef	5.5	21.93601	−159.35266
KAU-298	13-Aug	Shallow	Forereef	5.2	21.99459	−159.33639
KAU-320	15-Aug	Deep	Forereef	24.0	22.10336	−159.76027
KAU-330	15-Aug	Deep	Forereef	26.0	22.14170	−159.76622
KAU-333	15-Aug	Deep	Forereef	20.0	22.08782	−159.77669
KAU-341	15-Aug	Deep	Forereef	21.5	22.16819	−159.72291
KAU-346	15-Aug	Shallow	Forereef	3.1	22.16369	−159.69747
KAU-347	15-Aug	Moderate	Forereef	7.5	22.12306	−159.73647
KAU-348	15-Aug	Shallow	Forereef	3.3	22.15611	−159.71093
KAU-352	15-Aug	Shallow	Forereef	3.0	22.11830	−159.73855
KAU-357	15-Aug	Moderate	Forereef	13.0	22.16778	−159.68681
KAU-361	15-Aug	Moderate	Forereef	10.0	22.15461	−159.72221
KAU-363	15-Aug	Moderate	Forereef	14.5	22.16839	−159.70054
KAU-217	17-Aug	Deep	Forereef	19.0	21.88800	−159.57213
KAU-223	17-Aug	Deep	Forereef	29.4	21.86981	−159.51187
KAU-226	17-Aug	Deep	Forereef	20.0	21.88107	−159.49982
KAU-251	17-Aug	Moderate	Forereef	6.8	21.95108	−159.67921
KAU-252	17-Aug	Moderate	Forereef	14.0	21.88916	−159.56745
KAU-263	17-Aug	Moderate	Forereef	16.3	21.91213	−159.65217
KAU-266	17-Aug	Moderate	Forereef	16.1	21.88104	−159.49099
KAU-267	17-Aug	Shallow	Forereef	3.9	21.87837	−159.47192
KAU-271	17-Aug	Moderate	Forereef	10.9	21.87811	−159.47684
KAU-274	17-Aug	Moderate	Forereef	9.5	21.95393	−159.70635
KAU-281	17-Aug	Shallow	Forereef	5.5	21.95539	−159.70066
KAU-283	17-Aug	Moderate	Forereef	16.7	21.91752	−159.658
KAU-291	17-Aug	Moderate	Forereef	13.0	21.95187	−159.7026
KAU-292	17-Aug	Shallow	Forereef	5.2	21.89290	−159.6084
KAU-297	17-Aug	Shallow	Forereef	5.0	21.89968	−159.61136

APPENDIX D: LĀNA`I ISLAND

The island of Lāna`i is located at 20.81° N, 156.93° W in the north Pacific and is part of the main Hawaiian Island chain. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: Methods.

D.1. Climate and Ocean Acidification Monitoring: Instrumentation, Biological Installations, and Water Quality

Oceanographic operations during the cruise HA-13-04 at Lāna`i Island entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), autonomous reef monitoring structures (ARMS), bioerosion monitoring units (BMU), nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select National Coral Reef Monitoring Plan (NCRMP) sites, and shipboard water sampling and CTD casts offshore to a depth of 300 m, and acoustic Doppler current profiler (ADCP) transects.

At nearshore locations around Lāna`i Island, 7 shallow-water CTD casts were performed at each location where water samples were collected, this includes sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Eight shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 2 STRs were retrieved and 2 STRs were deployed. Fifteen CAUs were deployed at 3 locations around Lāna`i Island (Fig. D.1.1 and Table D.1.1).

From the NOAA Ship *Hi`ialakai*, ~ 37 km of ADCP transect lines were run in the 4 cardinal directions (N, S, E, W) away from this island during night operations. On the reciprocal course, shipboard CTD casts were conducted to a depth of 300 m per transect line every 2 km for a total of 11 deep-water CTD casts. Water samples were collected concurrently at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. Near Lāna`i Island, 40 chl-*a* shipboard water samples were collected (Fig. D.1.2).

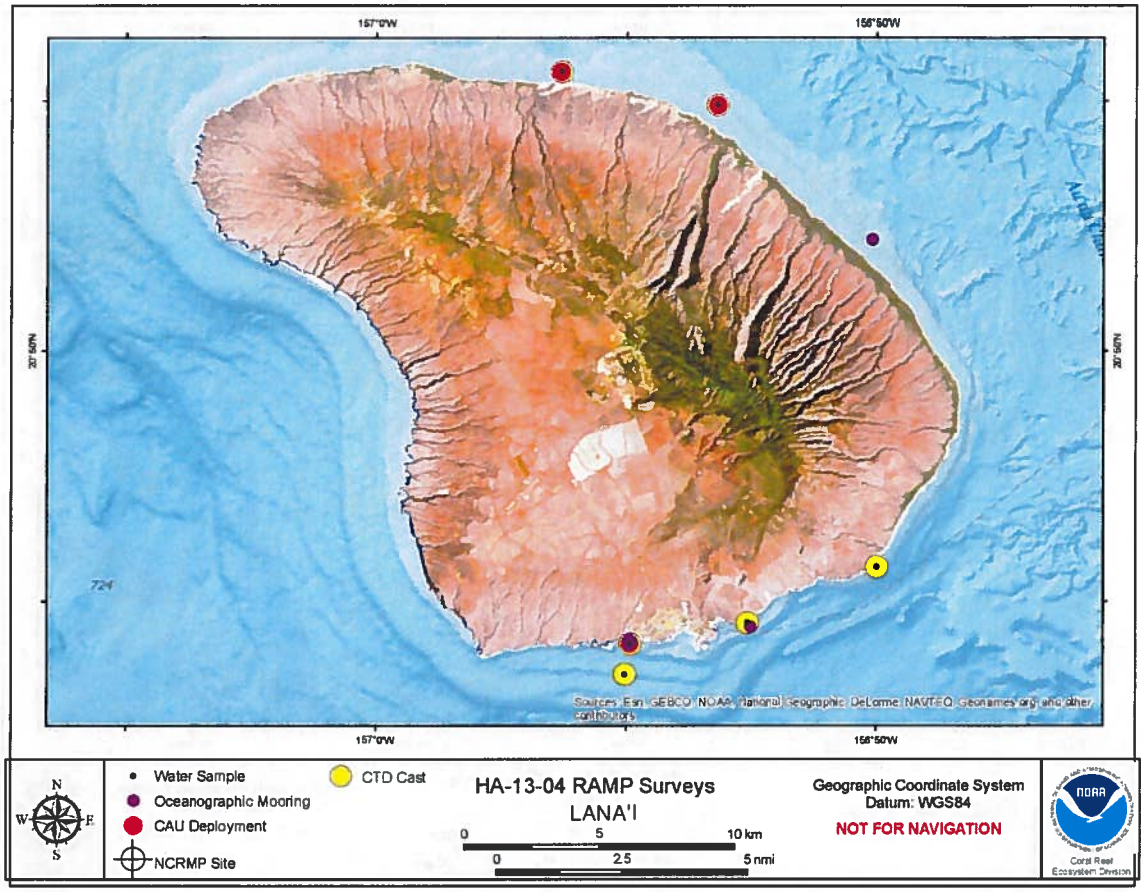

Figure D.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of nearshore CTD casts and water sampling performed at Lāna`i Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table D.1.1.-- Geographic coordinates and depths of the moored oceanographic instruments (STR and EAR) and biological installations (CAU, ARMS, and BMUs), that were retrieved or deployed at Lāna`i Island during cruise HA-13-04.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
LAN-005	21-Aug	STR	20.87055	−156.83471	14.6	1	–
LAN-10	21-Aug	CAU	20.91537	−156.88637	14.6	–	5
LAN-11	21-Aug	CAU	20.92656	−156.9386	14.0	–	5
LAN-001	22-Aug	STR	20.74159	−156.87528	11.6	1	–
LAN-006	22-Aug	STR	20.73587	−156.91552	15.2	–	1
LAN-007	22-Aug	STR	20.73727	−156.91575	5.5	–	1
LAN-12	22-Aug	CAU	20.73587	−156.91553	14.6	–	5

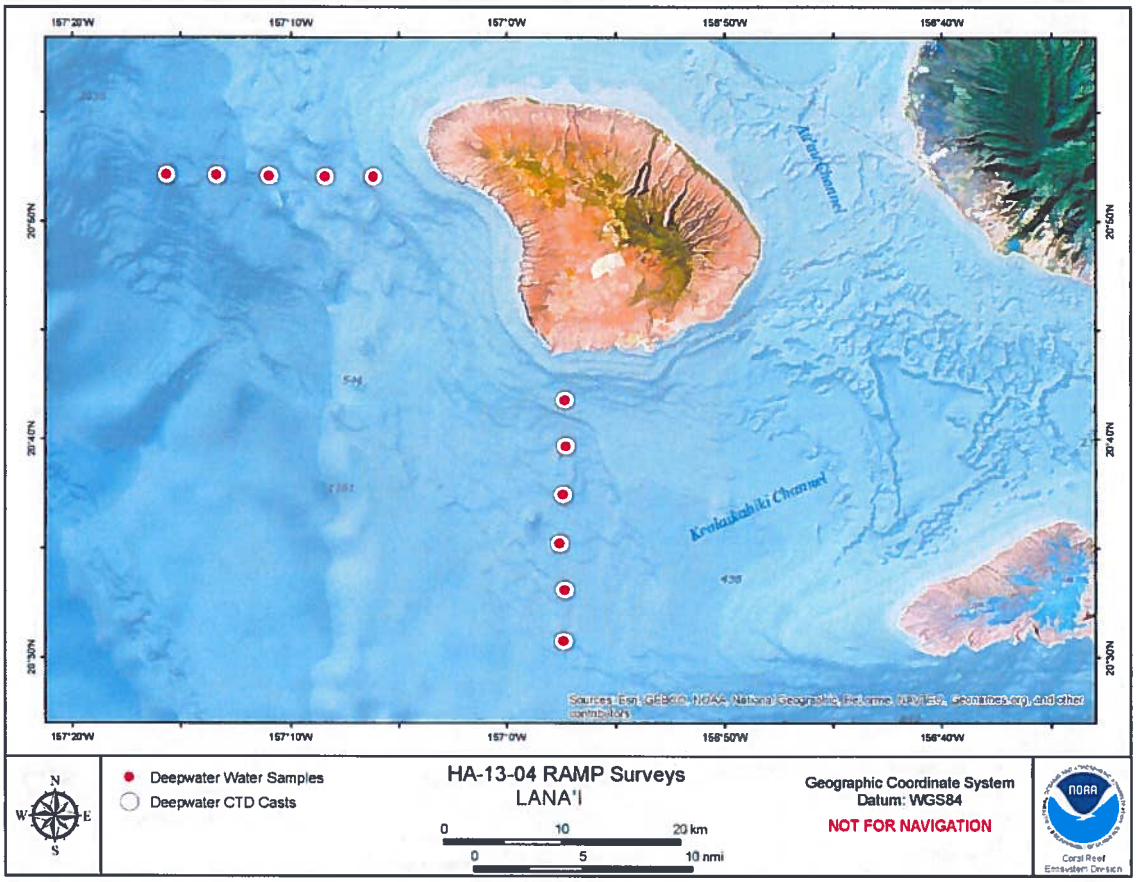

Figure D.1.2.--Locations of deep-water CTD casts and water sampling performed at Lāna`i Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

D.2. Biological Monitoring: Benthic Surveys and Microbial Sampling

Rapid Ecological Assessment (REA) benthic sampling utilized a two-stage stratified random sampling design approach that incorporated both broad categories of reef structure and depth to define habitat strata. Belt-transect surveys were conducted and photographs were taken along transect lines at 14 randomly located sites on Lāna`i Island. Six microbial water samples were collected at 3 benthic REA survey sites. (Fig. D.2.1 and Table D.2.1). For more information about collections made at REA sites, see Table I.1.1 in Appendix I: Biological Collections.

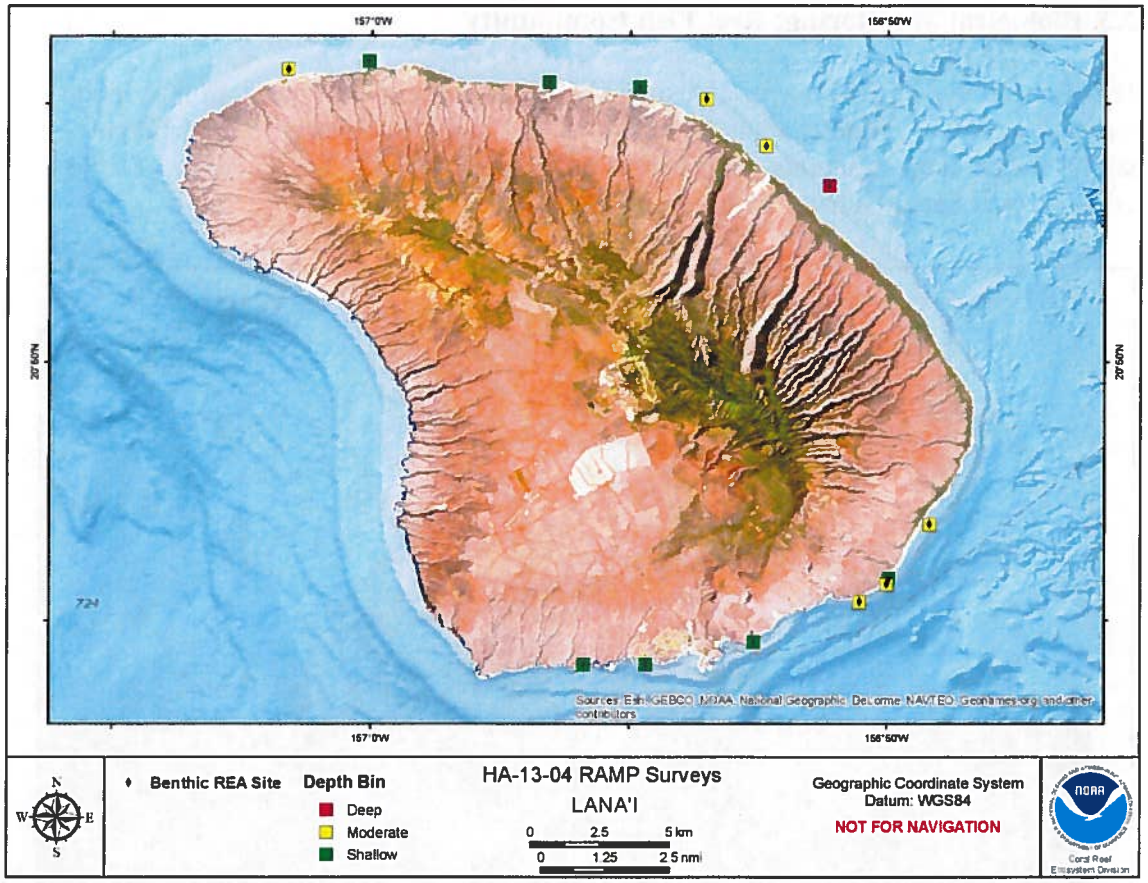

Figure D.2.1.--Locations of REA benthic sites surveyed at Lāna`i Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table D.2.1.--Summary of REA benthic surveys and microbial water samples performed at Lāna`i Island during cruise HA-13-04.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude	REA Coral Survey	Microbial Samples
LAN-1237	21-Aug	Shallow	Forereef	5.2	20.93033	−157.00107	x	
LAN-1246	21-Aug	Moderate	Forereef	13.9	20.92773	−157.02709	x	
LAN-1248	21-Aug	Moderate	Forereef	11.5	20.90297	−156.87286	x	2
LAN-1254	21-Aug	Shallow	Forereef	3.6	20.92208	−156.91354	x	2
LAN-1255	21-Aug	Shallow	Forereef	1.8	20.92357	−156.9429	x	
LAN-1307	21-Aug	Deep	Forereef	21.8	20.89012	−156.85217	x	
LAN-1311	21-Aug	Moderate	Forereef	13.3	20.91814	−156.89211	x	
LAN-1263	22-Aug	Moderate	Forereef	17.6	20.75595	−156.84221	x	
LAN-1265	22-Aug	Moderate	Forereef	16.7	20.78099	−156.81972	x	
LAN-1269	22-Aug	Moderate	Forereef	11.2	20.76167	−156.8334	x	3
LAN-1272	22-Aug	Shallow	Forereef	4.8	20.74299	−156.87636	x	
LAN-1284	22-Aug	Shallow	Forereef	5.2	20.73575	−156.91124	x	
LAN-1286	22-Aug	Shallow	Forereef	6.1	20.73576	−156.93139	x	
LAN-1300	22-Aug	Shallow	Forereef	4.2	20.76356	−156.83281	x	

D.3. Biological Monitoring: Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 29 REA sites at Lāna`i Island over three different habitat strata: deep, moderate, and shallow forereef (Fig. B.3.1 and Table B.3.1). No fishes were collected during these surveys.

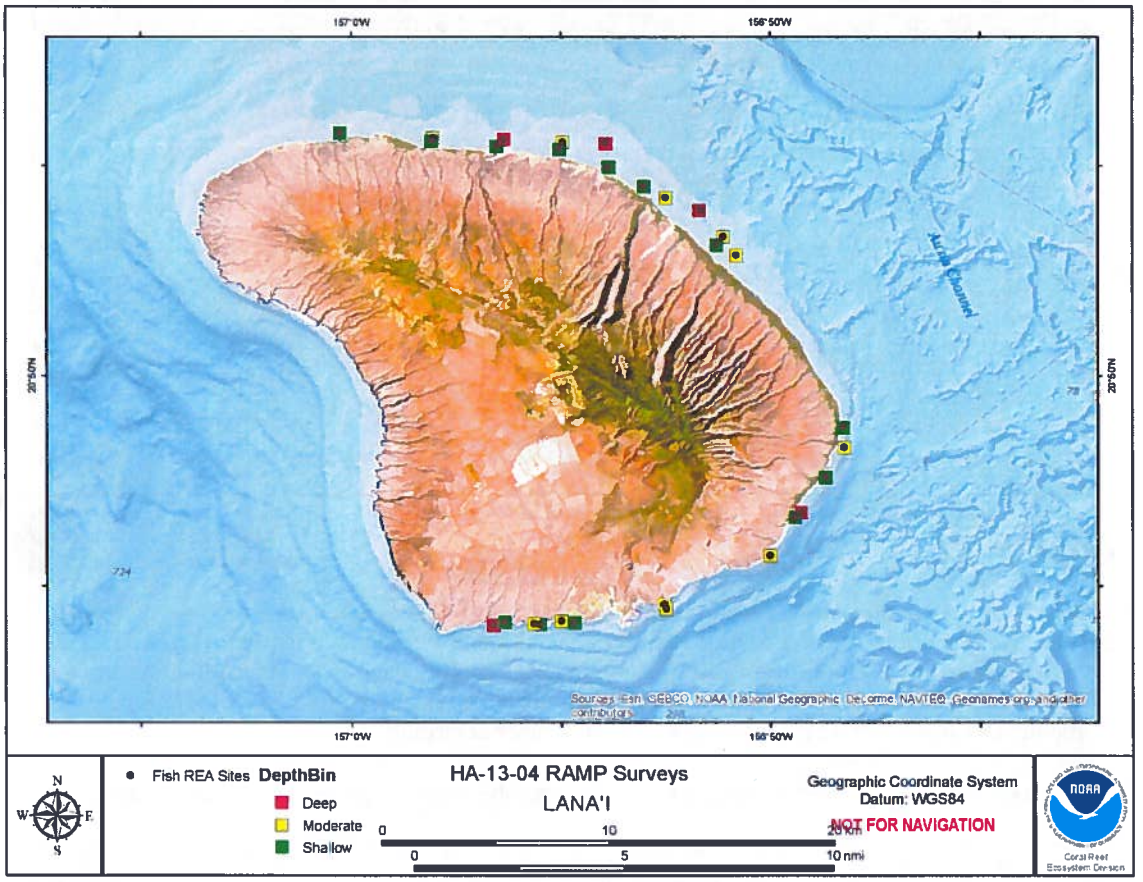

Figure D.3.1.--Locations of REA fish sites surveyed at Lāna`i Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table D.3.1.--Summary of sites where REA fish surveys were conducted at Lāna`i Island during cruise HA-13-04.

REA_Site	Date	DepthBin	Reef_Zone	Depth_(m)	Latitude	Longitude
LAN-237	21-Aug	Shallow	Forereef	4.4	20.92964	−157.00462
LAN-238	21-Aug	Moderate	Forereef	19.0	20.88844	−156.85221
LAN-239	21-Aug	Deep	Forereef	20.3	20.89887	−156.86178
LAN-241	21-Aug	Deep	Forereef	23.0	20.92537	−156.89893
LAN-242	21-Aug	Moderate	Forereef	7.3	20.90388	−156.87534
LAN-243	21-Aug	Shallow	Forereef	2.2	20.90838	−156.88388
LAN-244	21-Aug	Moderate	Forereef	15.5	20.92600	−156.91587
LAN-249	21-Aug	Shallow	Forereef	2.7	20.88515	−156.85482
LAN-250	21-Aug	Moderate	Forereef	9.1	20.92758	−156.96729
LAN-252	21-Aug	Moderate	Forereef	8.5	20.88109	−156.84683
LAN-254	21-Aug	Shallow	Forereef	3.6	20.92319	−156.91714
LAN-255	21-Aug	Shallow	Forereef	2.0	20.92447	−156.94203
LAN-309	21-Aug	Deep	Forereef	20.0	20.92708	−156.93919
LAN-312	21-Aug	Shallow	Forereef	2.8	20.92634	−156.968
LAN-313	21-Aug	Shallow	Forereef	3.0	20.91598	−156.89784
LAN-257	22-Aug	Deep	Forereef	20.0	20.73436	−156.94338
LAN-261	22-Aug	Shallow	Forereef	4.0	20.73477	−156.925
LAN-264	22-Aug	Moderate	Forereef	13.6	20.80496	−156.8038
LAN-265	22-Aug	Deep	Forereef	18.5	20.77903	−156.82091
LAN-269	22-Aug	Moderate	Forereef	9.7	20.76213	−156.83345
LAN-272	22-Aug	Moderate	Forereef	8.2	20.74276	−156.87604
LAN-277	22-Aug	Moderate	Forereef	14.8	20.74099	−156.87515
LAN-283	22-Aug	Moderate	Forereef	14.5	20.73609	−156.91657
LAN-284	22-Aug	Shallow	Forereef	4.4	20.73538	−156.91141
LAN-285	22-Aug	Shallow	Forereef	2.6	20.77728	−156.82345
LAN-289	22-Aug	Shallow	Forereef	3.9	20.79300	−156.81121
LAN-292	22-Aug	Shallow	Forereef	2.1	20.81281	−156.80439
LAN-295	22-Aug	Shallow	Forereef	5.2	20.73549	−156.93912
LAN-302	22-Aug	Moderate	Forereef	13.5	20.73498	−156.92741

APPENDIX E: MAUI ISLAND

The island of Maui is located at 20.80° N, 156.33° W in the north Pacific and is part of the main Hawaiian Island chain. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: Methods.

E.1. Climate and Ocean Acidification Monitoring: Instrumentation, Biological Installations and Water Quality

Oceanographic operations during the cruise HA-13-04 at Maui Island entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), autonomous reef monitoring structures (ARMS), bioerosion monitoring units (BMU), nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select National Coral Reef Monitoring Plan (NCRMP) sites, and shipboard water sampling and CTD casts offshore to a depth of 300 m, and acoustic Doppler current profiler (ADCP) transects.

At nearshore locations around Maui Island, 11 shallow-water CTD casts were performed at each location where water samples were collected, this includes sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Nine shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. Five STRs were retrieved and 3 STRs were deployed. 5 CAUs were deployed at 1 location around the island (Fig. E.1.1 and Table E.1.1).

From the NOAA Ship *Hi`ialakai*, ~ 22 km of ADCP transect lines were run in the 4 cardinal directions (N, S, E, W) away from this island during night operations. On the reciprocal course, shipboard CTD casts were conducted to a depth of 300 m per transect line every 2 km for a total of 6 deep water CTD casts. Water samples were collected concurrently at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. Near Maui Island, 30 chl-*a* shipboard water samples were collected (Fig. E.1.2).

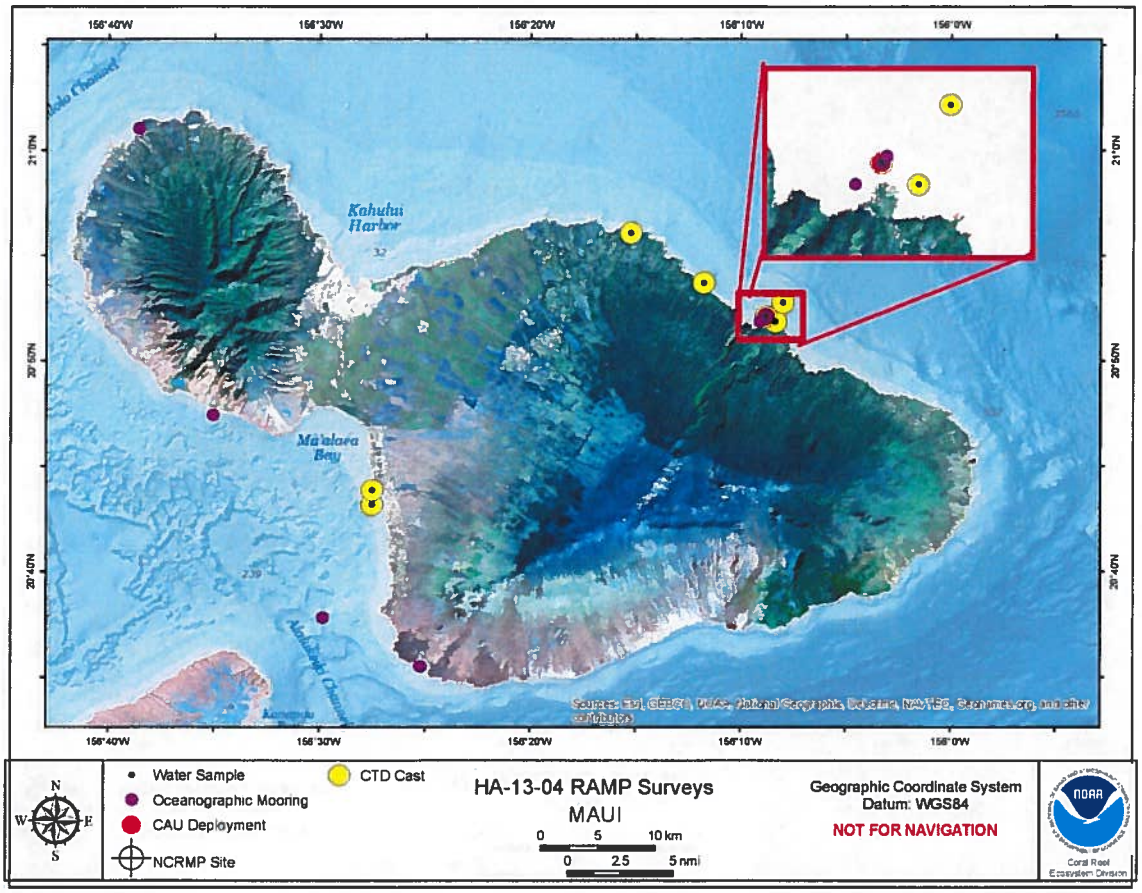

Figure E.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of nearshore CTD casts and water sampling performed at Maui Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table E.1.1.-- Geographic coordinates and depths of the moored oceanographic instruments (STR, EAR) and biological installations (CAU, ARMS, and BMUs), that were retrieved or deployed at Maui Island during cruise HA-13-04.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
MAI-003	2-Aug	STR	20.63027	−156.49716	10.7	1	1
MAI-005	2-Aug	EAR	20.59195	−156.42033	14.9	1	–
MAI-005	2-Aug	STR	20.59195	−156.42033	14.9	1	–
MAI-007	2-Aug	STR	20.79079	−156.58441	11.9	1	–
MAI-006	9-Aug	STR	20.86451	−156.15122	15.2	1	–
MAI-008	9-Aug	STR	20.86862	−156.14626	14.3	–	1
MAI-009	9-Aug	STR	20.86998	−156.14525	25.3	–	1
MAI-004	10-Aug	STR	21.01735	−156.64299	12.2	1	–
MAI-01	9-Aug	ARMS	20.76232	−155.97998	14.6	–	3
MAI-30	9-Aug	CAU	20.86863	−156.14626	0.0	–	5

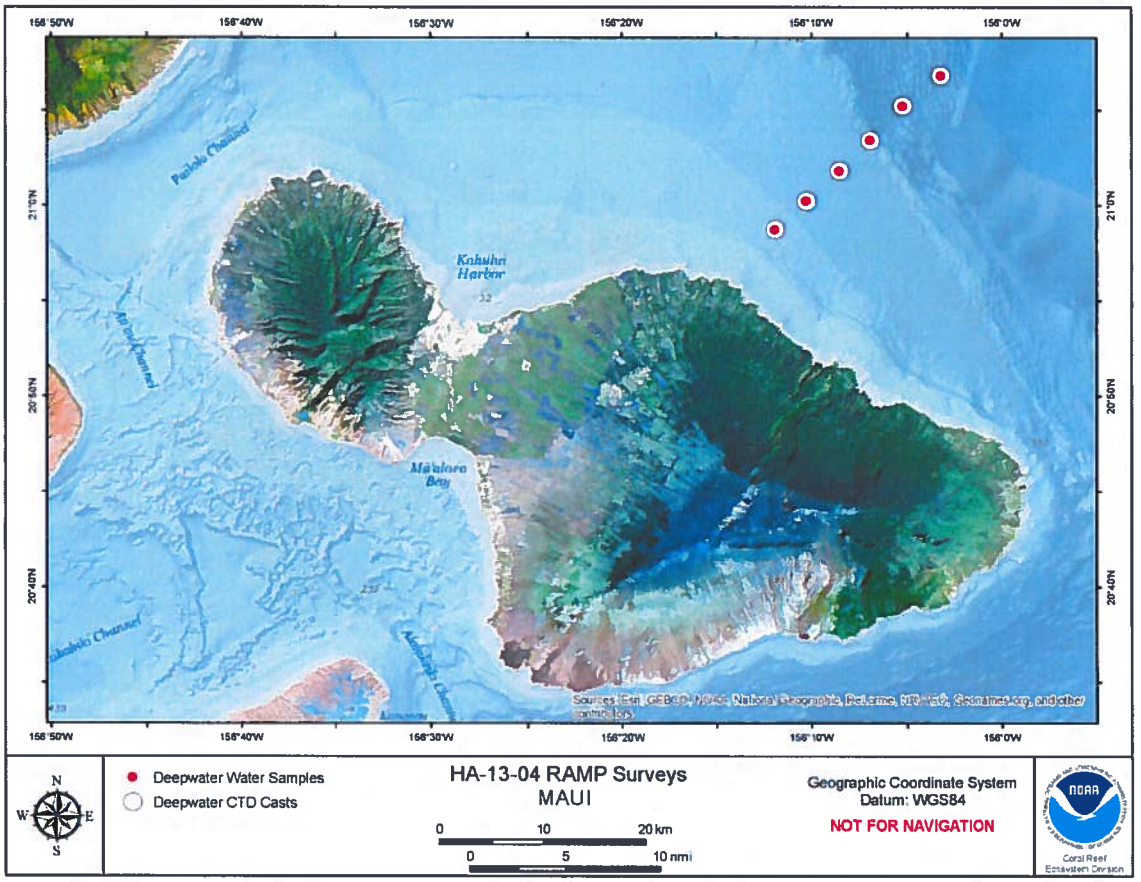

Figure E.1.2.--Locations of deep-water CTD casts and water sampling performed at Maui Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

E.2. Biological Monitoring: Benthic Surveys and Microbial Sampling

Rapid Ecological Assessment (REA) benthic sampling utilized a two-stage stratified random sampling design approach that incorporated both broad categories of reef structure and depth to define habitat strata. Belt-transect surveys were conducted and photographs were taken along transect lines at 8 sites randomly located on Maui Island. Six microbial water samples were collected at 3 benthic REA survey sites. (Fig. E.2.1 and Table E.2.1). For more information about collections made at REA sites, see Table I.1.1 in Appendix I: Biological Collections.

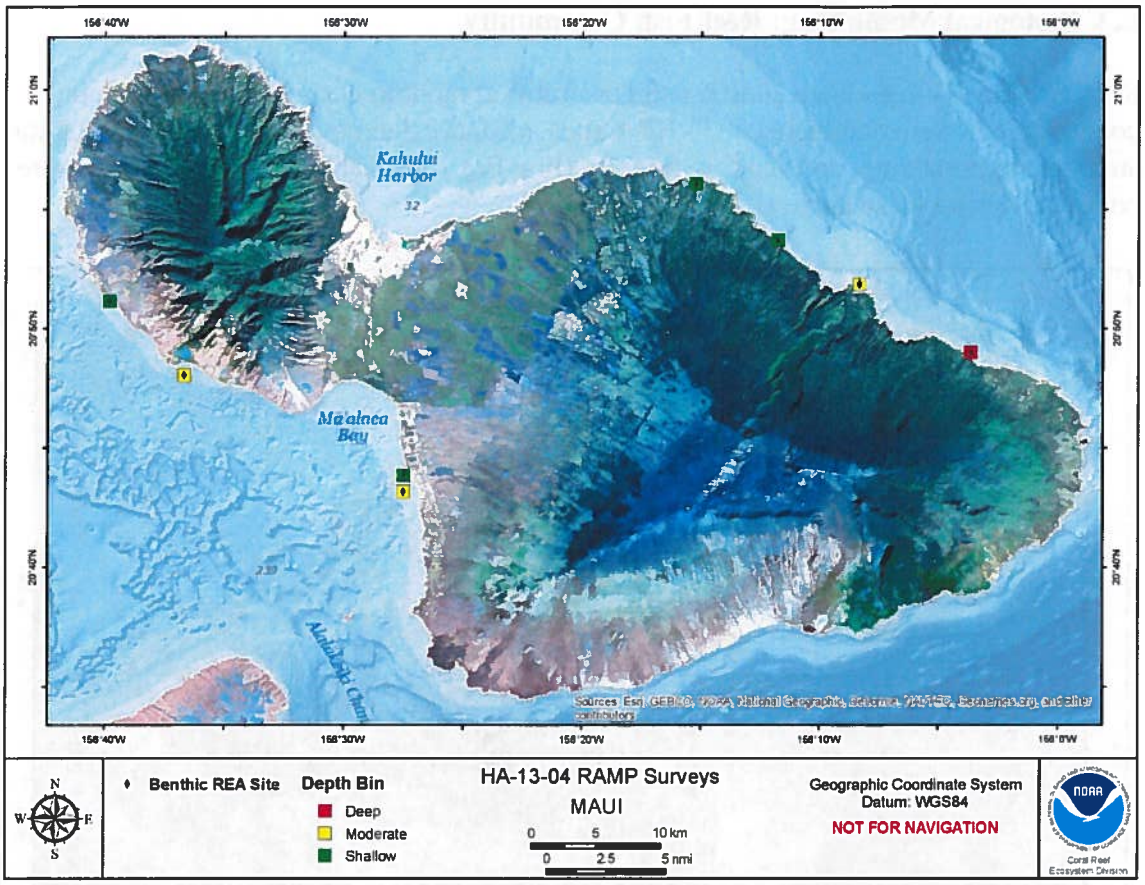

Figure E.2.1.--Locations of REA benthic sites surveyed at Maui Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table E.2.1.--Summary of REA benthic surveys and microbial water samples performed at Maui Island during cruise HA-13-04.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude	REA Coral Survey	Microbial Samples
MAI-1449	2-Aug	Shallow	Forereef	5.5	20.73105	−156.45834	x	
MAI-1587	2-Aug	Moderate	Forereef	14.8	20.7197	−156.45818	x	2
MAI-1488	9-Aug	Moderate	Forereef	12.1	20.86447	−156.13911	x	3
MAI-1502	9-Aug	Shallow	Forereef	7.0	20.93434	−156.25405	x	
MAI-1567	9-Aug	Deep	Forereef	24.2	20.81662	−156.06122	x	
MAI-1571	9-Aug	Shallow	Forereef	5.2	20.89485	−156.19643	x	
MAI-1443	10-Aug	Moderate	Forereef	15.8	20.80088	−156.6115	x	2
MAI-1478	10-Aug	Shallow	Forereef	21.8	20.85248	−156.66362	x	

E.3. Biological Monitoring: Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 34 REA sites at Maui Island over three different habitat strata: deep, moderate, and shallow forereef (Fig. E.3.1and Table E.3.1). No fishes were collected during these surveys.

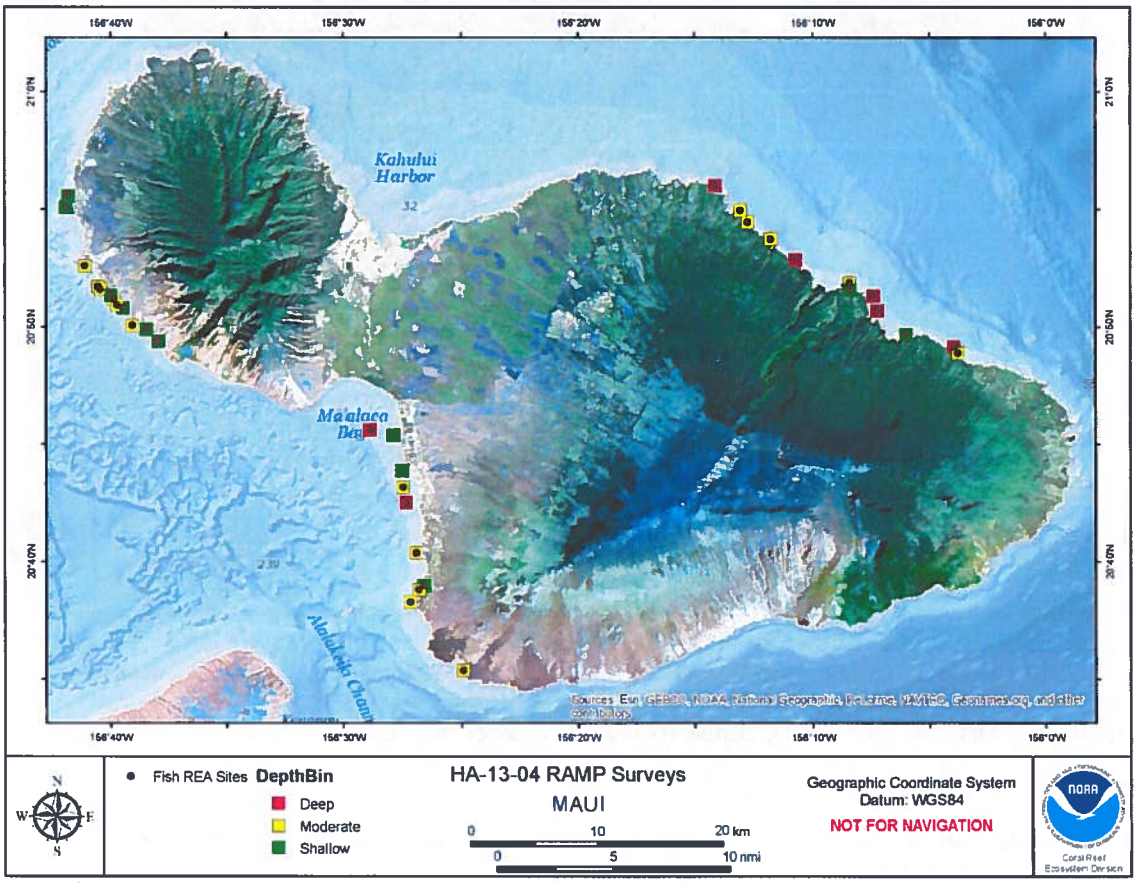

Figure E.3.1.--Locations of REA fish sites surveyed at Maui Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table E.3.1.--Summary of sites where REA fish surveys were conducted at Maui Island during cruise HA-13-04.

REA_Site	Date	DepthBin	Reef_Zone	Depth_(m)	Latitude	Longitude
MAI-430	2-Aug	Deep	Forereef	21.0	20.76042	−156.48109
MAI-432	2-Aug	Deep	Forereef	20.4	20.70869	−156.45578
MAI-433	2-Aug	Shallow	Forereef	4.5	20.64979	−156.44357
MAI-435	2-Aug	Moderate	Forereef	10.2	20.64672	−156.447
MAI-438	2-Aug	Moderate	Forereef	16.4	20.67286	−156.44864
MAI-439	2-Aug	Moderate	Forereef	13.0	20.58950	−156.4157
MAI-441	2-Aug	Moderate	Forereef	10.5	20.63803	−156.45287
MAI-447	2-Aug	Shallow	Forereef	5.0	20.75611	−156.46478
MAI-449	2-Aug	Shallow	Forereef	3.6	20.73141	−156.4586
MAI-587	2-Aug	Moderate	Forereef	13.0	20.71947	−156.45785
MAI-471	9-Aug	Deep	Forereef	23.4	20.81943	−156.06585
MAI-477	9-Aug	Deep	Forereef	23.5	20.93379	−156.23528
MAI-484	9-Aug	Shallow	Forereef	4.6	20.82797	−156.10058
MAI-486	9-Aug	Deep	Forereef	24.8	20.85534	−156.12395
MAI-488	9-Aug	Moderate	Forereef	14.6	20.86477	−156.14077
MAI-492	9-Aug	Deep	Forereef	21.2	20.84505	−156.12125
MAI-493	9-Aug	Moderate	Forereef	9.4	20.81489	−156.06313
MAI-497	9-Aug	Moderate	Forereef	17.3	20.90755	−156.21247
MAI-500	9-Aug	Moderate	Forereef	12.2	20.91567	−156.21738
MAI-568	9-Aug	Deep	Forereef	24.4	20.88077	−156.17862
MAI-571	9-Aug	Moderate	Forereef	14.2	20.89575	−156.1962
MAI-572	9-Aug	Shallow	Forereef	5.0	20.85941	−156.14049
MAI-464	10-Aug	Moderate	Forereef	8.0	20.86186	−156.67585
MAI-468	10-Aug	Shallow	Forereef	2.4	20.92632	−156.69717
MAI-470	10-Aug	Shallow	Forereef	4.8	20.82309	−156.63266
MAI-472	10-Aug	Shallow	Forereef	3.9	20.91798	−156.69872
MAI-474	10-Aug	Shallow	Forereef	5.5	20.83161	−156.64108
MAI-478	10-Aug	Moderate	Forereef	7.1	20.85260	−156.66441
MAI-480	10-Aug	Moderate	Forereef	7.3	20.87631	−156.68547
MAI-481	10-Aug	Moderate	Forereef	8.5	20.83435	−156.65094
MAI-482	10-Aug	Shallow	Forereef	3.0	20.84660	−156.65783
MAI-565	10-Aug	Moderate	Forereef	8.8	20.85980	−156.6741
MAI-576	10-Aug	Moderate	Forereef	9.4	20.84880	−156.66217
MAI-583	10-Aug	Shallow	Forereef	3.6	20.85585	−156.66659

APPENDIX F: MOLOKA'I ISLAND

The island of Moloka`i is located at 21.14° N, 157.02° W in the north Pacific and is part of the main Hawaiian Island chain. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: Methods.

F.1. Climate and Ocean Acidification Monitoring: Instrumentation, Biological Installations, and Water Quality

Oceanographic operations during the cruise HA-13-04 at Moloka`i Island entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), autonomous reef monitoring structures (ARMS), bio-erosion monitoring units (BMU), nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select National Coral Reef Monitoring Plan (NCRMP) sites, and shipboard water sampling and CTD casts offshore to a depth of 300 m, and acoustic Doppler current profiler (ADCP) transects.

At nearshore locations around Moloka`i Island, 8 shallow-water CTD casts were performed at each location where water samples were collected, this includes sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Fourteen shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 2 STRs were retrieved and 6 STRs were deployed. Twenty-five CAUs were deployed at 5 locations around the island (Fig. F.1.1 and Table F.1.1).

From the NOAA Ship *Hi`ialakai*, ~16 km of ADCP transect lines were run in the 4 cardinal directions (N, S, E, W) away from this island during night operations. On the reciprocal course, shipboard CTD casts were conducted to a depth of 300 m per transect line every 2 km for a total of 5 deep-water CTD casts. Water samples were collected concurrently at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. Near Moloka`i Island, 10 chl-*a* shipboard water samples were collected (Fig. F.1.2).

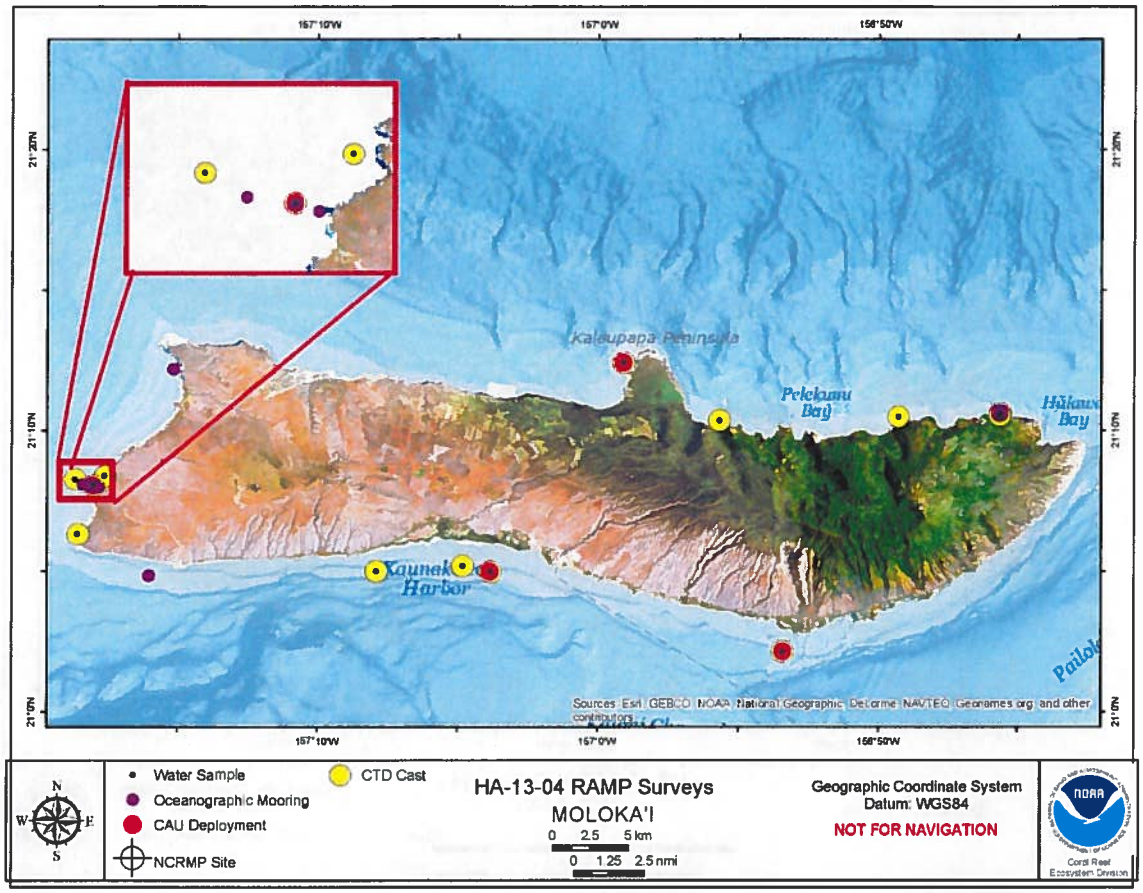

Figure F.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of nearshore CTD casts and water sampling performed at Moloka`i Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table F.1.1.-- Geographic coordinates and depths of the moored oceanographic instruments (STR, EAR) and biological installations (CAU, ARMS, and BMUs), that were retrieved or deployed at Moloka`i Island during cruise HA-13-04.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
MOL-20	11-Aug	CAU	21.03569	−156.89041	13.1	–	5
MOL-21	11-Aug	CAU	21.08295	−157.06422	13.7	–	5
MOL_001	19-Aug	STR	21.20306	−157.25239	9.8	1	–
MOL_002	19-Aug	STR	21.08091	−157.26696	19.5	1	–
MOL_003	19-Aug	STR	21.13411	−157.30027	15.2	–	1
MOL_004	19-Aug	STR	21.13487	−157.30593	25.6	–	1
MOL_005	19-Aug	STR	21.13317	−157.29747	4.9	–	1
MOL-22	19-Aug	CAU	21.13411	−157.30028	15.2	–	5
MOL_006	20-Aug	STR	21.17692	−156.76045	14.0	–	1
MOL_007	20-Aug	STR	21.17581	−156.76072	5.5	–	1
MOL_008	20-Aug	STR	21.17865	−156.76057	24.1	–	1
MOL-23	20-Aug	CAU	21.17692	−156.76045	15.2	–	5
MOL-24	20-Aug	CAU	21.20709	−156.9847	14.0	–	5

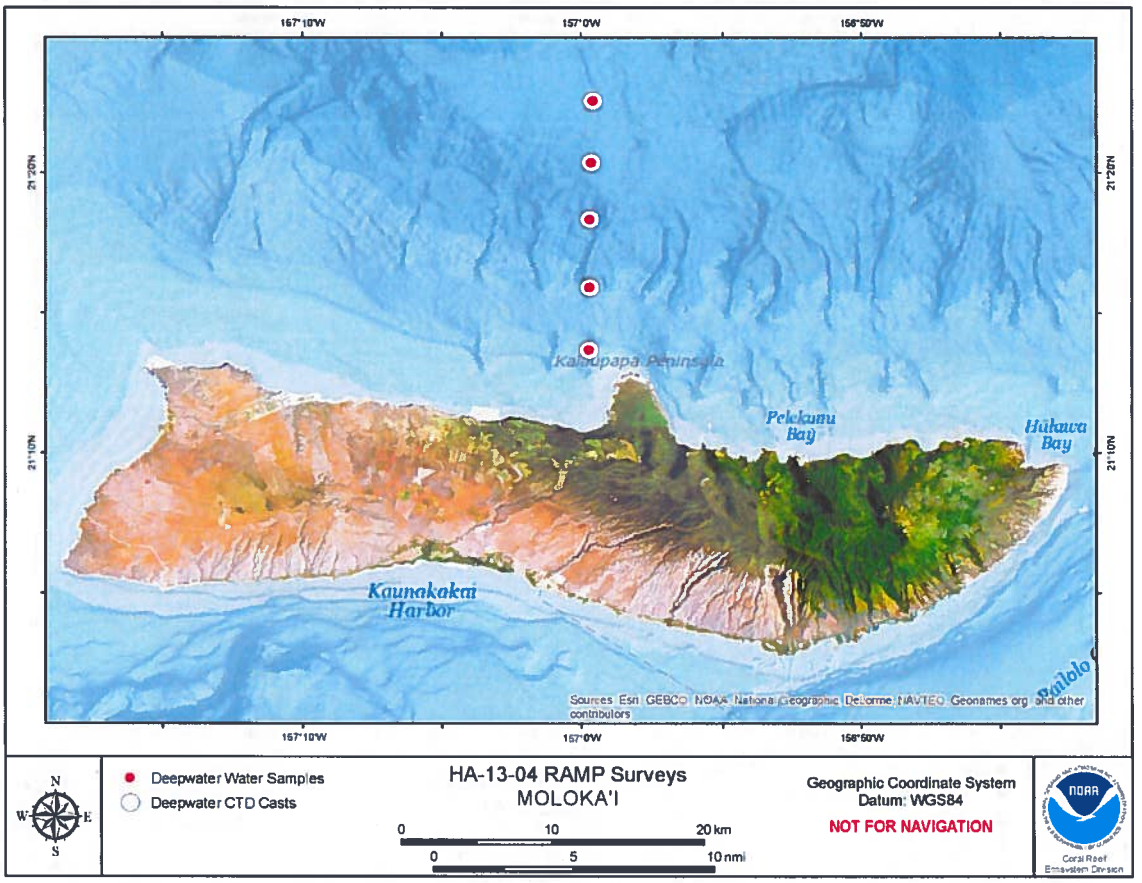

Figure F.1.2.--Locations of deep-water CTD casts and water sampling performed at Moloka`i Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

F.2. Biological Monitoring: Benthic Surveys and Microbial Sampling

Rapid Ecological Assessment (REA) benthic sampling utilized a two-stage stratified random sampling design approach that incorporated both broad categories of reef structure and depth to define habitat strata. Belt-transect surveys were conducted and photographs were taken along transects lines at 21 randomly located sites on Moloka`i Island. Nine microbial water samples were collected at 3 benthic REA survey sites (Fig. F.2.1 and Table F.2.1.). For more information about collections made at REA sites, see Table I.1.1 in Appendix I: Biological Collections.

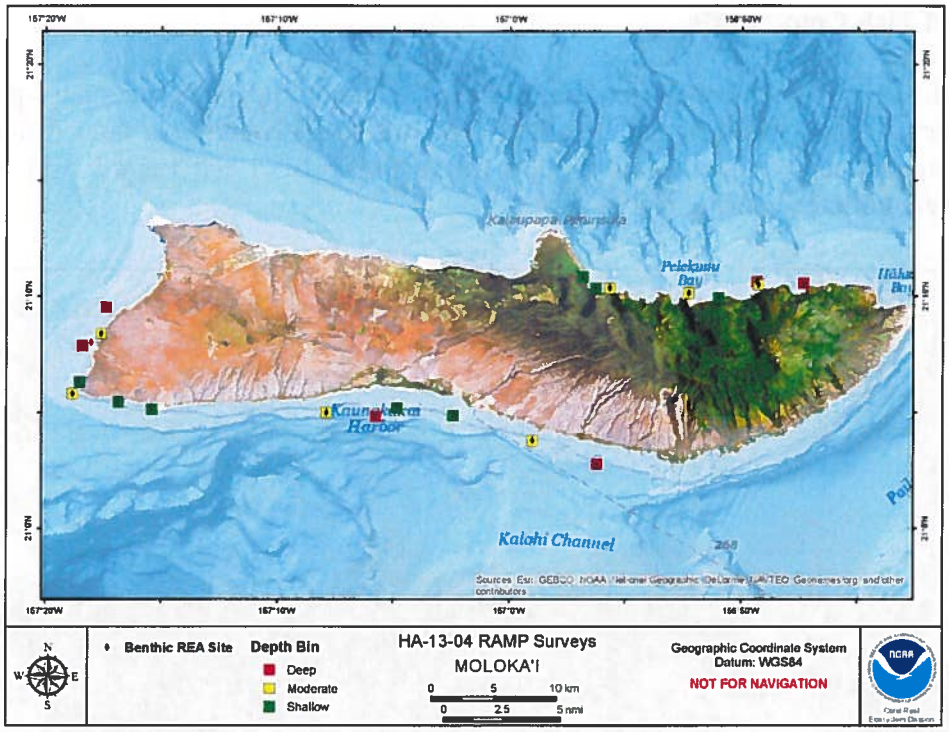

Figure F.2.1.--Locations of REA benthic sites surveyed at Moloka`i Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table F.2.1.--Summary of REA benthic surveys and microbial water samples performed at Moloka`i Island during cruise HA-13-04.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude	REA Coral Survey	Microbial Samples
MOL-1446	11-Aug	Deep	Forereef	21.2	21.08059	−157.09617	x	
MOL-1447	11-Aug	Deep	Forereef	24.2	21.04606	−156.9372	x	
MOL-1453	11-Aug	Moderate	Forereef	16.1	21.06312	−156.98348	x	
MOL-1456	11-Aug	Shallow	Forereef	3.0	21.08641	−157.0804	x	
MOL-1461	11-Aug	Moderate	Forereef	13.6	21.08328	−157.13172	x	2
MOL-1487	11-Aug	Shallow	Forereef	3.9	21.08082	−157.04028	x	
MOL-1501	19-Aug	Deep	Forereef	23.0	21.15873	−157.28991	x	
MOL-1502	19-Aug	Deep	Forereef	23.0	21.13176	−157.30653	x	
MOL-1509	19-Aug	Moderate	Forereef	8.8	21.13988	−157.29341	x	2
MOL-1510	19-Aug	Moderate	Forereef	11.8	21.09679	−157.31383	x	
MOL-1513	19-Aug	Shallow	Forereef	2.7	21.09064	−157.28095	x	
MOL-1514	19-Aug	Shallow	Forereef	4.2	21.08535	−157.25667	x	
MOL-1516	19-Aug	Shallow	Forereef	5.8	21.10546	−157.30902	x	
MOL-1425	20-Aug	Deep	Forereef	23.6	21.17602	−156.78873	x	
MOL-1427	20-Aug	Shallow	Forereef	4.2	21.1723	−156.93785	x	
MOL-1432	20-Aug	Deep	Forereef	23.0	21.17712	−156.82255	x	
MOL-1435	20-Aug	Moderate	Forereef	15.2	21.17481	−156.82139	x	3
MOL-1436	20-Aug	Moderate	Forereef	12.1	21.16903	−156.87125	x	
MOL-1437	20-Aug	Shallow	Forereef	6.1	21.18056	−156.94754	x	
MOL-1440	20-Aug	Shallow	Forereef	3.6	21.16573	−156.84983	x	
MOL-1444	20-Aug	Moderate	Forereef	13.6	21.17254	−156.9281	x	

F.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 39 REA sites at Moloka`i Island over three different habitat strata: deep, moderate, and shallow forereef (Fig. F.3.1 and Table F.3.1). No fishes were collected during these surveys.

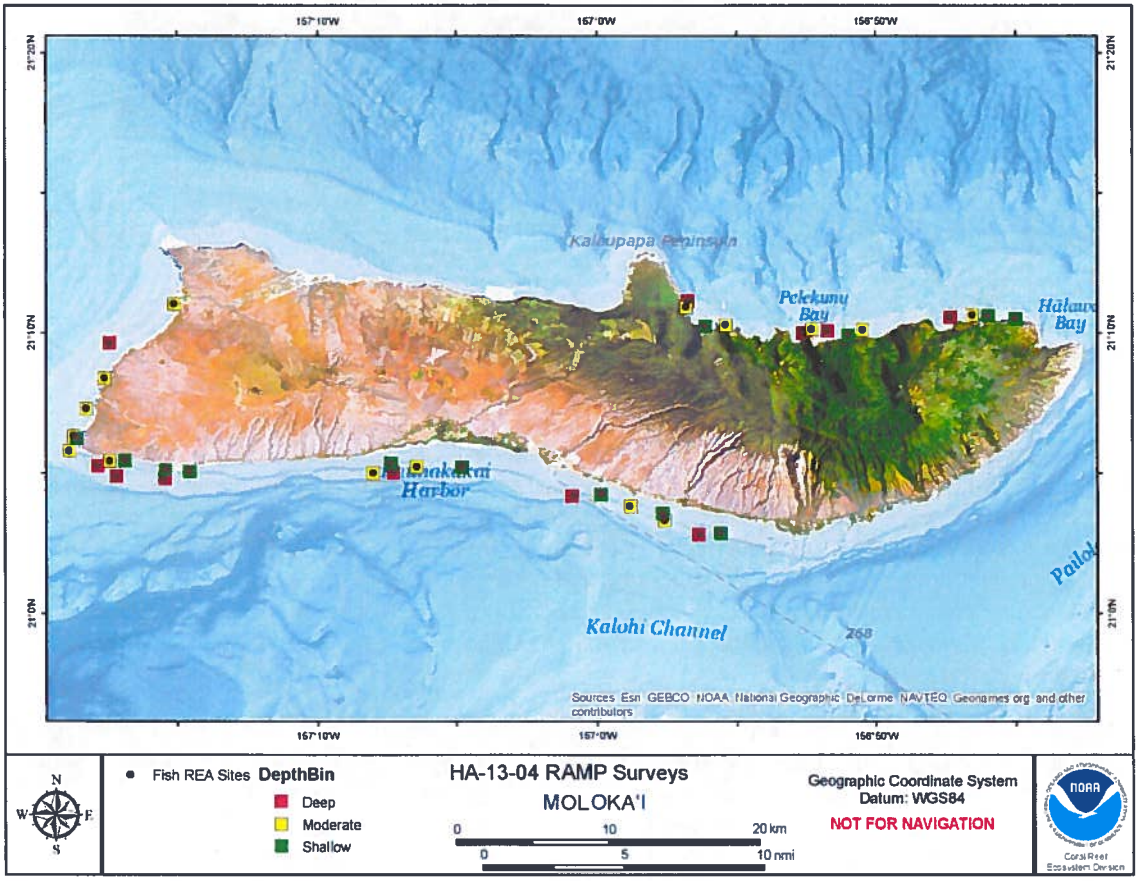

Figure F.3.1.--Locations of REA fish sites surveyed at Moloka`i Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table F.3.1.--Summary of sites where REA fish surveys were conducted at Moloka`i Island during cruise HA-13-04.

REA_Site	Date	DepthBin	Reef_Zone	Depth_(m)	Latitude	Longitude
MOL-445	11-Aug	Deep	Forereef	21.2	21.08371	−157.1205
MOL-448	11-Aug	Moderate	Forereef	13.0	21.08717	−157.1067
MOL-451	11-Aug	Deep	Forereef	20.6	21.06972	−157.01452
MOL-456	11-Aug	Shallow	Forereef	2.5	21.08684	−157.0799
MOL-461	11-Aug	Moderate	Forereef	10.3	21.08337	−157.1328
MOL-465	11-Aug	Deep	Forereef	19.5	21.04681	−156.93979
MOL-467	11-Aug	Moderate	Forereef	11.5	21.05541	−156.95994
MOL-471	11-Aug	Moderate	Forereef	9.4	21.06391	−156.98067
MOL-482	11-Aug	Shallow	Forereef	5.0	21.04763	−156.9266
MOL-489	11-Aug	Shallow	Forereef	2.4	21.08930	−157.12201
MOL-490	11-Aug	Shallow	Forereef	5.2	21.05930	−156.96112
MOL-493	11-Aug	Shallow	Forereef	1.5	21.07069	−156.9977
MOL-497	19-Aug	Deep	Forereef	18.8	21.07987	−157.25769
MOL-499	19-Aug	Deep	Forereef	26.0	21.08159	−157.28633
MOL-500	19-Aug	Deep	Forereef	19.4	21.08781	−157.29736
MOL-501	19-Aug	Deep	Forereef	29.0	21.16082	−157.29008
MOL-502	19-Aug	Moderate	Forereef	13.3	21.12186	−157.30438
MOL-505	19-Aug	Moderate	Forereef	8.2	21.18395	−157.25198
MOL-506	19-Aug	Moderate	Forereef	7.3	21.09063	−157.29026
MOL-508	19-Aug	Moderate	Forereef	9.6	21.10531	−157.31183
MOL-509	19-Aug	Moderate	Forereef	7.6	21.13993	−157.29331
MOL-510	19-Aug	Moderate	Forereef	12.5	21.09668	−157.31423
MOL-512	19-Aug	Shallow	Forereef	3.0	21.08440	−157.24283
MOL-513	19-Aug	Shallow	Forereef	4.0	21.09088	−157.28107
MOL-514	19-Aug	Shallow	Forereef	4.8	21.08532	−157.25718
MOL-516	19-Aug	Shallow	Forereef	3.7	21.10414	−157.30966
MOL-425	20-Aug	Deep	Forereef	23.2	21.17620	−156.78884
MOL-426	20-Aug	Deep	Forereef	25.5	21.18591	−156.9461
MOL-429	20-Aug	Deep	Forereef	19.0	21.16691	−156.87683
MOL-430	20-Aug	Deep	Forereef	23.0	21.16802	−156.86231
MOL-435	20-Aug	Moderate	Forereef	8.8	21.16860	−156.84092
MOL-436	20-Aug	Moderate	Forereef	12.1	21.16909	−156.87167
MOL-437	20-Aug	Moderate	Forereef	13.0	21.18218	−156.94722
MOL-438	20-Aug	Moderate	Forereef	16.0	21.17746	−156.77569
MOL-439	20-Aug	Moderate	Forereef	10.4	21.17159	−156.9232
MOL-440	20-Aug	Shallow	Forereef	3.0	21.16553	−156.84961
MOL-441	20-Aug	Shallow	Forereef	4.5	21.17540	−156.75033
MOL-443	20-Aug	Shallow	Forereef	4.2	21.17694	−156.76639
MOL-444	20-Aug	Shallow	Forereef	4.2	21.17069	−156.93566

APPENDIX G: NI`IHAU ISLAND AND LEHUA ROCK

The island of Ni`ihau Island and Lehua Rock are is located approximately at 21.89° N, 160.16° W and 22.02° N, 160.10° W in the north Pacific and are part of the main Hawaiian Island chain. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: Methods.

G.1. Climate and Ocean Acidification Monitoring: Instrumentation, Biological Installations, and Water Quality

Oceanographic operations during the cruise HA-13-04 at Ni`ihau Island and Lehua Rock entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), autonomous reef monitoring structures (ARMS), bioerosion monitoring units (BMU), nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select National Coral Reef Monitoring Plan (NCRMP) sites, and shipboard water sampling and CTD casts offshore to a depth of 300 m, and acoustic Doppler current profiler (ADCP) transects.

At nearshore locations around Ni`ihau Island and Lehua Rock, 7 shallow-water CTD casts were performed at each location where water samples were collected, this includes sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Eight shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 2 STRs were retrieved and 3 STRs were deployed; and 10 CAUs deployed at 2 locations around the Ni`ihau (Fig. G.1.1 and Table G.1.1)

From the NOAA Ship *Hi`ialakai*, ~ 16 km of ADCP transect lines were run in the 4 cardinal directions (N, S, E, W) away from this island during night operations. On the reciprocal course, shipboard CTD casts were conducted to a depth of 300 m per transect line every 2 km for a total of 11 deep water CTD casts. Water samples were collected concurrently at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. Near Ni`ihau Island, 55 chl-*a* shipboard water samples were collected (Fig. G.1.2).

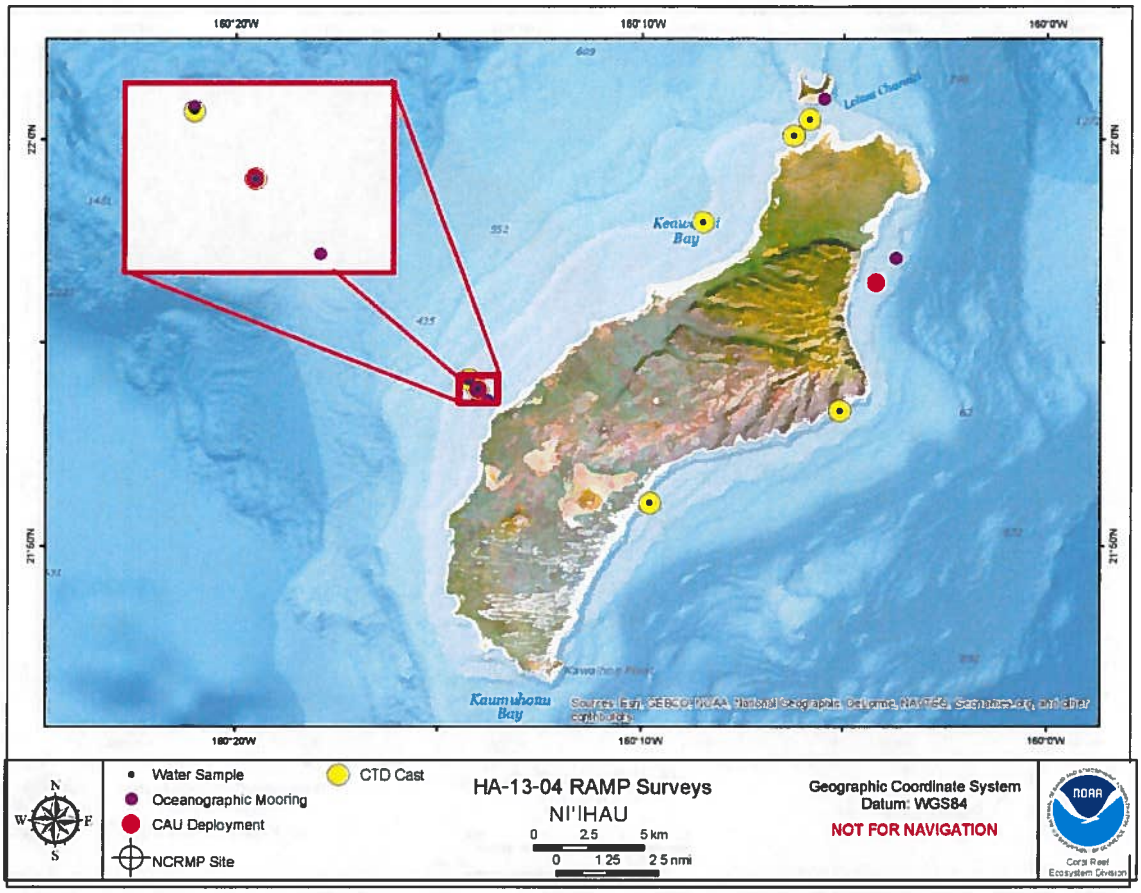

Figure G.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of nearshore CTD casts and water sampling performed at Ni`ihau Island and Lehua Rock during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table G.1.1.-- Geographic coordinates and depths of the moored oceanographic instruments (STR, EAR) and biological installations (CAU, ARMS, and BMUs), that were retrieved or deployed at Ni`ihau Island and Lehua Rock during cruise HA-13-04.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
NII-002	14-Aug	STR	21.95129	−160.06177	12.5	1	–
NII-10	14-Aug	CAU	21.94140	−160.07005	16.2	–	5
LEH-003	16-Aug	STR	22.01662	−160.09137	12.5	1	–
NII-003	16-Aug	STR	21.89751	−160.23392	16.2	–	1
NII-004	16-Aug	STR	21.90174	−160.23757	25.3	–	1
NII-005	16-Aug	STR	21.89307	−160.23002	4.9	–	1
NII-11	16-Aug	CAU	21.89751	−160.23392	16.2	–	5

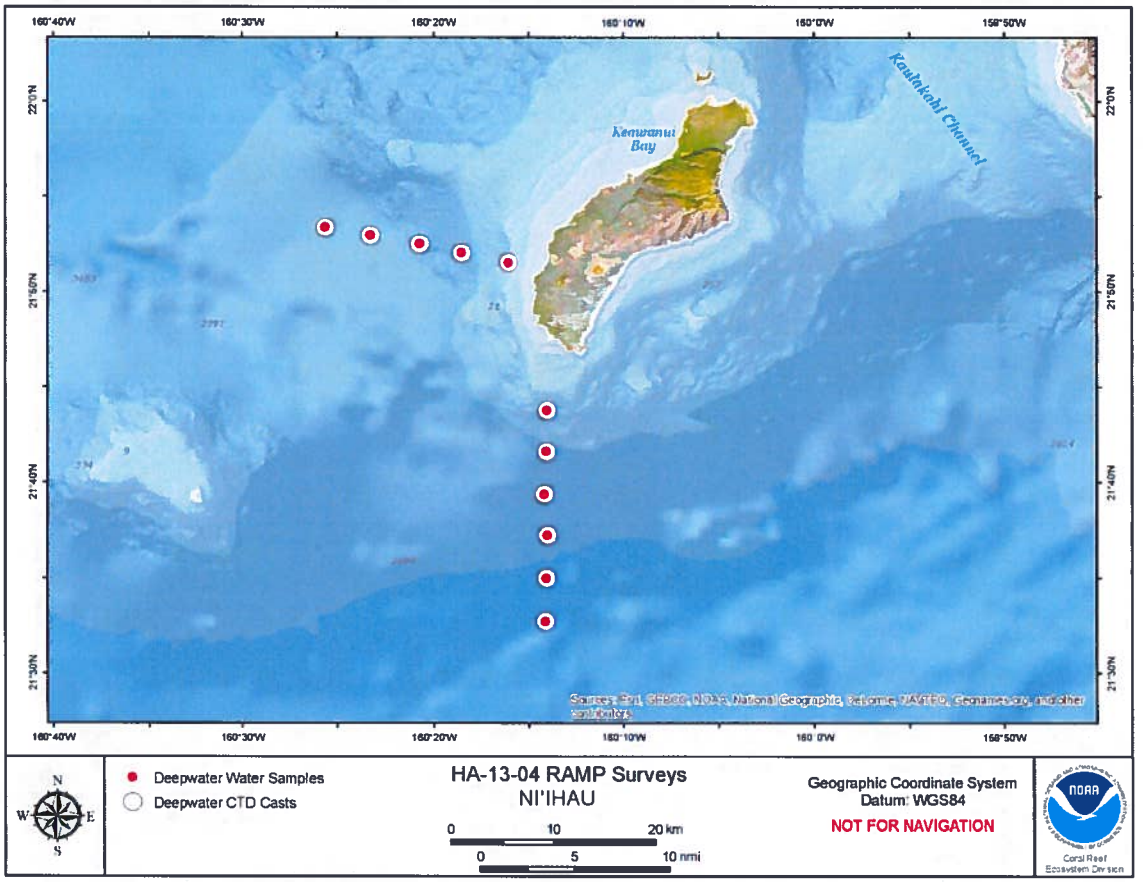

Figure G.1.2.--Locations of deep-water CTD casts and water sampling performed at Ni`ihau Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

G.2. Biological Monitoring: Benthic Surveys and Microbial Sampling

Rapid Ecological Assessment (REA) benthic sampling utilized a two-stage stratified random sampling design approach that incorporated both broad categories of reef structure and depth to define habitat strata. Belt-transect surveys were conducted and photographs were taken along transects lines at 17 randomly located sites on Ni`ihau Island and Lehua Rock. Five microbial water samples were collected at 2 benthic survey sites (Fig. G.2.1 and Table G.2.1.). For more information about collections made at REA sites, see Table I.1.1 in Appendix I: Biological Collections.

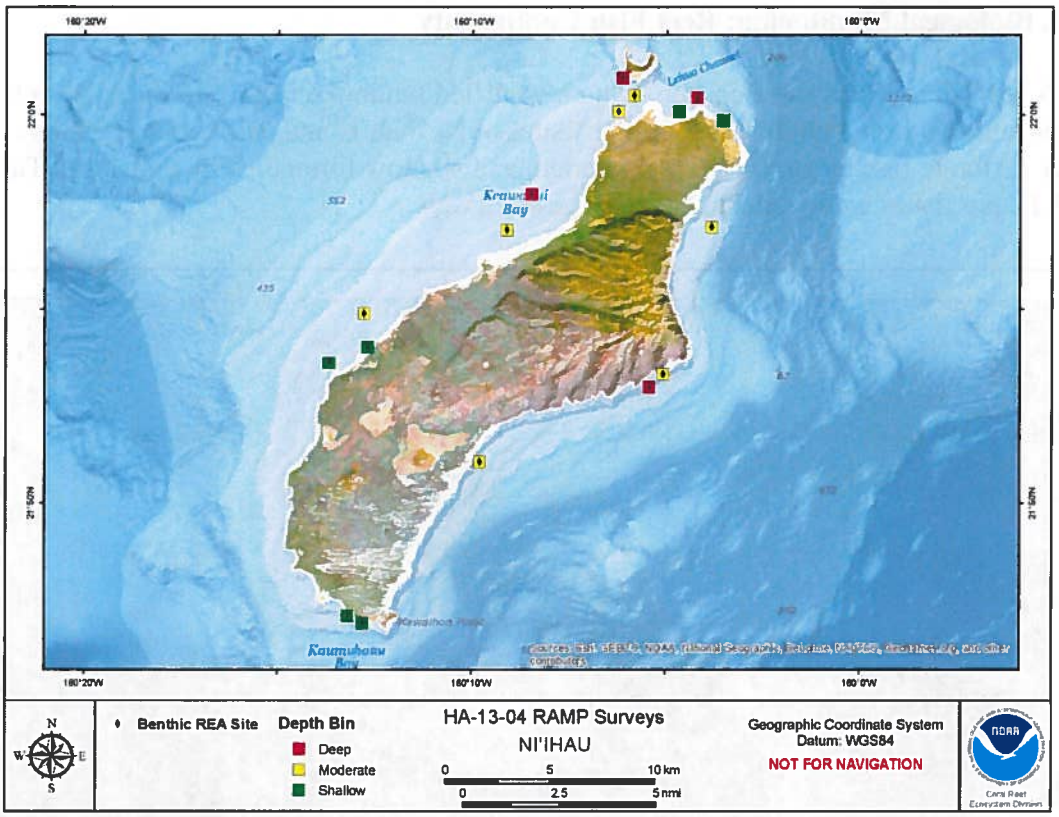

Figure G.2.1.--Locations of REA benthic sites surveyed at Ni`ihau Island and Lehua Rock during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table G.2.1.--Summary of REA benthic surveys and microbial water samples performed at Ni`ihau Island and Lehua Rock during cruise HA-13-04.

REA Site	Date	Depth Bin	Reef Zone	Depth (ft)	Latitude	Longitude	REA Coral Survey	Microbial Samples
NII-1193	14-Aug	Deep	Forereef	21.5	21.88318	−160.09076	x	
NII-1215	14-Aug	Moderate	Forereef	11.2	21.88882	−160.0848	x	
NII-1219	14-Aug	Deep	Forereef	20.9	22.0074	−160.07039	x	
NII-1231	14-Aug	Shallow	Forereef	3.6	21.99753	−160.05922	x	
NII-1272	14-Aug	Shallow	Forereef	5.8	21.7819	−160.21368	x	
NII-1284	14-Aug	Shallow	Forereef	9.4	21.78511	−160.2201	x	
NII-1302	14-Aug	Moderate	Forereef	10.9	21.95185	−160.06381	x	
NII-1303	14-Aug	Moderate	Forereef	13.6	21.85115	−160.16328	x	3
NII-1224	16-Aug	Deep	Forereef	23.9	22.01583	−160.10245	x	
NII-1225	16-Aug	Moderate	Forereef	12.1	22.00824	−160.09767	x	
NII-1227	16-Aug	Moderate	Forereef	11.8	22.00152	−160.10421	x	2
NII-1235	16-Aug	Shallow	Forereef	5.2	22.0012	−160.07817	x	
NII-1251	16-Aug	Deep	Forereef	19.4	21.96605	−160.14151	x	
NII-1254	16-Aug	Moderate	Forereef	12.1	21.95061	−160.15197	x	
NII-1255	16-Aug	Moderate	Forereef	13.9	21.91468	−160.21308	x	
NII-1275	16-Aug	Shallow	Forereef	4.2	21.90014	−160.21142	x	
NII-1290	16-Aug	Shallow	Forereef	6.7	21.89361	−160.22819	x	

G.3. Biological Monitoring: Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 26 REA sites at Ni`ihau Island and Lehua Rock over three different habitat strata: deep, moderate, and shallow forereef (Fig. G.3.1 and Table G.3.1). No fishes were collected during these surveys.

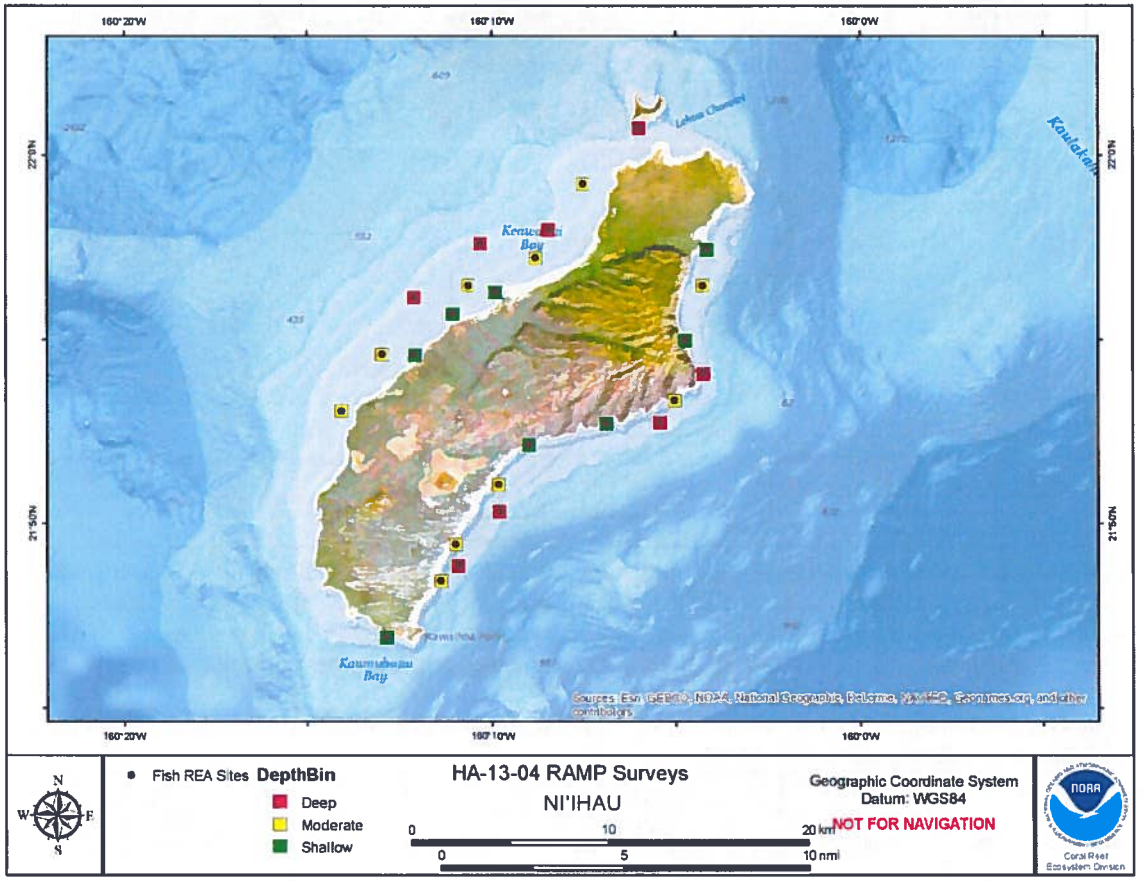

Figure G.3.1.--Locations of REA fish sites surveyed at Ni`ihau Island and Lehua Rock during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table G.3.1.--Summary of sites where REA fish surveys were conducted at Ni`ihau Island and Lehua Rock during cruise HA-13-04.

REA_Site	Date	DepthBin	Reef_Zone	Depth_(m)	Latitude	Longitude
NII-190	14-Aug	Deep	Forereef	23.9	21.83896	−160.16314
NII-194	14-Aug	Deep	Forereef	24.2	21.81438	−160.18243
NII-195	14-Aug	Deep	Forereef	27.6	21.87901	−160.0904
NII-197	14-Aug	Deep	Forereef	23.3	21.90111	−160.07099
NII-199	14-Aug	Moderate	Forereef	16.1	21.94093	−160.07127
NII-204	14-Aug	Moderate	Forereef	9.5	21.82393	−160.1837
NII-205	14-Aug	Shallow	Forereef	5.5	21.86897	−160.14998
NII-206	14-Aug	Shallow	Forereef	5.0	21.91621	−160.079
NII-207	14-Aug	Shallow	Forereef	5.8	21.95723	−160.06936
NII-209	14-Aug	Shallow	Forereef	5.0	21.87860	−160.11467
NII-210	14-Aug	Moderate	Forereef	15.5	21.80734	−160.19023
NII-215	14-Aug	Moderate	Forereef	11.2	21.88904	−160.08385
NII-272	14-Aug	Shallow	Forereef	4.5	21.78182	−160.21471
NII-303	14-Aug	Moderate	Forereef	12.7	21.85087	−160.16359
NII-220	16-Aug	Deep	Forereef	28.0	22.01224	−160.09995
NII-249	16-Aug	Deep	Forereef	19.4	21.95996	−160.17195
NII-251	16-Aug	Deep	Forereef	22.0	21.96618	−160.14099
NII-259	16-Aug	Moderate	Forereef	15.2	21.98708	−160.12524
NII-268	16-Aug	Moderate	Forereef	6.7	21.88420	−160.23492
NII-285	16-Aug	Shallow	Forereef	5.0	21.92810	−160.18484
NII-286	16-Aug	Shallow	Forereef	2.9	21.93802	−160.16508
NII-287	16-Aug	Shallow	Forereef	5.4	21.90959	−160.20206
NII-293	16-Aug	Deep	Forereef	21.7	21.93568	−160.20241
NII-296	16-Aug	Moderate	Forereef	16.7	21.95337	−160.1468
NII-297	16-Aug	Moderate	Forereef	16.2	21.90993	−160.21649
NII-300	16-Aug	Moderate	Forereef	17.3	21.94105	−160.17774

APPENDIX H: O`AHU ISLAND

The island of O`ahu are is located approximately at 21.44° N, 158.00° W in the north Pacific and are part of the main Hawaiian Island chain. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: Methods.

H.1. Instrumentation, Biological Installations, and Water Quality

Oceanographic operations during the cruise HA-13-04 at O`ahu Island entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), autonomous reef monitoring structures (ARMS), bioerosion monitoring units (BMU), nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select National Coral Reef Monitoring Plan (NCRMP) sites, and shipboard water sampling and CTD casts offshore to a depth of 300 m, and acoustic Doppler current profiler (ADCP) transects.

At nearshore locations around O`ahu Island, 4 shallow-water CTD casts were performed at each location where water samples were collected, this includes sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Five shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 1 STR was retrieved and 3 STRs were deployed. Three ARMS were recovered and processed for taxonomic analysis and 3 ARMS were deployed. Five CAUs were deployed at 1 location around the island and 5 BMUs were collocated at the CAU site, which is a part of the NCRMP monitoring stations (Fig. H.1.1 and Table H.1.1).

From the NOAA Ship *Hi`ialakai*, ~ 20 km of ADCP transect lines were run in the 4 cardinal directions (N, S, E, W) away from this island during night operations. On the reciprocal course, shipboard CTD casts were conducted to a depth of 300 m per transect line every 2 km for a total of 25 deep water CTD casts. Water samples were collected concurrently at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. Near O`ahu Island, 30 chl-*a* shipboard water samples were collected (Fig. H.1.2).

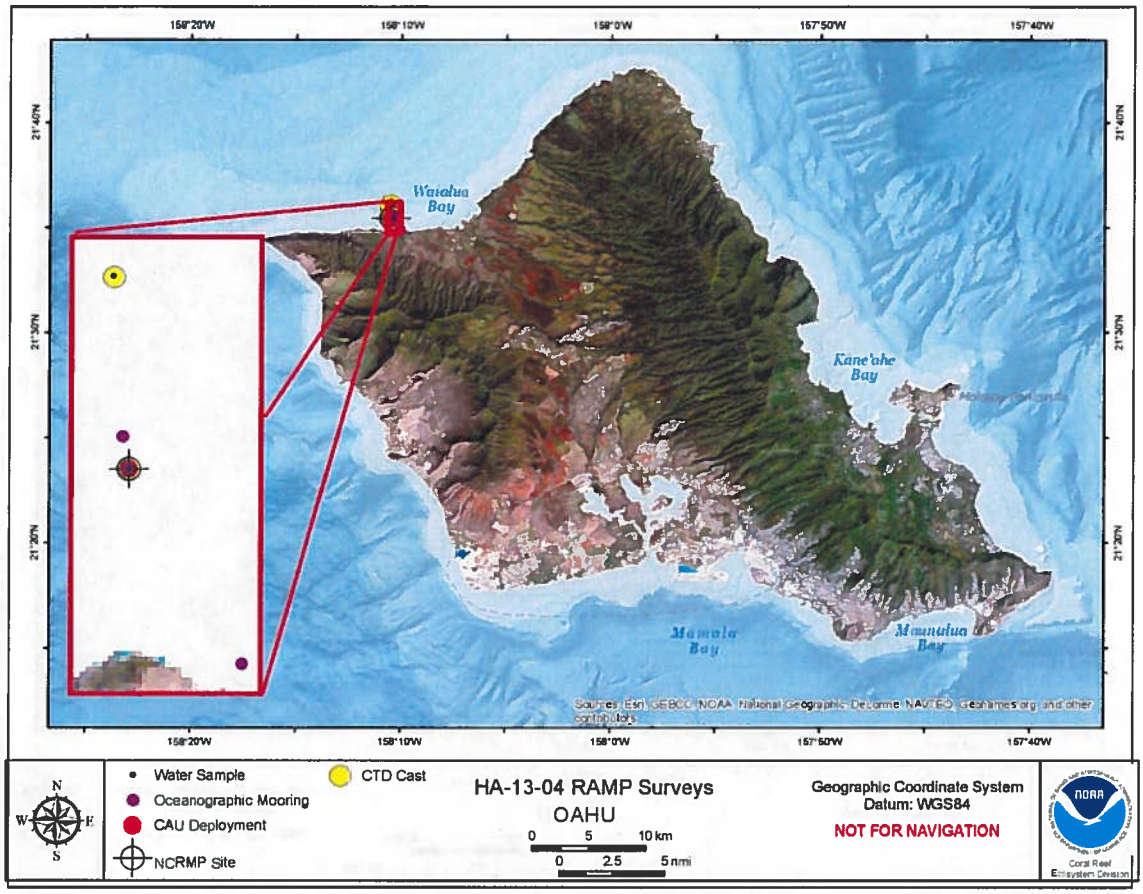

Figure H.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of nearshore CTD casts and water sampling performed at O`ahu Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table H.1.1.-- Geographic coordinates and depths of the moored oceanographic instruments (STR, EAR) and biological installations (CAU, ARMS, and BMUs), that were retrieved or deployed at O`ahu Island during cruise HA-13-04.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
OAH-001	18-Aug	STR	21.58088	−158.16856	5.5	1	1
OAH-017	18-Aug	STR	21.59090	−158.17439	14.6	–	1
OAH-018	18-Aug	STR	21.59256	−158.17472	25.3	–	1
OAH-20	18-Aug	ARMS	21.59090	−158.17439	14.6	–	3
OAH-20	18-Aug	BMU	21.59090	−158.17439	14.6	–	5
OAH-20	18-Aug	CAU	21.59090	−158.17439	14.6	–	5

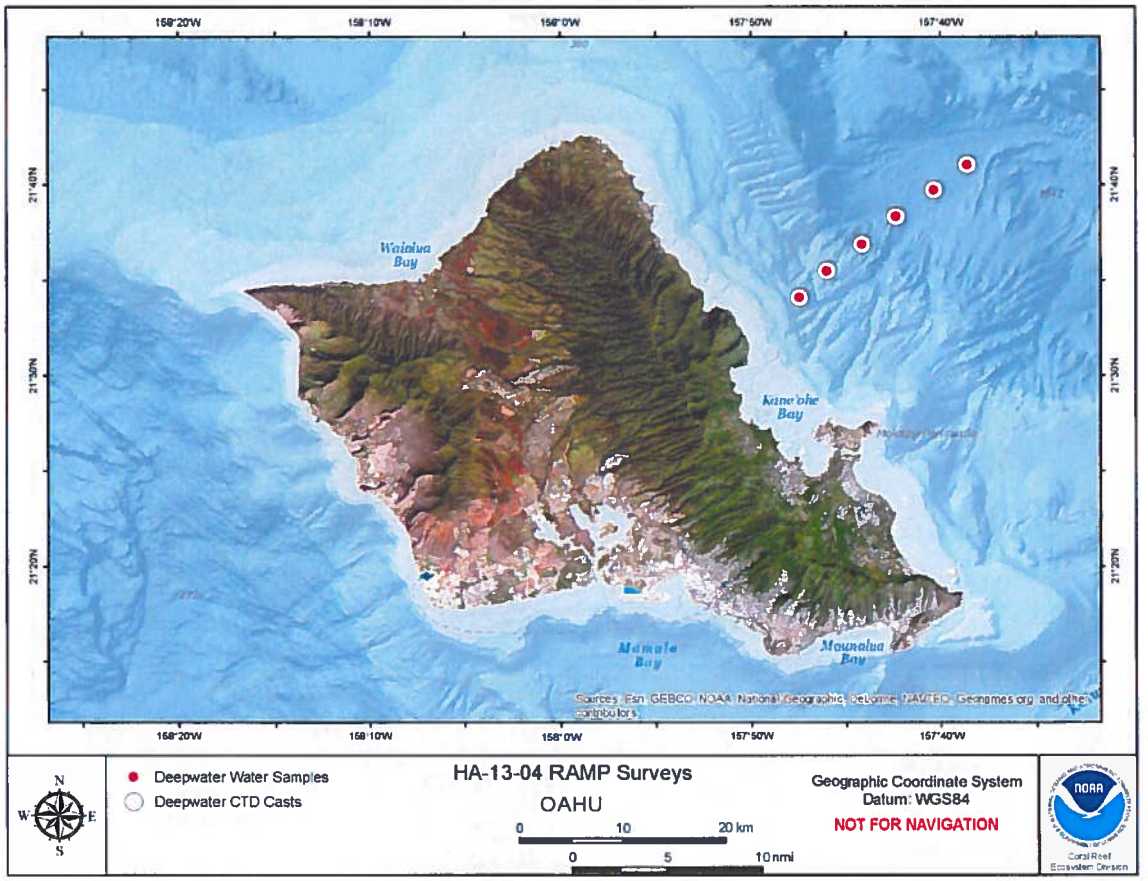

Figure H.1.2.--Locations of deep-water CTD casts and water sampling performed at O`ahu Island during cruise HA-13-04. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

H.2. Biological Monitoring: Benthic Surveys and Microbial Sampling

Rapid Ecological Assessment (REA) benthic sampling utilized a two-stage stratified random sampling design approach that incorporated both broad categories of reef structure and depth to define habitat strata. Belt-transect surveys were conducted and photographs were taken along transect lines at 6 randomly located sites on O`ahu Island. Two microbial water samples were collected at 1 benthic REA survey site (Fig. H.2.1 and Table H.2.1). For more information about collections made at REA sites, see Table I.1.1 in Appendix I: Biological Collections.

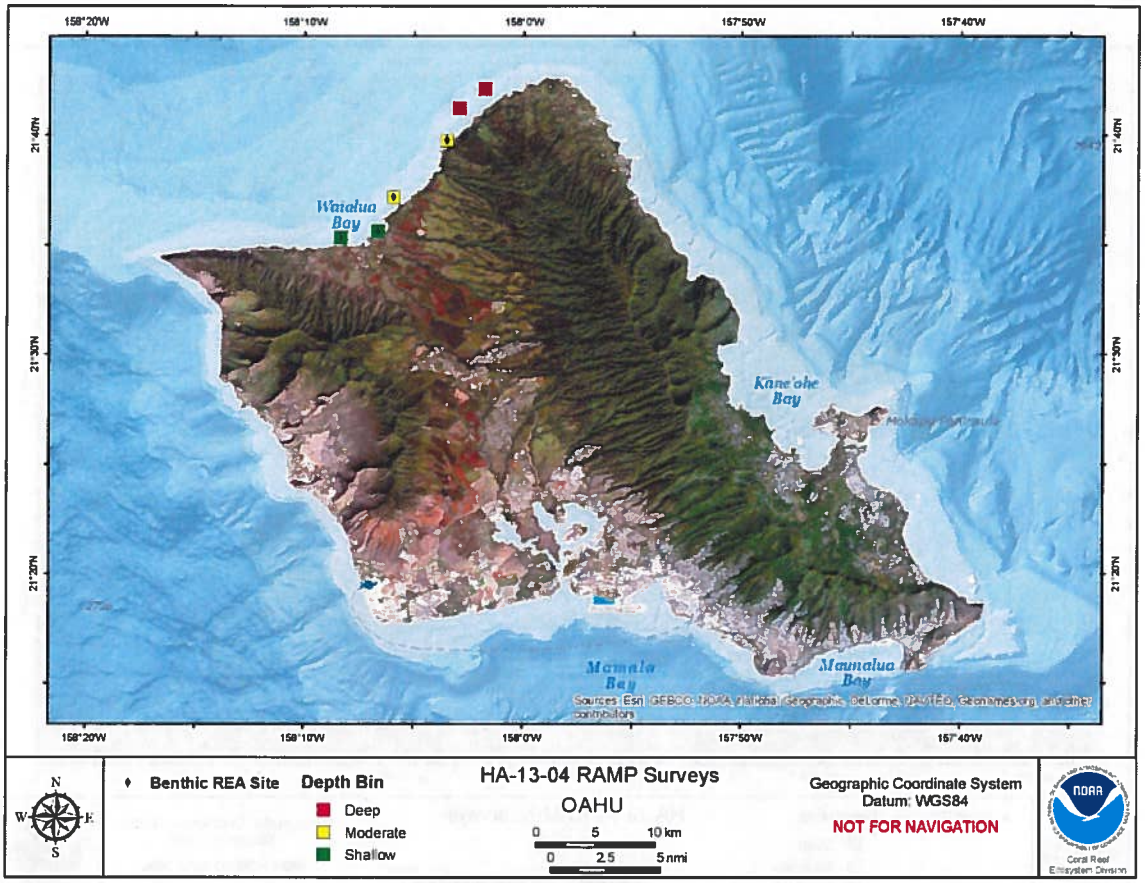

Figure H.2.1.--Locations of REA benthic sites surveyed at O`ahu Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table H.2.1.--Summary of REA benthic surveys and microbial water collections performed at O`ahu Island during cruise HA-13-04.

REA Site	Date	Depth Bin	Reef Zone	Depth (ft)	Latitude	Longitude	REA Coral Survey	Microbial Samples
OAH-1508	18-Aug	Deep	Forereef	23.0	21.68721	−158.0486	x	
OAH-1509	18-Aug	Deep	Forereef	20.3	21.70166	−158.02944	x	
OAH-1529	18-Aug	Moderate	Forereef	9.7	21.6626	−158.05841	x	
OAH-1537	18-Aug	Moderate	Forereef	13.3	21.61967	−158.09922	x	3
OAH-1543	18-Aug	Shallow	Forereef	4.2	21.58879	−158.13884	x	
OAH-1558	18-Aug	Shallow	Forereef	2.7	21.59353	−158.1109	x	

H.3. Biological Monitoring: Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 14 REA sites at O`ahu Island over three different habitat strata: deep, moderate, and shallow forereef (Fig. H.3.1 and Table H.3.1). No fishes were collected during these surveys.

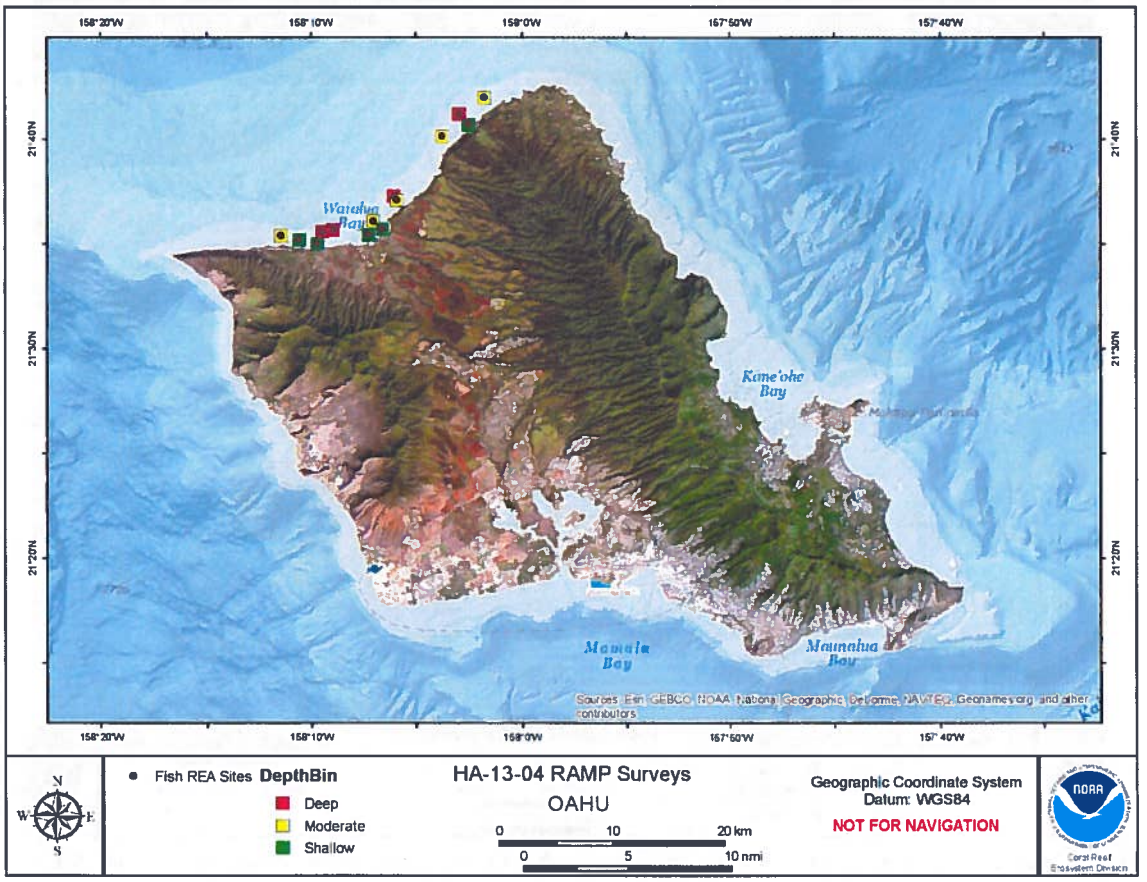

Figure H.3.1.--Locations of REA fish sites surveyed at O`ahu Island during cruise HA-13-04. All of these REA sites were selected using a stratified random design. (Sources: Landsat satellite imagery data from the U.S. Geological Survey; bathymetry imagery data from Esri, GEBCO, NOAA, National Geographic, DeLorme, NAVTEQ, Geonames.org, and other contributors.)

Table H.3.1.--Summary of sites where REA fish surveys were conducted at Ni`ihau Island and Lehua Rock during cruise HA-13-04.

REA_Site	Date	DepthBin	Reef_Zone	Depth_(m)	Latitude	Longitude
OAH-504	18-Aug	Deep	Forereef	24.2	21.62143	−158.10065
OAH-508	18-Aug	Deep	Forereef	23.5	21.68698	−158.04889
OAH-511	18-Aug	Deep	Forereef	24.2	21.59315	−158.15797
OAH-515	18-Aug	Deep	Forereef	28.0	21.59451	−158.14942
OAH-522	18-Aug	Moderate	Forereef	11.2	21.66921	−158.06214
OAH-523	18-Aug	Shallow	Forereef	4.0	21.58317	−158.16212
OAH-524	18-Aug	Moderate	Forereef	14.2	21.69970	−158.02915
OAH-532	18-Aug	Moderate	Forereef	10.0	21.60149	−158.11759
OAH-537	18-Aug	Moderate	Forereef	9.1	21.61841	−158.09855
OAH-549	18-Aug	Shallow	Forereef	3.6	21.59095	−158.1215
OAH-554	18-Aug	Shallow	Forereef	3.3	21.67846	−158.04152
OAH-558	18-Aug	Shallow	Forereef	4.2	21.59508	−158.11047
OAH-620	18-Aug	Moderate	Forereef	9.4	21.59008	−158.19099
OAH-625	18-Aug	Shallow	Forereef	3.3	21.58682	−158.17659

APPENDIX I: BIOLOGICAL COLLECTIONS

Biological and other samples were collected at Hawai`i Island, Kaua`i Island, Lāna`i Island, Maui Island, Moloka`i Island, Ni`ihau Island, and O`ahu Island and their surrounding waters for multiple research purposes. These collections are listed here in Table I.1.1.

Table I.1.1.--Samples collected at Hawai`i, Island, Kaua`i Island. Lāna`i Island, Maui Island, Moloka`i Island, Ni`ihau Island and Lehua Rock, and O`ahu Island, for microbial analyses during cruise HA-13-04.

REA Site	Date	Latitude	Longitude	Specimen Collected	Number of Samples	Depth (m)
Microbial Collections: Water Samples and Coral Rubble						
HAW-1411	3-Aug	20.23514	-155.75179	2 L	2	12.8
HAW-1566	4-Aug	19.16066	-155.91548	2 L	2	13.7
HAW-1643	5-Aug	19.74482	-155.05386	2 L	2	13.1
HAW-1648	6-Aug	19.40823	-154.90147	2 L	2	13.7
HAW-1743	6-Aug	19.35570	-154.96618	2 L	2	13.7
HAW-1693	7-Aug	19.07674	-155.55323	2 L	2	13.7
HAW-1540	8-Aug	20.00324	-155.83318	2 L	2	15.2
HAW-1540	8-Aug	20.00324	-155.83318	80 L	1	15.2
MAI-1488	9-Aug	20.86447	-156.13911	2 L	2	12.2
MAI-1488	9-Aug	20.86447	-156.13911	80 L	1	12.2
MAI-1443	10-Aug	20.80088	-156.61150	2 L	2	13.7
MOL-1461	11-Aug	21.08328	-157.13172	2 L	2	13.7
MOL-1461	11-Aug	21.08328	-157.13172	Coral rubble	2	15.2
KAU-1246	13-Aug	21.96207	-159.32846	2 L	2	13.7
NII-1303	14-Aug	21.85115	-160.16328	2 L	2	12.5
NII-1303	14-Aug	21.85115	-160.16328	80 L	1	12.5
KAU-1363	15-Aug	22.16861	-159.70004	2 L	2	12.5
NII-1227	16-Aug	22.00152	-160.10421	2 L	2	10.7
NII-1227	16-Aug	22.00152	-160.10421	Coral rubble	1	11.9
KAU-1263	17-Aug	21.91232	-159.65221	2 L	2	12.2
KAU-1263	17-Aug	21.91232	-159.65221	80 L	1	12.2
OAH-1537	18-Aug	21.61967	-158.09922	2 L	2	13.4
OAH-1537	18-Aug	21.61967	-158.09922	80 L	1	13.4
MOL-1509	19-Aug	21.13988	-157.29341	2 L	2	9.1
MOL-1435	20-Aug	21.17481	-156.82139	2 L	2	14.0
MOL-1435	20-Aug	21.17481	-156.82139	80 L	1	14.0
MOL-1435	20-Aug	21.17481	-156.82139	Coral rubble	1	14.0
LAN-1248	21-Aug	20.90297	-156.87286	2 L	2	11.6
LAN-1254	21-Aug	20.92208	-156.91354	2 L	2	3.7
LAN-1269	22-Aug	20.76167	-156.83340	2 L	2	12.5
LAN-1269	22-Aug	20.76167	-156.83340	80 L	1	12.5