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-10-08

CRUISE PERIOD: 07 October–05 November 2010

AREA OF OPERATION: Main Hawaiian Islands: Hawai`i Island, Maui Island, Lāna`i Island, Kaua`i Island, Ni`ihau Island, Lehua Rock, 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 and the Division of Aquatic Resources of the Hawai`i Department of Land and Natural Resources conducted interdisciplinary Pacific Reef and Assessment Program (Pacific RAMP) surveys in waters surrounding the main Hawaiian Islands. All research activities described in this report were conducted in compliance with and following guidance provided by the Hawai`i Department of Land and Natural Resources, Division of Aquatic Resources.

ITINERARY:

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

October 7 Start of cruise. Embarked all scientific crew. Departed Pearl Harbor, Honolulu, O`ahu Island, at 1400, and began transit to Hawai`i Island.

October 8 Arrived at Hawai`i Island and began field operations. A subsurface temperature recorder (STR) was replaced. Nearshore water samples were collected for chlorophyll-*a* (Chl-*a*), nutrient, dissolved inorganic carbon (DIC), salinity, and microbial community analyses. Nearshore conductivity, temperature, and depth (CTD) profiles were collected. No shipboard CTD casts were collected because of a malfunction of the winch equipment.

[1] PIFSC Cruise Report CR-11-001
Issued 21 February 2011

October 9 Continued field operations at Hawai`i Island. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included acoustic Doppler current profiler (ADCP) transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 10 Continued field operations at Hawai`i Island. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 11 Continued field operations at Hawai`i Island. Retrieved and deployed the following types of instruments: STR, autonomous reef monitoring structure (ARMS), and ecosystem acoustic recorder (EAR).Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected. No shipboard operations were conducted due to unfavorable weather conditions.

October 12 Continued field operations at Hawai`i Island. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 13 Continued field operations at Hawai`i Island. ARMS were recovered and redeployed. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Neashore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 14 Continued field operations at Hawai`i Island. Retrieved and deployed the following types of instruments: STR and EAR. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations. Began transit to Maui Island.

October 15 Arrived at Maui Island, and started field operations. ARMS were recovered and redeployed. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included

ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 16 Continued field operations at Maui Island. An STR was replaced. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 17 Rest day. No diving activities occurred.

October 18 Continued field operations at Maui Island. An STR was replaced. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 19 Continued field operations at Maui Island. An STR was replaced. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 20 Continued field operations at Maui Island. Retrieved and deployed STRs and an EAR. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 21 Began field operations at Lāna`i Island. Retrieved and deployed an STR. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 22 Continued field operations at Lāna`i Island. Retrieved and deployed STRs. Nearshore water samples were collected for Chl-*a*, nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 23 Conducted field operations at Moloka`i Island. Retrieved and deployed STRs. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 24 Began field operations at O`ahu Island. Retrieved and deployed ARMS. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 25 Continued field operations at O`ahu Island. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected. No shipboard operations were conducted.

October 26 Arrived at Pearl Harbor for refueling. Disembarked Tomoko Acoba, Mary Donovan, Pollyana Fisher-Pool, Kaylyn McCoy, Jill Zamzow, and Jonatha Giddens. Embarked Ivor Williams, Emily Donham, Julia Ehses, Lisa Munger, and Courtney Couch. Departed Pearl Harbor, Honolulu, O`ahu Island, at 1600 in transit to Kaua`i Island.

October 27 Arrived at Kaua`i Island, and began field operations. Retrieved and deployed the following types of instruments: STR, wave-and-tide recorder (WTR), ARMS, and EAR. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected; no shipboard operations were conducted.

October 28 Began field operations at Ni`ihau Island and Lehua Rock. Retrieved and deployed an STR. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 29 Continued field operations at Kaua`i Island. Retrieved and deployed ARMS. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 30 Continued field operations at Kaua`i Island. Retrieved and deployed an STR. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

October 31 Continued field operations at Kaua`i Island. Retrieved and deployed ARMS. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations.

November 1 Continued field operations at Ni`ihau Island. Retrieved and deployed an STR. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included ADCP transects, deepwater CTD casts, and deepwater water sampling for Chl-*a* and nutrient concentrations. Transited to O`ahu Island.

November 2 Arrived at O`ahu Island, and continued field operations. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected; no shipboard operations were conducted.

November 3 Continued field operations at Moloka`i Island. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected; no shipboard operations were conducted.

November 4 Continued field operations at Moloka`i Island. Nearshore water samples were collected for Chl-*a,* nutrient, DIC, salinity, and microbial community analyses. Nearshore CTD profiles were collected; no shipboard operations were conducted.

November 5 Arrived at Pearl Harbor, Honolulu, O`ahu Island. Disembarked all scientific crew. End of cruise.

MISSIONS:

A. Conducted ecosystem monitoring of the species composition, abundance, percentage of cover, size distribution, and general health of the fishes, corals, target macroinvertebrates, and algae of the shallow-water (≤ 30 m) coral reef ecosystems of the main Hawaiian Islands.

B. Deployed and retrieved an array of instruments—including STRs, WTRs, ARMS, and EARs—to allow for remote, long-term monitoring of oceanographic, environmental, and ecological conditions affecting the coral reef ecosystems of the main Hawaiian Islands.

C. Conducted shallow-water CTD casts and collected water samples for Chl-*a*, nutrient, DIC, 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, using CTD casts deployed to a depth of 500 m, collecting water samples to a depth of 150 m, collecting ADCP data around reef ecosystems, measuring sea-surface temperature and salinity, and collecting fundamental meteorological data, such as air temperature, wind speed and direction, barometric pressure, and relative humidity to examine physical and biological linkages supporting and maintaining these island ecosystems.

E. 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-10-08, and a summary of important observations. For more information pertaining to the data collected and methodology employed at the islands visited, see Appendices A–I.

Table 1. Statistics for the Pacific RAMP 2010 cruise to the main Hawaiian Islands (cruise HA-10-08), including the islands of Hawai`i (HAW), Maui (MAI), Lāna`i (LAN), Kaua`i (KAU), Ni`ihau (NII), Lehua (LEH), O`ahu (OAH), and Moloka`i (MOL). The total numbers for REA sites includes 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**	**MAI**	**LAN**	**KAU**	**NII**	**LEH**	**OAH**	**MOL**	**Total**
Scuba Dives	334	233	108	179	120	7	79	134	1194
Biological Surveys									
Towed-diver Surveys: Benthic and Fish	37	24	10	22	7	2	14	11	127
Combined Length (km) of Towed-diver Surveys	80.6	55.6	26.4	55.5	15.2	4.4	30.4	25.7	293.8
REA Sites: Benthic	21	15	6	12	6	0	8	10	78
REA Sites: Fish	43	33	16	26	16	0	15	10	159
Biological Sample Collections									
Metagenomic Microbial Water Samples Collected	3	3	3	3	0	0	3	0	12
Microbial Water Samples Collected	28	20	8	16	8	0	12	12	100
Biological Moored Installations									0
ARMS Retrieved	9	3	0	10	0	0	6	0	31
ARMS Deployed	6	3	0	6	0	0	3	0	18
EARs Retrieved	2	1	0	1	0	0	0	0	4
EARs Deployed	2	1	0	1	0	0	0	0	4
Oceanographic Moored Instruments									
STRs Retrieved	6	5	2	2	1	1	0	2	18
STRs Deployed	6	5	2	2	1	1	0	2	18
WTRs Retrieved	0	0	0	1	0	0	0	0	1
Anchors Retrieved	0	1	0	1	0	0	0	0	2
Anchors Deployed	0	1	0	0	0	0	0	0	1
Hydrographic Surveys									
Shallow-water CTD Casts (from small boats)	13	9	4	5	3	0	3	6	43
Deepwater CTD Casts (from *Hi`ialakai*): Total	24	50	10	15	7	0	18	9	133
Total Length (km) of ADCP Transects	120	200	50	65	40	0	90	200	765
Water-quality Sampling									
Shallow-water DIC Water Samples Collected	26	18	8	10	6	0	8	12	88
Shallow-water Chl-*a* Water Samples Collected	25	18	8	10	6	0	8	12	87
Shallow-water Nutrient Water Samples Collected	29	18	8	12	6	0	8	12	88
Shallow-water Salinity Water Samples Collected	26	18	8	10	6	0	8	12	88
Deepwater Chl-*a* Water Samples Collected	53	75	15	30	10	0	25	15	223
Deepwater Nutrient Water Samples Collected	55	75	15	30	10	0	25	15	225

The coral reef ecosystems of the main Hawaiian Islands are surveyed biennially through CRED's Pacific RAMP. The cruise HA-10-08 marked this program's fourth expedition around the islands of Hawai`i, Maui, Lāna`i, O`ahu, Kaua`i, Ni`ihau, and Moloka`i and Lehua Rock. Here, 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 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.
- A few cases of coral disease involving ciliates (only recently discovered in the main Hawaiian Islands) were noted affecting colonies of *Montipora capitata*.
- Several new permanent benthic REA sites were added along the northwest and southwest exposures. Noteworthy were results from REA site HAW-39 on the southwest coast, where some of the highest overall coral cover and the highest overall coral colony counts of any site visited around the Big Island were recorded.
- The finescaled triggerfish (*Balistes polylepis*), native to the eastern Pacific and only recently seen in the main Hawaiian Islands, was observed guarding one of its nests off the southwest forereef.

Maui Island

- 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.
- Notable coral species richness and structural complexity, as well as fair amounts of disease, were observed for benthic communities in the vicinity of Hana Bay, in particular at HAN-01.
- Large schools (100+) of the juvenile sleek unicornfish (*Naso hexacanthus*) were seen at several sites on the southwestern forereef.
- The rarely seen longnose hawkfish (*Oxycirrhites typus*) was seen perched on black coral on the northern forereef.

Lāna`i 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.

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.

- Two shallow (depths < 35 m) coral communities on north and south Kaua`i were notable for the prevalence of coral diseases, particularly tissue loss lesions on *Monitpora* at the northern site KAU-13 and skeletal growth anomalies on *Porites* at the southern site KAU-05.

Ni`ihau Island

- 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 benthic communities surveyed around Ni`ihau Island were coral depauperate. Surge-soured bottoms and runoff appeared to be major factors limiting coral community development in this area.

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.

Moloka`i Island

- This cruise HA-10-08 in 2010 was the first time CRED teams surveyed the Moloka`i reef, which is an outstanding formation with notable percentage of live coral cover and merits continued monitoring.
- An outbreak of crown-of-thorns seastars (COTS) was sighted along the Moloka`i reef, with several focal points of increased COTS densities.

The following data and samples were collected during this expedition:

REA Benthic Surveys:

- Digital still photos of overall site character and typical benthos
- Digital photoquadrat images of the benthos
- Quantitative assessments of benthic composition from line-point-intercept surveys
- Algal voucher specimens necessary for algal species identification
- Field notes of algal species diversity and relative abundance
- Quantitative assessments of the number of coral colonies by genus, within belt transects of known area, and overall coral colony density
- Size-class metrics of corals within belt transects of known area
- Quantitative assessments of the number of coral colonies exhibiting signs of bleaching and disease within belt transects of known area
- Digital photographs of diseased corals and coralline algae
- Field notes on signs of coral bleaching or disease
- Quantitative assessments of target macroinvertebrate taxa
- Field notes on the size and relative abundance of sea urchins and crown-of-thorns seastars

REA Fish Surveys:

- Number, species, and estimated sizes of all fishes observed within a 7.5-m radius from stationary-point-count surveys
- Visual estimates of benthic cover, habitat type, and habitat complexity
- Digital still photographs to characterize benthic coral reef community cover
- Digital photographs of rare or interesting fish species
- Species presence checklists for estimates of fish community diversity

Towed-diver Surveys:

- Digital photographs and video of benthic habitats
- Temperature data
- Counts of target macroinvertebrates, including crown-of-thorns seastars, sea cucumbers, and sea urchins
- Quantitative assessments of large (≥ 50 cm in total length) reef fishes to species level
- Quantitative and qualitative assessments of key protected species and species of concern, including cetaceans, sea turtles, and rare fishes
- Benthic habitat characterization

Shipboard Oceanography:

- Deepwater CTD profiles to a depth of 500 m
- Chl-*a* and nutrient concentrations from water samples collected at variable depths
- Dissolved oxygen, turbidity, and fluorescence measurements from 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

- Select surface measurements of partial pressure of carbon dioxide (pCO_2)
- Surface temperature and salinity measurements

Nearshore Oceanography from Small Boats:

- Shallow-water CTD profiles to a depth of ~ 30 m.
- Shallow-water CTD profiles with dissolved oxygen measurements at sites identified for potential deployments of calcification acidification units (CAUs)
- Chl-*a* and nutrient concentrations from water samples collected in concert with shallow-water (≤ 30 m) CTD casts
- Chl-*a*, nutrient, salinity, and carbonate chemistry samples from potential CAU sites
- DIC and salinity concentrations from water samples collected in concert with shallow-water (≤ 30 m) CTD casts

Moored Biological Instruments:

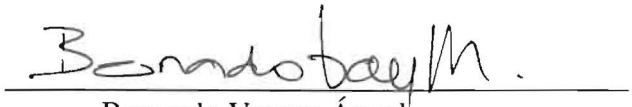
- Environmental acoustics of reefs, marine mammals, and boat traffic from EARs
- Assessment of taxonomic diversity of coral reef species by collection of invertebrate specimens from retrieved ARMS

Moored Oceanographic Instruments:

- Sea-surface and subsurface temperature at variable depths
- Sea-surface and subsurface salinity at variable depths
- Spectral wave and tidal elevation
- Single-point and directional ocean currents
- Surface air temperature, wind speed and direction, barometric pressure, and ultraviolet radiation

SCIENTIFIC PERSONNEL:

Bernardo Vargas-Ángel, Chief Scientist, Benthic Team—Coral Populations and Disease, University of Hawai`i (UH)-Joint Institute for Marine and Atmospheric Research (JIMAR), Pacific Islands Fisheries Science Center (PIFSC)-Coral Reef Ecosystems Division (CRED)
Tomoko Acoba, Data Manager, UH-JIMAR, PIFSC-CRED
Jeff Anderson, Towed-diver Benthic Team, UH-JIMAR, PIFSC-CRED
Jacob Asher, Benthic Team—Coral Populations and Disease, UH-JIMAR, PIFSC-CRED
Paula Ayotte, Fish Team, UH-JIMAR, PIFSC-CRED
Edmund Coccagna, Towed-diver Fish Team, UH-JIMAR, PIFSC-CRED
Emily Donham, Fish Team, UH-JIMAR, PIFSC-CRED
Mary Donovan, Fish Team, UH-JIMAR, PIFSC-CRED
Julia Ehses, Data Manager, UH-JIMAR, PIFSC-CRED
Pollyanna Fisher-Pool, Oceanography Team, UH-JIMAR, PIFSC-CRED
Jason Helyer, Towed-diver Benthic Team, UH-JIMAR, PIFSC-CRED
Kevin Lino, Towed-diver Fish Team, UH-JIMAR, PIFSC-CRED
Frank Mancini, Oceanography Team, UH-JIMAR, PIFSC-CRED
Kaylyn McCoy, Towed-diver Fish Team, UH-JIMAR, PIFSC-CRED
Lisa Munger, Oceanography Team, UH-JIMAR, PIFSC-CRED and Hawai`i Institute of Marine Biology
Noah Pomeroy, Oceanography Team, UH-JIMAR, PIFSC-CRED
Max Sudnovsky, Benthic Team—Invertebrates/ARMS, UH-JIMAR, PIFSC-CRED
Molly Timmers, Benthic Team—Invertebrates/ARMS, UH-JIMAR, PIFSC-CRED
Oliver Vetter, Oceanography Team, UH-JIMAR, PIFSC-CRED
Ivor Williams, Fish Team, UH-JIMAR, PIFSC-CRED
Rodney Withall, Benthic Team—Benthic Composition, UH-JIMAR, PIFSC-CRED
Jill Zamzow, Fish Team, UH-JIMAR, PIFSC-CRED
Courtney Couch, Benthic Team—Benthic Composition, Cornell University
Jonatha Giddens, Fish Team, University of Hawai`i
Chris Sullivan, Microbial Biologist, San Diego State University
Darla White, Fish Team and Benthic Team—Benthic Composition, Division of Aquatic Resources, Hawai`i Department of Land and Natural Resources

Submitted by: 

Bernardo Vargas-Ángel
Chief Scientist

Approved by: 

Steven Thur
Acting Program Manager
NOAA Coral Reef Conservation Program

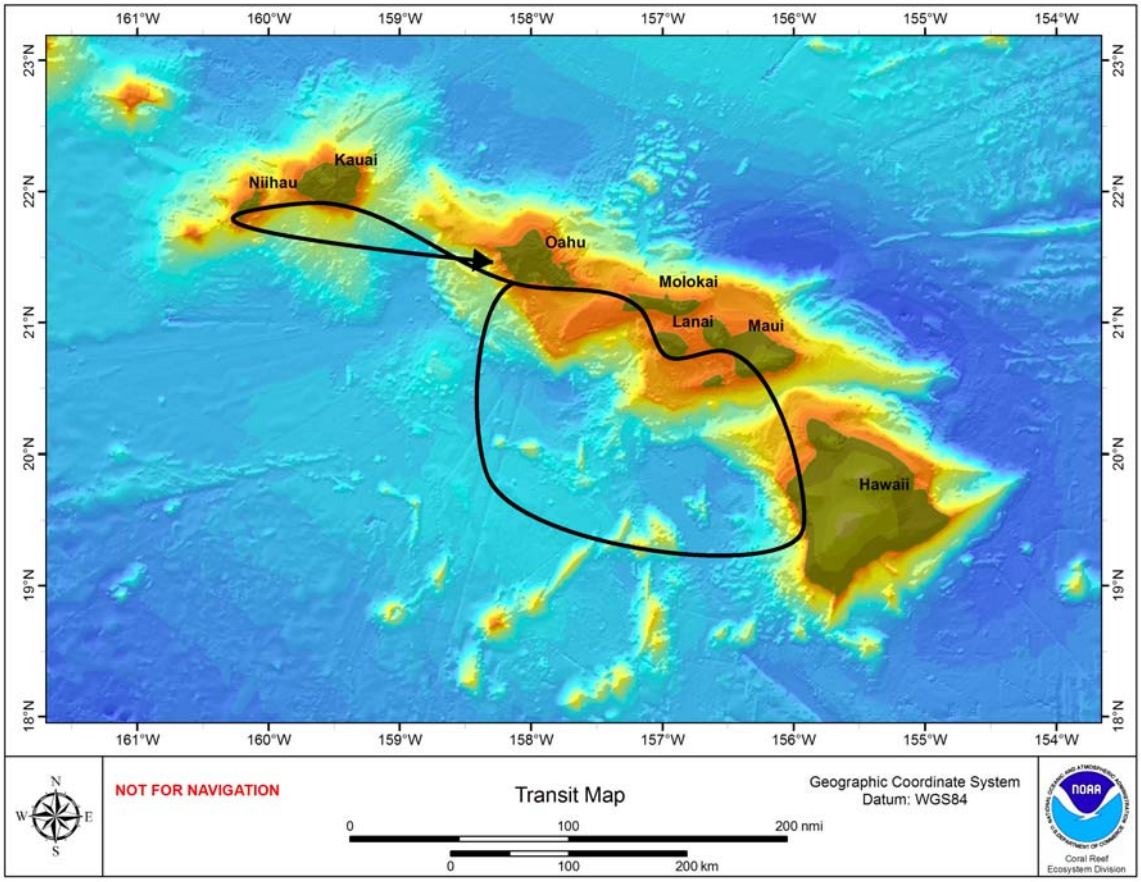


Figure 1.--Track of the NOAA Ship *Hi`ialakai* for the cruise HA-10-08, October 7–November 5, 2010, with Hawai`i Island, Maui Island, Lāna`i Island, Kaua`i Island, Ni`ihau Island, Lehua Rock, O`ahu Island, and Moloka`i Island surveyed. Satellite image SIO, NOAA, U.S. Navy, NGA, GEBCO (Becker, 2009; Smith and Sandwell, 1997) © 2008 The Regents of the University of California.

(This page is left blank intentionally.)

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-10-08 on the NOAA Ship *Hi`ialakai* during the period of October 7–November 5, 2010. The first coral reef assessments led by CRED at the islands of Hawai`i, Maui, Lāna`i, Kaua`i, O`ahu, Ni`ihau, and Moloka`i were conducted in 2005.

A.1. Oceanography and Water Quality

(Pollyanna Fisher-Pool, Frank Mancini, Lisa Munger, Noah Pomeroy, and Oliver Vetter)

To assess and monitor the oceanographic, bioacoustic, and water-quality parameters influencing the coral reef ecosystems in the main Hawaiian Islands (MHI), the oceanography team performed the following activities: (1) conducted deepwater oceanographic surveys characterizing prevailing water properties and ocean currents around these islands and atoll, (2) completed nearshore oceanographic and water-quality surveys, (3) deployed and retrieved an array of subsurface moored instruments designed to provide continuous, high-resolution time-series observations. In addition, shipboard meteorological observations, including wind speed and direction, relative humidity, air temperature, and barometric pressure, were recorded.

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 instrument platforms that internally record in situ observations and telemeter that data in near real time. The following types of instruments were retrieved or deployed during this cruise.

Subsurface Temperature Recorder (STR): provides near-real-time, high-resolution temperature data (SBE 39 sensor, Sea-Bird Electronics Inc., Bellevue, Wash., accuracy of 0.002°C). Data are internally recorded at 30-min intervals. This type of subsurface instrument is deployed at depths of 0.5–40 m.

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.

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 (CTD) Casts: a CTD profiler deployed from a small boat provided data on temperature, conductivity, which is related to salinity, and pressure, which is related to depth (SBE 19*plus* Seacat Profiler, accuracy of 0.005 S m^{-1} in conductivity, 0.0002°C in temperature, and 0.1% in pressure). A transmissometer (C-Star, WET Labs, Philomath, Ore.) provided profiles of beam transmittance, which is related to turbidity. A dissolved oxygen sensor (SBE 43, accuracy of 2% of saturation) was also attached and measurements were made in concert with CTD measurements. Data were collected by hand lowering this profiler off a small boat at descent rates of ~ 0.5–0.75 m s^{-1} at depths ≤ 30 m.

Deepwater (Shipboard) CTD Casts: a ship-based CTD profiler provided high-resolution conductivity, temperature, and pressure data (Sea-Bird Electronics, 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 (SBE43) 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 500 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, Calif.). 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. Data were continuously collected throughout the research cruise.

Water Chemistry: water samples for analyses of concentrations of chlorophyll-*a* (Chl-*a*), dissolved inorganic carbon (DIC), Total Alkalinity (TA), and the nutrients phosphate, PO_4^{3-}; silicate, $Si(OH)_4$; nitrate, NO_3^-; and nitrite, NO_2^-, were collected at select locales concurrently with shallow-water and shipboard CTD casts.

A.2. Benthic Surveys, Monitoring Installations, and Microbial Sampling

(Jeff Anderson, Jake Asher, Edmund Coccagna, Courtney Couch, Jason Helyer, Max Sudnovsky, Chris Sullivan, Molly Timmers, Bernardo Vargas-Ángel, Darla White, and Rodney Withall)

CRED collected integrated information on the species composition (diversity), condition, abundance, and distribution of communities of corals, algae, and target macroinvertebrates and on benthic habitat complexity and substrates using 2 primary methodologies: Rapid Ecological Assessment (REA) surveys and towed-diver surveys. Performed at selected hard-bottom locations, REA benthic surveys include multiple methodologies that use two 25-m transect lines deployed at each REA site. Towed-diver surveys, which follow a depth contour of ~ 15 m and encompass various substrates, cover an area that is much broader than the area surveyed using fine-scale REA techniques. In addition, autonomous reef monitoring structures (ARMS) serve as a mechanism to quantify marine invertebrates that are not easily identifiable during REA surveys. The

REA sites where benthic surveys were conducted typically differ in location from the REA sites selected for fish surveys.

A.2.1. Benthic Composition

Using a line-point-intercept (LPI) method, hard corals, octocorals, macroalgae, crustose coralline red algae, and target macroinvertebrates were identified to the highest possible taxonomic resolution and recorded at 20-cm intervals along two 25-m transect lines set in a single file row (separated by 5 m). These surveys generate 125 points per transect (250 points per site) that can be used to generate percentage of cover of benthic organisms at each REA site. Additionally, in concert with LPI surveys, photoquadrat images were collected to record the benthos at predetermined points along the same 2 transect lines with a high-resolution digital camera mounted on a photoquadrat pole. This work generates 30 photographs per site that are later analyzed by staff at CRED and partners at Scripps Institution of Oceanography, University of California San Diego, using the computer program Coral Point Count with Excel extensions (CPCe), to determine the benthic composition at higher taxonomic levels for each REA site (photographs from similar surveys at REA sites surveyed by the fish team will also be analyzed).

Time permitting at each REA site, roving-diver surveys were conducted after LPI surveys, covering a swath of 3–5 m on either side of the transect lines to record algal species richness.

If algal species encountered during LPI or roving-diver surveys were not identifiable in the field, an example was collected for a voucher specimen and are cataloged and critically analyzed in a CRED laboratory to ensure positive species identification. Provisions were made to ensure appropriate preservation and curation of each algal specimen. These voucher specimens along with the photoquadrat images form permanent historical records, the former of algal diversity and the latter of the composition of benthic communities at each REA site.

In addition to site-specific REA surveys, broad-scale towed-diver surveys were used to determine the benthic composition of shallow-water habitats around each island and to quantify the abundance of target macroinvertebrates, including crown-of-thorns seastars (COTS), sea urchins, and sea cucumbers. A pair of divers, by means similar to a manta-tow technique, were towed 60 m behind a small boat, a 6-m survey launch from SAFE Boats International (Port Orchard, Wash.), with one diver quantifying the benthos and the other quantifying fish populations. Each towed-diver survey lasted 50 min, broken into ten 5-min segments, and covered ~ 2 km. To georeference the survey launch's track, latitude and longitude coordinates were recorded at 5-s intervals using a Garmin GPSMap 76 global positioning system (GPS) unit on the boat. A custom algorithm was used to calculate the track of the divers based on speed and course of the boat and depth of the diver. Each towed-diver platform, or towboard, was equipped with an SBE 39 temperature and depth recorder programmed to record at 5-s intervals. At the end of each day, data were downloaded, processed, and presented in ArcGIS and can be displayed in

conjunction with IKONOS satellite imagery, NOAA chart data, or other spatial data layers.

Towed-diver benthic surveys recorded habitat type and complexity; percentages of cover of benthic fauna, including hard corals, stressed hard corals, octocorals, macroalgae, and crustose coralline red algae, and of physical features, including sand and rubble; and counts of target macroinvertebrates and marine debris. Towed divers classified percentage of cover using a system of 10 bins, ranging from 0%–100% cover of the benthos. Target macroinvertebrates were counted up to 25 individuals per segment and then binned into larger groups when exceeding 25. The benthic towboard was equipped with a downward-facing, high-resolution digital still camera. The camera took a photo of the substrate every 15 s. These photos, like the SBE 39 data, are linked spatially with GPS track files taken aboard the survey launch. Benthic photos can be analyzed later for community structure information.

A.2.2. Community Structure and Disease

At each REA site, the belt-transect method, with two 25-m transect lines as the focal point, was used to quantitatively assess generic richness, colony density, and size class of coral colonies. On each transect, five 2.5-m^2 segments were surveyed (0–2.5 m; 5.0–7.5 m; 10–12.5 m; 15–17.5 m; 20–22.5 m), whereby all coral colonies whose center fell within 0.5 m on either side of each transect line were identified to the highest possible taxonomic resolution and measured using 2 planar size metrics: maximum diameter and diameter perpendicular to the maximum diameter.

For each coral colony identified during belt-transect surveys, the extent of mortality, both recent and old, was estimated and signs of disease or compromised health were recorded, including type of lesion (bleaching, skeletal growth anomaly, white syndrome, tissue loss other than white syndrome, trematodiasis, necrosis, pigmentation responses, algal overgrowth, or other), extent (percentage of colony affected), severity (mild, moderate, marked, severe, or acute). Photographic documentation of affected corals was conducted. Tissue samples were catalogued and fixed in buffered zinc-formalin solution for further histopathological analyses. Levels of predation of corals were also recorded. In tandem with these coral disease surveys at each REA site, the belt-transect method also was used to quantify coralline-algal disease and syndromes, including coralline lethal orange disease, coralline white band syndrome, and coralline cyanobacterial disease. Photographic documentation of affected algae was conducted.

Surveys of target macroinvertebrates were conducted on an opportunistic basis at REA sites where no ARMS installations occurred. Time permitting, macroinvertebrate surveys were conducted along 2 belt transects (1 × 25 m) at selected sites. Target macroinvertebrates were enumerated along these transects, and urchin test sizes were measured. COTS were counted along two belt transects (5 ×25 m). Prey selection was noted for each COTS present within the first belt transect.

Target macroinvertebrates included taxa from the following groups:

CNIDARIA
Actinaria–anemones

ECHINODERMATA
Echinoids—sea urchins
Holothuroids—sea cucumbers
Ophiuroids—brittle starts (generally cryptic but are visible in some cases)

MOLLUSCA
Bivalves—ark shells, spondylid oysters, pearl oysters, tridacnid clams
Nudibranch—sea slugs
Gastropods—snails
Cephalopod—octopus

CRUSTACEA
Hermit crabs, brachyuran crabs, shrimps, and lobsters

A.2.3. Moored Installations for Monitoring Benthic Communities

CRED accomplishes long-term monitoring of benthic biodiversity and the sounds of marine animals through the use of the following types of instruments that were retrieved or deployed during this cruise.

Autonomous Reef Monitoring Structures (ARMS): deployed at several sites at each island, ARMS provide a mechanism to quantify marine invertebrates that were not easily identifiable or accountable on the transect lines used for REA surveys. ARMS were previously installed on the benthos by pounding stainless steel rods by hand into bare substrate during the MHI RAMP 2008 cruise. They remained on the benthos for 2 years, enabling the recruitment and colonization of lesser known, cryptic marine invertebrates, upon which time they will be collected and analyzed.

ARMS previously deployed during the MHI RAMP 2008 cruise were retrieved. First, on the seafloor, the ARMS were covered in a mesh-lined lid to trap the contents, and then they were removed and transported to the ship. There, each unit was systematically disassembled and photo-documented, and all organisms contained in these structures were preserved in ethanol for later genetic and other molecular analyses. At a subsample of these sites, new ARMS units were redeployed onto the stainless steel rods, with the goal of recovering them during the next MHI RAMP cruise scheduled for 2012.

Ecosystem Acoustic Recorder (EAR): the EAR is a passive acoustic device developed specifically for monitoring marine mammals, fishes, crustaceans, other sound-producing marine life, and human activity in marine habitats. The EAR is a digital, low-power system that records ambient sounds up to 30 kHz on a programmable schedule and can also respond to transient acoustic events that meet specific criteria, such as motorized

vessels passing nearby or cetaceans. This type of subsurface instrument typically was deployed at depths of 5–25 m. Note: information about retrievals and deployments of EARs are provided along with information about STR installations in the island appendices, since those instruments are sometimes moored to the same anchor and EARs are typically installed by members of the oceanography team.

A.2.4. Microbial Communities and Water Chemistry

Microbes are a fundamental aspect of all marine ecosystems. The amount of energy from primary production remineralized within the microbial fraction determines the amount of energy available for the entire food web. The abundance and function of the microbial community on reefs may also play an important role in coral health.

Microbial and viral communities on coral reefs have been found to change along with coral reef health. Degraded coral reefs support microbial communities that include a high abundance of potential pathogens and are primarily heterotrophic (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). A primarily heterotrophic and pathogenic microbial community in the water column could potentially lead to coral disease and death.

Collection of Microbial Water Samples: At select REA sites, four 2-L samples of water were collected daily from < 1 m above the benthos using diver-deployable Niskin bottles (4–5 L). These water samples were returned to the ship, where samples were collected first for analyses of dissolved organic carbon (DOC) and particulate organic carbon (POC) and then for determining microbial size and abundance, including bacteria and archaea (single-celled microorganisms). These samples are used for the analyses described here. Also, at one REA site at each island, ~ 60 L of water was collected at reef crevices and surfaces for more in-depth analysis on the microbial community.

Microscopy: 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 milliliter of seawater in the open ocean to 1×10^8 VLPs per milliliter in more productive coastal waters. The number of microbial and protistan cells in seawater is typically 1×10^6 and 1×10^3 cells per milliliter, respectively. Microbial and viral loading and the dominance of heterotrophic bacteria in reef water are linked to coral disease. Trophic-level interactions among bacteria, phages, and protists also affect global nutrient and carbon cycling. The most direct method for assessing and monitoring changes in the abundance of these microbiological components is by fluorescent microscopy using nucleic acid staining.

Enumeration of microbes and viruses. Two replicate 5-mL samples were collected and fixed using paraformaldehyde and filtered through 0.2-µm filters. These filters were

stained using SYBR Gold (Molecular Probes Inc., Eugene, Ore.), a general nucleic acid stain, and mounted onto a microscope slide.

Enumeration of protists. 50-mL of water from each sample was fixed with glutaraldehyde; stained with 4',6-Diamidino-2-phenylindole (DAPI), a general nucleic acid stain for staining double-stranded DNA (dsDNA); and filtered onto a 0.8-µm black polycarbonate filter.

Frequency of dividing cells. Two replicate 5-mL samples were fixed with glutaraldehyde and filtered through 0.2-µm filters. These filters were then stained with DAPI and mounted onto a glass microscope slide.

The filters described previously will be used to count the number and size of microbial components and quantify actively dividing microbial cells. This enumeration will be performed using fluorescent microscopy at San Diego State University. All filters will be stored at −20ºC for archival purposes.

Water Chemistry (DOC/POC): Spatial assessment of microbial, viral, and protist components with respect to levels of DOC, nutrients, and particulate organics within coral reef ecosystems may identify important predictors of coral reef ecosystem degradation—information that will be essential for designing the most effective coral reef ecosystem monitoring strategy possible.

To assess dissolved organic carbon (DOC) concentrations, ~ 30 mL of seawater was filtered through pre-combusted glass fiber filters from each of the 4 Niskin bottles and the filtrate was collected in pre-combusted glass bottles. Hydrochloric acid was added to each bottle to remove DIC, and the bottles were stored upright at 4°C. To assess particulate organic carbon (POC), a total of 500 mL of seawater was filtered through a glass fiber filter, one for each Niskin bottle, and the filters were stored at –20°C. DOC and POC and stable isotopes of carbon and nitrogen will be later analyzed by partners at San Diego State University, via standard protocols after return to shore.

Microbial DNA Samples: The structure of the bacterial community will be assessed by metagenomic analysis, which involves collection of environmental DNA via filtration followed by 454 sequencing. Metagenomics is a powerful tool for studying environmental populations, as < 1% of all environmental microbial diversity is currently cultivable. The remaining water in each Niskin bottle was pushed through a 20-µm pre-filter to remove large eukaryotic organisms. This 20-µm filtrate was then pushed through 0.22-µm Sterivex filters to trap microbes (2 filters, ~ 2.5 L each). These filters were stored at –20ºC and will be used to determine microbial community diversity and function. DNA isolation and metagenomic analysis will be completed at San Diego State University.

Flow Cytometry: Flow cytometry will be used primarily to characterize the size structure of microbial communities (e.g., autotroph vs. heterotroph abundance and viral

abundance). This technique will also provide complementary data for abundance counts, metagenomic analysis, and Chl-*a* analysis.

Five 1-mL samples of water from each REA site were pushed through a 20-µm filter. This filtrate was dispensed into cryovials (5 × 1 mL) and fixed with glutaraldehyde. Vials were inverted to mix and incubated in the dark for 15 min. Glutaraldehyde-preserved samples were flash frozen in liquid nitrogen contained in a dry shipper to prevent damage to microbial cells. These samples were shipped upon return to Honolulu on dry ice to San Diego State University for flow cytometry analysis.

Large Water Samples at Reef Crevices: At one REA site per island, ~ 60 L of water was collected using a manual bilge pump, which fills four 20-L collapsible carboys with water from reef crevices. This sample was then pre-filtered through 100-µm mesh upon return to the ship and then concentrated using tangential flow filtration, which concentrates the bacteria and viruses in the water. The initial ~ 60 L of water was brought 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 then frozen. The DNA of the entire community will be extracted and sequenced at San Diego State University, and the diversity and function of the microbial communities on the sampled reefs will be analyzed. The filtrate from this sample was also kept and contains concentrated viruses. Chloroform was added to this filtrate to kill any small microbes, and then this sample was stored at 4°C. Once shipped to San Diego State University, 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.

A.3. Surveys of Reef Fishes

(Paula Ayotte, Edmund Coccagna, Emily Donham, Mary Donovan, Jonatha Giddens, Kevin Lino, Kaylyn McCoy, Darla White, Ivor Williams, and Jill Zamzow)

Four 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 either 1 or 2 SPC surveys 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. 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, 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. All fishes observed off transect were recorded for presence data, as were more mobile, non-cryptic fishes that were seen after the initial 5 min of a survey.

After a survey was completed, divers recorded benthic habitat information from their respective cylindrical survey areas. Divers recorded habitat complexity, habitat type, and percentage of cover for hard corals, macroalgae, crustose coralline red algae, turf algae, and sand. Every 2 m along the transect line, photoquadrat images were taken of the benthos at a distance of 1 m from the right side of the line. If only one replicate was completed, photoquadrat images were taken at each meter mark. Like the photoquadrat images taken during surveys at REA benthic sites, these images will later be analyzed by staff at CRED and partner organizations.

If bottom time and air permitted, the 30-m transect line was moved to another location 5–10 m away at the same depth stratum, and this procedure was repeated.

In addition to site-specific REA surveys, broad-scale towed-diver surveys were used to characterize the fish communities of shallow-water habitats around each island. A pair of divers, by means similar to a manta-tow technique, was towed 60 m behind a small boat, a 6-m survey launch from SAFE Boats International, with one diver quantifying fish populations and the other quantifying the benthos. Each towed-diver survey lasted 50 min, broken into ten 5-min segments, and covered ~ 2 km. To georeference the survey launch's track, latitude and longitude coordinates were recorded at 5-s intervals using a Garmin GPSMap 76 GPS unit on the boat. A custom algorithm was used to calculate the track of the divers based on the track, speed, and course of the boat and depth of the diver. Each towed-diver platform, or towboard, was equipped with an SBE 39 temperature and depth recorder set to record at 5-s intervals. At the end of each day, data were downloaded, processed, and presented in ArcGIS and can be displayed in conjunction with IKONOS satellite imagery, NOAA chart data, or other spatial data layers.

Towed-diver fish surveys record, to the lowest possible taxon, all fishes > 50 cm in total length along a 10-m swath during each 5-min segment. Individual fishes were counted and their species (or lowest possible taxon) and length in centimeters recorded. Sightings of species of particular concern observed outside the survey swath were classified as presence/absence data and were recorded separately from the quantitative swath data. At the end of each day, data were transcribed from field data sheets into a centralized Microsoft Access database. Biomass values are calculated using species-specific length-weight parameters and are normalized by area (i.e., kg 100 m^{-2}). The fish towboard was equipped with a forward-looking digital video camera that created a visual archive of the survey track that can be used to evaluate stochastic changes in reef environments, particularly following episodic events, such as coral bleaching and grounding of a vessel.

(This page is left blank intentionally.)

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 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."

B.1. Oceanography and Water Quality

Oceanographic operations during HA-10-08 at Hawai`i Island entailed numerous retrievals and deployments of oceanographic moored instruments, nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, and shipboard water sampling and CTD casts offshore to a depth of 500 m.

Five subsurface temperature recorders (STRs) were retrieved, and 5 were deployed (Fig. B.1.1). Two of these STRs were deployed on environmental acoustic recorder (EAR) moorings. Two EAR moorings were serviced, and their EAR units were swapped. (Table B.1.1).

At nearshore locations around Hawai`i Island, 13 shallow-water CTD casts were performed at 13 select REA sites (Fig. B.1.2), all of which have been identified as possible locations for future installations of calcification acidification units (CAUs). In concert with each CTD cast and at 3 additional REA sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. Accounting for losses and microbiological nutrients taken alone, a total of 26 DIC and TA, 26 salinity, 29 nutrient, and 25 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each REA site.

From the NOAA Ship *Hi`ialakai*, ~ 120 km of ADCP transect lines were run in the 4 cardinal directions away from this island during night operations. On the reciprocal course, shipboard CTD casts were conducted to a depth of 500 m per transect line every 5 km for a total of 24 deepwater CTD casts. Water samples were collected concurrently with 11 select shipboard CTD casts at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast (Fig. B.1.3). Near Hawai`i Island, 55 nutrient and 53 Chl-*a* (including 2 lost Chl-*a* samples) shipboard water samples were collected.

Table B.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments retrieved or deployed at Hawai`i Island during cruise HA-10-08.

Mooring Site	Instrument Type	Latitude	Longitude	Depth (m)	Retrieval	Deployment
HAW-001	STR	20.19118298	–155.9035246	10.1	×	×
HAW-002	STR	19.48637883	–154.8175975	12.8	×	×
HAW-003	STR	18.92252502	–155.6843083	13.7	×	×
HAW-005	EAR	19.39413808	–154.9241594	15.8	×	×
HAW-005	STR	19.39413808	–154.9241594	15.8	×	×
HAW-006	EAR	19.07380932	–155.9016245	17.7	×	×
HAW-006	STR	19.07380932	–155.9016245	17.7	×	×

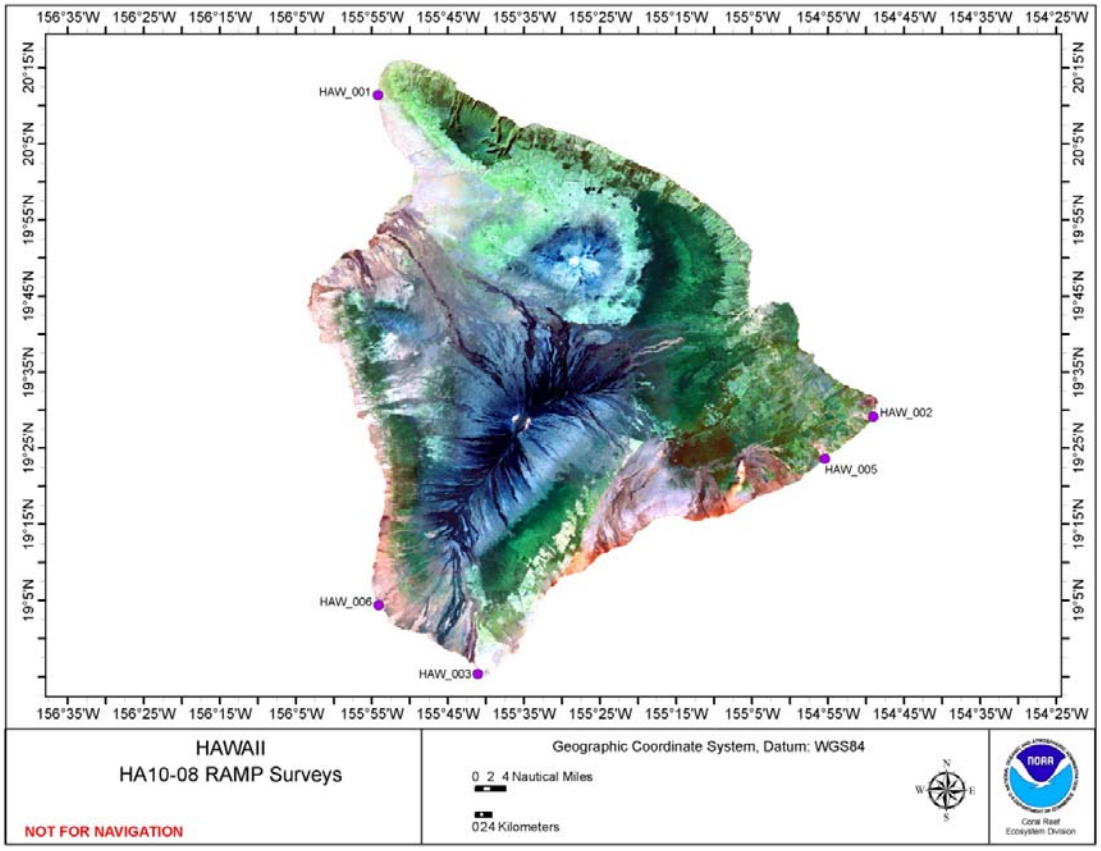


Figure B.1.1.--Locations of moored instruments retrieved and deployed at Hawai`i Island during cruise HA-10-08. Landsat satellite imagery data used in this map and the other maps in this appendix are available from the U.S. Geological Survey.

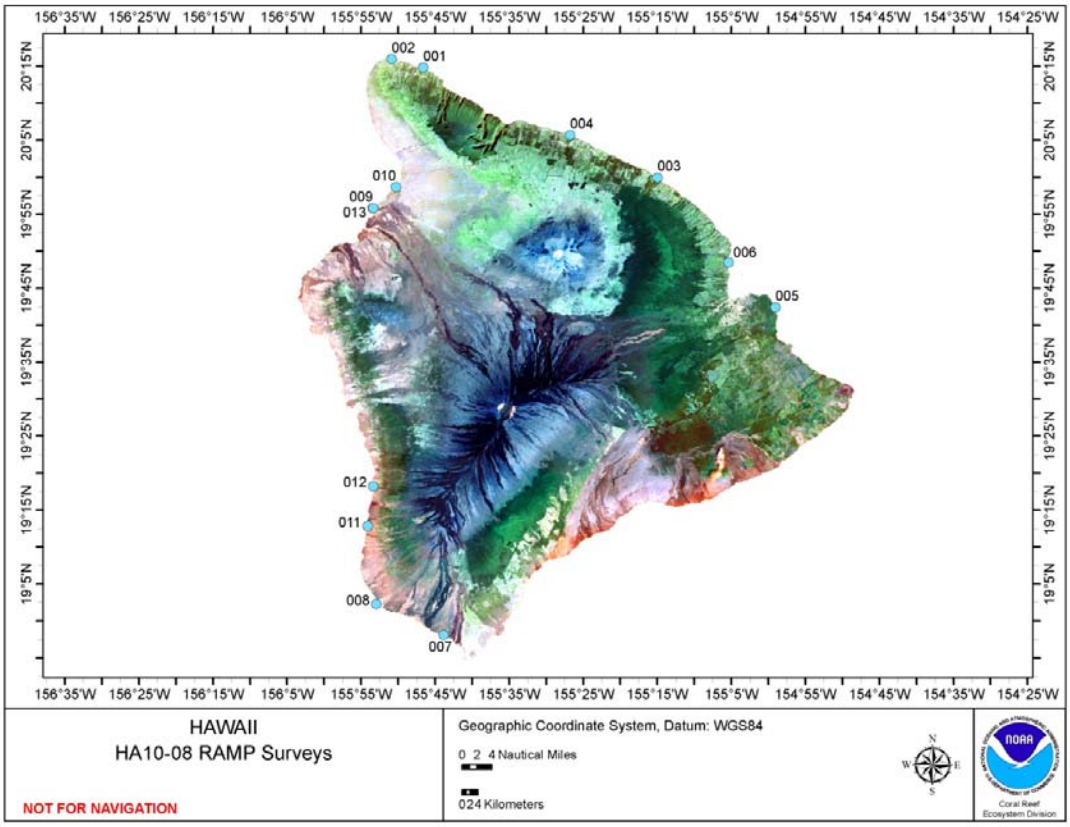


Figure B.1.2.--Locations of shallow-water CTD casts performed at Hawai`i Island during cruise HA-10-08. At all 13 nearshore cast locations, water samples for analyses of DIC, TA, salinity, nutrient, and Chl-*a* concentrations were collected.

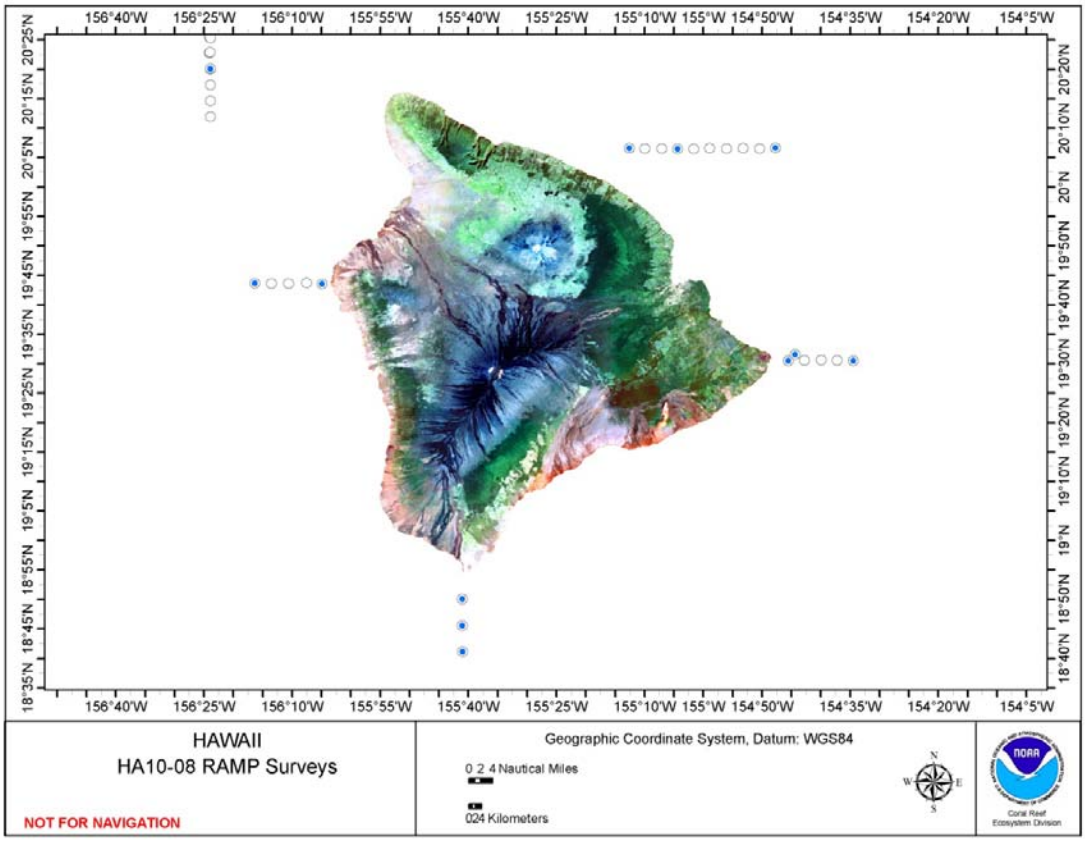


Figure B.1.3.--Locations of deepwater CTD casts conducted at Hawai`i Island from the NOAA Ship *Hi`ialakai* to a depth of 500 m. Shipboard water samples for analyses of nutrient and Chl-*a* concentrations were collected in concert with the casts conducted at the 11 locations displayed in blue.

B.2. Benthic Environment

Belt-transect and line-point-intercept (LPI) surveys were conducted and photoquadrat images were collected at 21 REA sites around Hawai`i Island to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. B.2.1 and Table B.2.1). At the end of LPI surveys, roving-diver algal surveys were conducted if time permitted. A subset of 9 REA sites was also surveyed for target macroinvertebrates, and 9 autonomous reef monitoring structures (ARMS) were recovered from 3 REA sites: HAW-14, HAW-22, and HAW-24 (Table B.2.1); 6 ARMS were redeployed at HAW-22 and HAW-24.

At 7 select REA sites, 31 microbial water samples were collected, with four 2-L samples at each site and three 20-L samples at HAW-36. For information about collections of algal voucher specimens, see Table I.1.1 in Appendix I: "Biological Collections."

In total, the benthic team conducted 106 individual dives around Hawai`i Island.

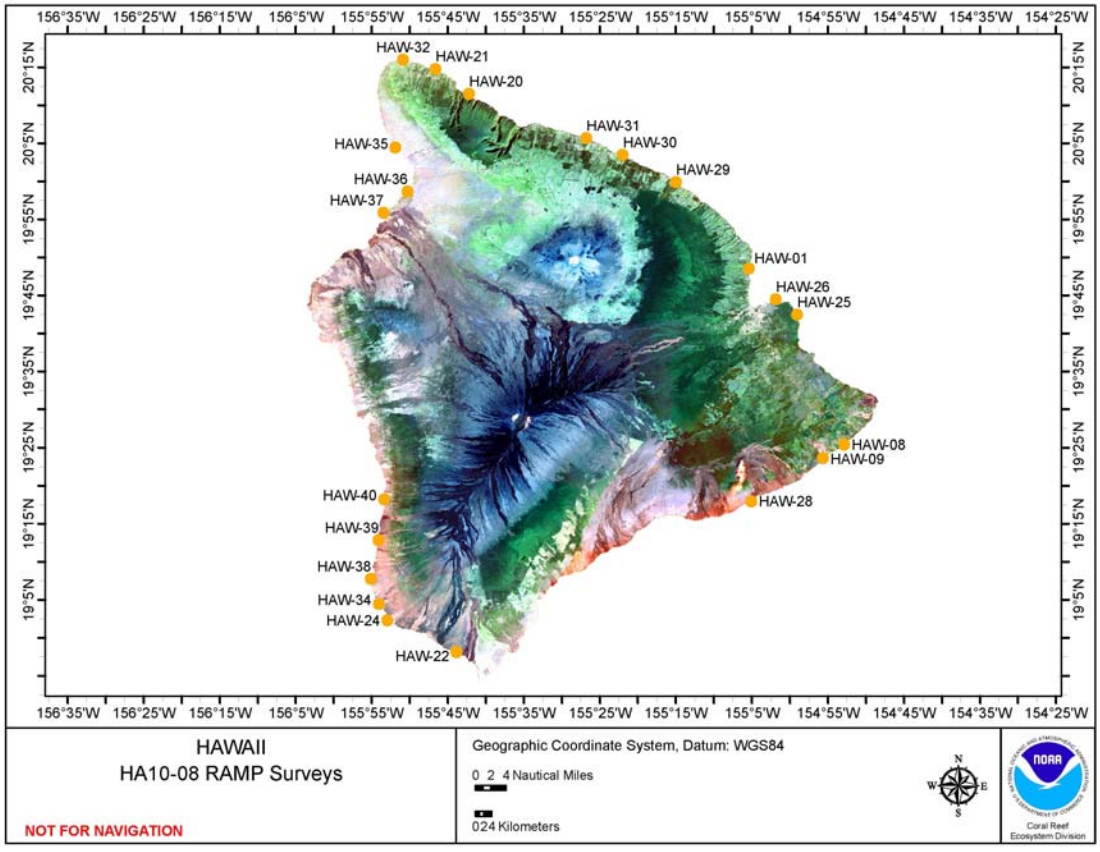


Figure B.2.1.--Locations of REA benthic sites surveyed at Hawai`i Island during cruise HA-10-08.

Table B.2.1. Summary of REA benthic surveys and ARMS retrievals (Ret.) and deployments (Dep.) performed as well as algal voucher specimens and microbial water samples collected at Hawai`i Island during cruise HA-10-08. Photoquadrat images were collected in concert with LPI surveys, after which roving-diver algal surveys were conducted if time permitted. For more details, see Appendix A: "Methods."

REA Site	Date	Latitude	Longitude	REA Surveys			Installations and Collections		
				LPI	Corals	Inverts	ARMS Ret/Dep	Algae	Microbial Samples
HAW-20	8-Oct	20.192383	–155.703383	×	×	×	–	–	–
HAW-21	8-Oct	20.247200	–155.776600	×	×	×	–	–	–
HAW-32	8-Oct	20.267028	–155.847965	×	×	×	–	–	4 × 2 L
HAW-29	9-Oct	19.999000	–155.249400	×	×	×	–	–	–
HAW-30	9-Oct	20.058200	–155.366100	×	×	×	–	1	–
HAW-31	9-Oct	20.095100	–155.446300	×	×	×	–	–	4 × 2 L
HAW-01	10-Oct	19.808717	–155.089600	×	×	×	–	–	4 ×2 L
HAW-25	10-Oct	19.707700	–154.984300	×	×	×	–	–	–
HAW-26	10-Oct	19.741500	–155.030400	×	×	×	–	4	–
HAW-22	11-Oct	18.968567	–155.730850	×	×	–	3/3	–	4 × 2 L
HAW-24	11-Oct	19.038300	–155.882600	×	×	–	3/3	–	–
HAW-34	11-Oct	19.074833	–155.901017	×	×	–	–	–	–
HAW-35	12-Oct	20.074712	–155.864840	×	×	–	–	–	–
HAW-36	12-Oct	19.978029	–155.838034	×	×	–	–	–	4 × 2 L; 3 × 20 L
HAW-37	12-Oct	19.931246	–155.890466	×	×	–	–	–	–
HAW-14	13-Oct	18.939085	–155.688301	–	–	–	3/0	–	–
HAW-38	13-Oct	19.129124	–155.918186	×	×	–	–	–	–
HAW-39	13-Oct	19.214207	–155.901757	×	×	–	–	–	4 × 2 L
HAW-40	13-Oct	19.304231	–155.889506	×	×	–	–	–	–
HAW-08	14-Oct	19.424000	–154.880600	×	×	–	–	–	–
HAW-09	14-Oct	19.394000	–154.927400	×	×	–	–	–	4 × 2 L
HAW-28	14-Oct	19.299600	–155.084000	×	×	–	–	1	–

CRED completed 37 towed-diver surveys at Hawai`i Island, covering a total length of 80.6 km (an area of 80.6 ha) on the ocean floor (Fig. B.2.2). The mean survey length was 2.2 km with a range of 1.1–2.8 km. The mean survey depth was 15.5 m with a range of 11.7–18.8 m. The mean temperature from data recorded during these surveys was 25.9°C with a range of 25°C–26.4°C.

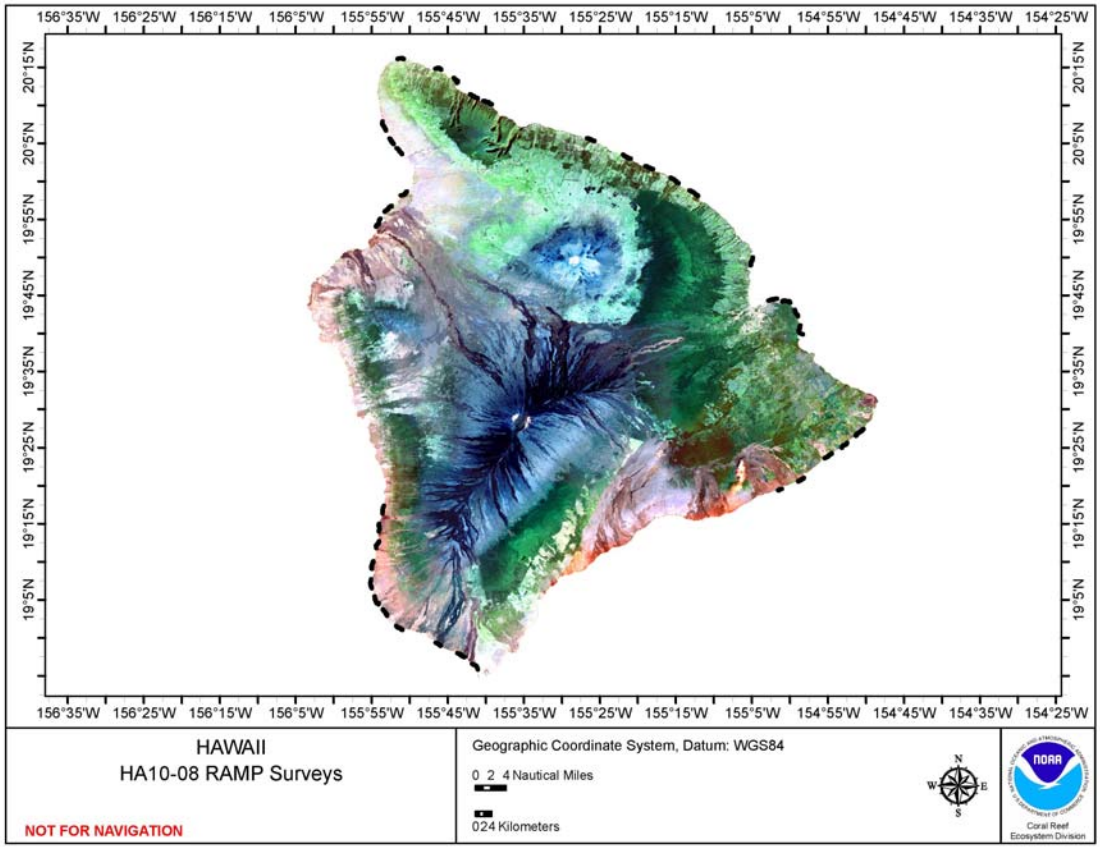


Figure B.2.2.--Track locations of towed-diver-surveys conducted at Hawai`i Island during cruise HA-10-08.

B.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary point count surveys were conducted at 43 REA sites at Hawai`i Island in the deep, moderate, and shallow forereef strata (Table B.3.1 and Fig.B.3.1). No fishes were collected during these surveys.

In addition, CRED completed a total of 37 towed-diver surveys at Hawai`i Island, as described previously in Section B.2 of this appendix.

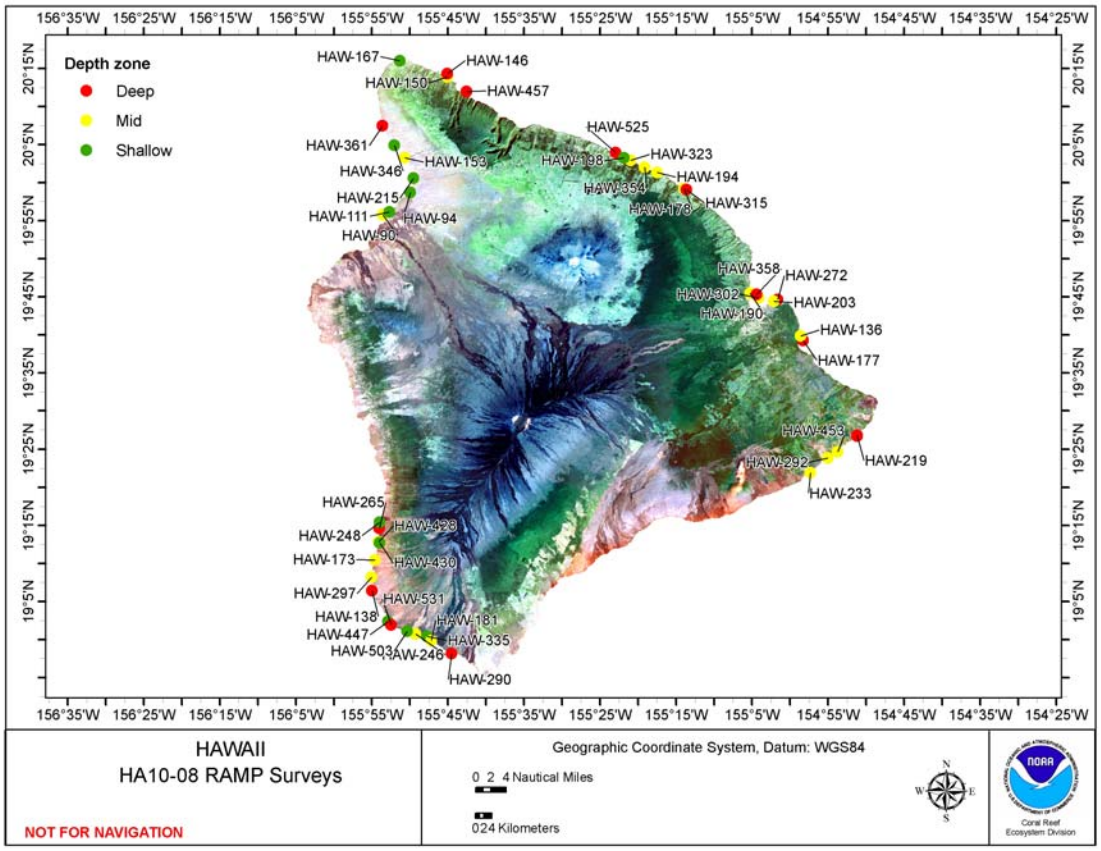


Figure B.3.1.--Locations of REA fish sites surveyed at Hawai`i Island during cruise HA-10-08. All of these REA sites were selected using a stratified random design.

Table B.3.1.--Summary of sites where REA fish surveys were conducted at Hawai`i Island during cruise HA-10-08.

REA Site	Date	Depth Zone	Stratum	Depth (m)	Latitude	Longitude
HAW-146	8-Oct	Deep	Forereef	22	20.23945042	–155.7513162
HAW-150	8-Oct	Mid	Forereef	11	20.23244122	–155.7512105
HAW-167	8-Oct	Shallow	Forereef	6	20.26778779	–155.855388
HAW-457	8-Oct	Deep	Forereef	25	20.20014013	–155.7091341
HAW-178	9-Oct	Mid	Forereef	14	19.98708649	–155.2322548
HAW-194	9-Oct	Mid	Forereef	12	20.02240791	–155.2914663
HAW-198	9-Oct	Shallow	Forereef	5	20.05500748	–155.3638895
HAW-315	9-Oct	Deep	Forereef	26	19.98493443	–155.226814
HAW-323	9-Oct	Mid	Forereef	12	20.04969385	–155.3492215
HAW-354	9-Oct	Mid	Forereef	17	20.03393152	–155.3185486
HAW-525	9-Oct	Deep	Forereef	24	20.06635465	–155.3824007
HAW-136	10-Oct	Mid	Forereef	12	19.66447676	–154.9769788
HAW-177	10-Oct	Deep	Forereef	22	19.65415243	–154.971091

REA Site	Date	Depth Zone	Stratum	Depth (m)	Latitude	Longitude
HAW-190	10-Oct	Mid	Forereef	12	19.75809826	–155.087413
HAW-203	10-Oct	Mid	Forereef	13	19.74035217	–155.0356113
HAW-272	10-Oct	Deep	Forereef	21	19.74435185	–155.0273058
HAW-302	10-Oct	Mid	Forereef	10	19.74751619	–155.0688391
HAW-358	10-Oct	Deep	Forereef	24	19.75570179	–155.0729444
HAW-181	11-Oct	Mid	Forereef	15	18.99763014	–155.7862736
HAW-246	11-Oct	Mid	Forereef	13	19.01212153	–155.8204122
HAW-290	11-Oct	Deep	Forereef	23	18.96924701	–155.7417628
HAW-335	11-Oct	Shallow	Forereef	4	19.00717646	–155.7955527
HAW-447	11-Oct	Shallow	Forereef	6	19.03992992	–155.8815182
HAW-503	11-Oct	Shallow	Forereef	4	19.01857392	–155.838986
HAW-531	11-Oct	Deep	Forereef	25	19.03261788	–155.8746872
HAW-90	12-Oct	Mid	Forereef	15	19.9299064	–155.8927204
HAW-94	12-Oct	Shallow	Forereef	4	19.97885806	–155.8322626
HAW-111	12-Oct	Shallow	Forereef	4	19.93578823	–155.8781193
HAW-153	12-Oct	Mid	Forereef	8	20.05506028	–155.8444195
HAW-215	12-Oct	Shallow	Forereef	2	20.01060066	–155.825602
HAW-346	12-Oct	Shallow	Forereef	6	20.08223919	–155.8678176
HAW-361	12-Oct	Deep	Forereef	26	20.12523802	–155.8932205
HAW-138	13-Oct	Deep	Forereef	25	19.10705287	–155.9163557
HAW-173	13-Oct	Mid	Forereef	12	19.17447103	–155.9098846
HAW-248	13-Oct	Shallow	Forereef	5	19.25695055	–155.8994194
HAW-265	13-Oct	Deep	Forereef	24	19.24453033	–155.900432
HAW-297	13-Oct	Mid	Forereef	14	19.1370999	–155.9174
HAW-428	13-Oct	Mid	Forereef	12	19.21418038	–155.901572
HAW-430	13-Oct	Shallow	Forereef	5	19.2123574	–155.8998144
HAW-219	14-Oct	Deep	Forereef	24	19.44592735	–154.8527585
HAW-233	14-Oct	Mid	Forereef	14	19.3660173	–154.9554415
HAW-292	14-Oct	Mid	Forereef	14	19.39825846	–154.9172909
HAW-453	14-Oct	Mid	Forereef	12	19.41163539	–154.895444

(This page is left blank intentionally.)

APPENDIX C: 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."

C.1. Oceanography and Water Quality

Oceanographic operations during cruise HA-10-08 at Maui Island entailed numerous retrievals and deployments of oceanographic moored instruments, nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, and shipboard water sampling and CTD casts offshore to a depth of 500 m.

Five subsurface temperature recorders (STRs) were retrieved, and 5 STRs were deployed (Fig. C.1.1). One of these STRs was co-located with an Environmental Acoustic Recorder (EAR) unit, which was also retrieved and redeployed. One of the 2 STRs previously deployed at the small island of Molokini off Maui Island was lost and not replaced; the second one, was found and replaced (Table C.1.1).

At nearshore locations around Maui Island, 9 shallow-water CTD casts were performed at REA sites MAI-01, MAI-14, MAI-02, MAI-19, MAI-10, MAI-07, MAI-22, MAI-09, and MAI-06, all of which have been identified as possible locations for future installations of calcification acidification units (CAUs) and potential carbonate chemistry work (Fig. C.1.2). In concert with the CTD cast at each of these REA sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. A total of 18 DIC and TA, 18 salinity, 18 nutrient, and 18 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each REA site.

From the NOAA Ship *Hi`ialakai*, ~ 200 km of ADCP transect lines were run away from this island during night operations. On the reciprocal course, shipboard CTD casts to depths of 500 m were conducted per transect line every 5 km for a total of 50 deepwater CTD casts (Fig. C.1.3). Water samples were collected concurrently with select shipboard CTD casts at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. Near Maui, 75 nutrient and 75 Chl-*a* shipboard water samples were collected.

Table C.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments retrieved or deployed at Maui Island during cruise HA-10-08.

Mooring Site	Instrument Type	Latitude	Longitude	Depth (m)	Retrieval	Deployment
MAI-003	STR	20.63029454	–156.4971169	10.7	×	–
MAI-003	STR	20.63029999	–156.4971800	11.3	–	×
MAI-004	STR	21.01738391	–156.6429598	12.2	×	×
MAI-005	Anchor	20.59194298	–156.4203084	14.6	×	×
MAI-005	EAR	20.59194298	–156.4203084	14.6	×	×
MAI-005	STR	20.59194298	–156.4203084	14.6	×	×
MAI-006	STR	20.86449942	–156.1511988	15.2	×	–
MAI-006	STR	20.86454459	–156.1511998	14.9	–	×
MAI-007	STR	20.79081117	–156.5844528	11.9	×	×

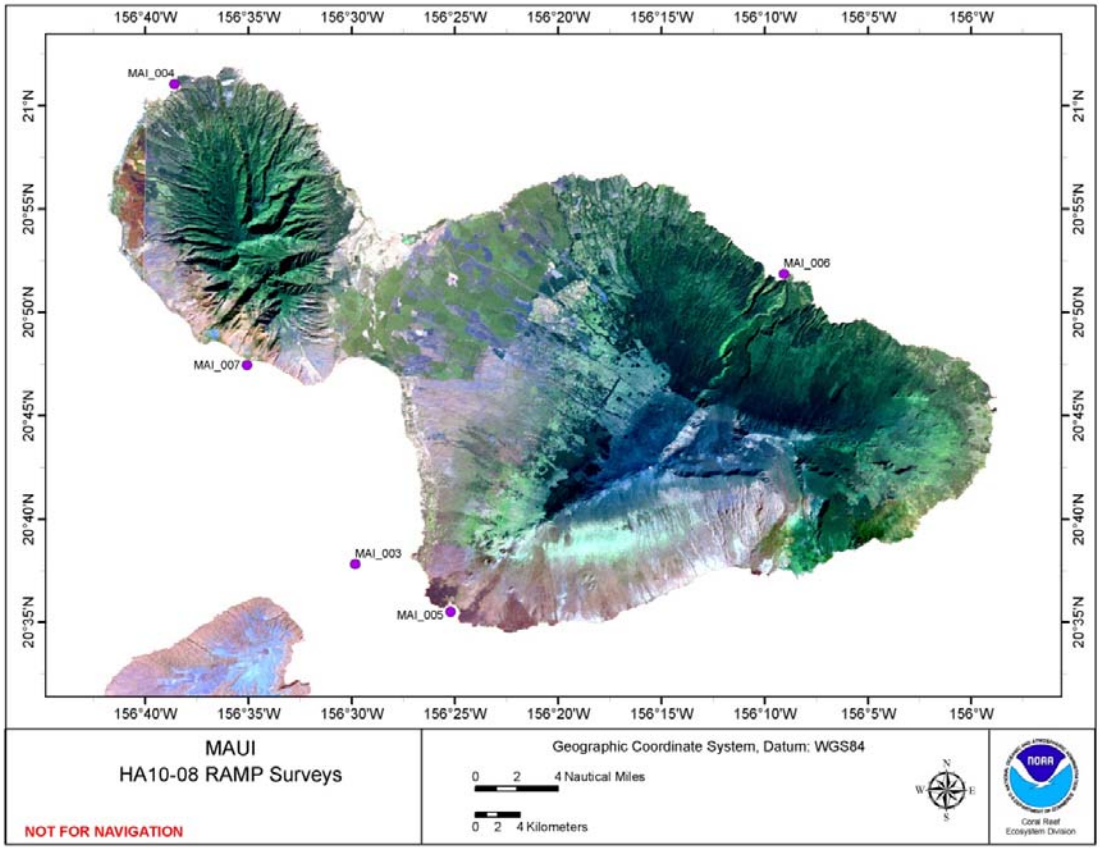


Figure C.1.1.--Locations of moored instruments retrieved and deployed at Maui Island during cruise HA-10-08. Landsat satellite imagery data used in this map and the other maps in this appendix are available from the U.S. Geological Survey.

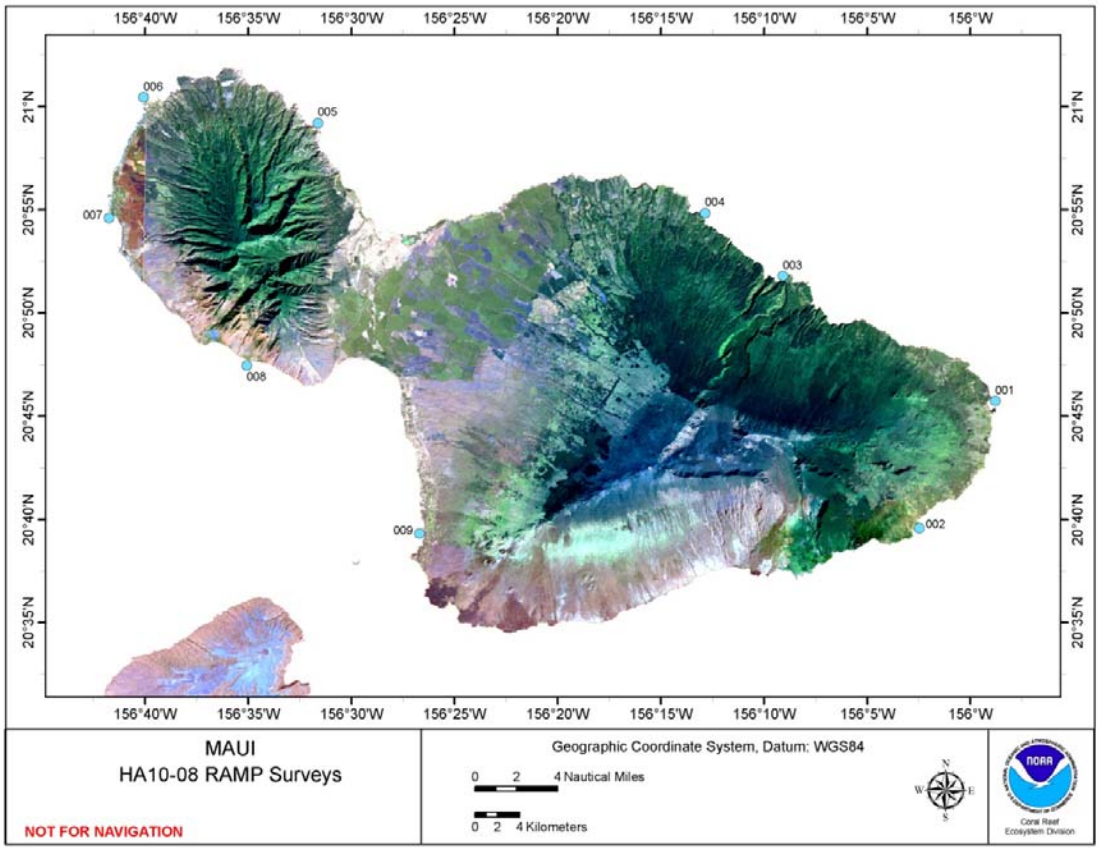


Figure C.1.2.--Locations of shallow-water CTD casts performed at Maui Island during cruise HA-10-08. At all 9 nearshore cast locations, water samples for analyses of DIC, TA, salinity, nutrient, and Chl-*a* concentrations were collected.

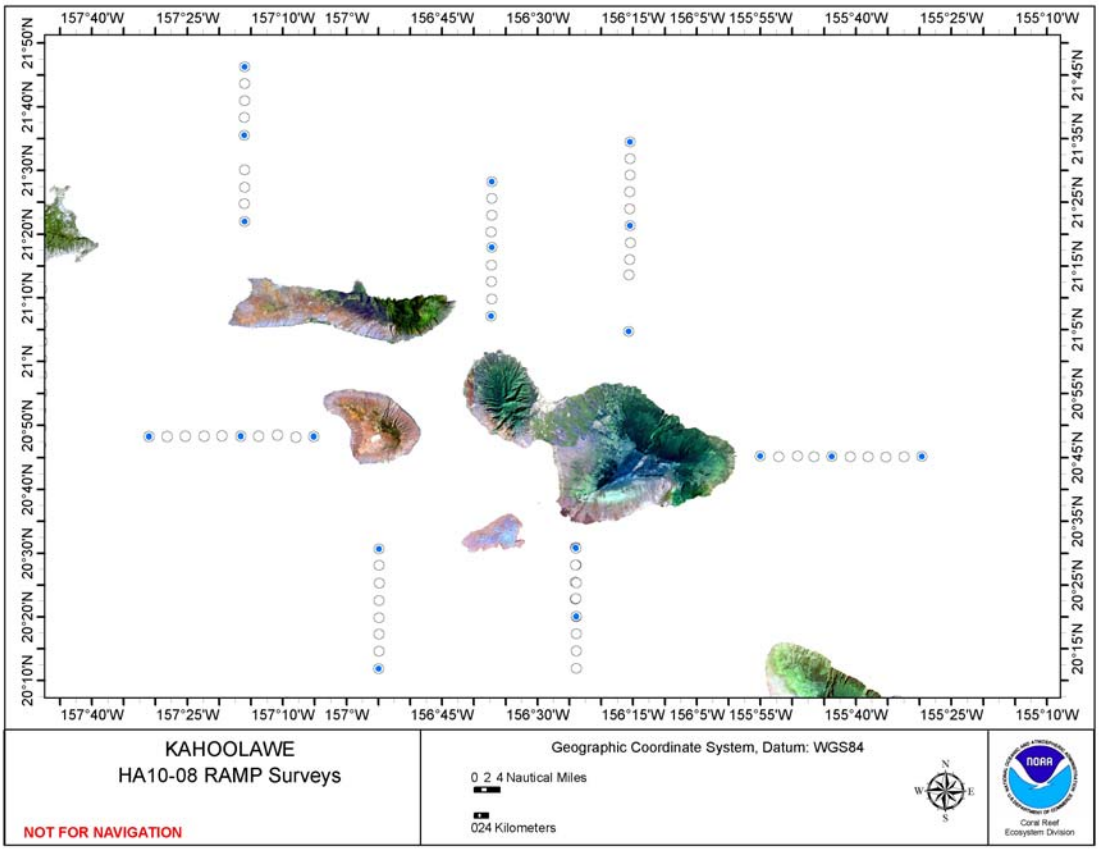


Figure C.1.3.--Locations of deepwater CTD casts conducted at Maui Island and Maui County from the NOAA Ship *Hi`ialakai* to a depth of 500 m. Shipboard water samples for analyses of nutrient and Chl-*a* concentrations were collected in concert with the casts conducted at the locations displayed in blue.

C.2. Benthic Environment

Belt-transect and line-point-intercept (LPI) surveys were conducted and photoquadrat images were collected at 15 REA sites around Maui Island to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. C.2.1 and Table C.2.1). At the end of LPI surveys, roving-diver algal surveys were conducted if time permitted. A subset of 12 REA sites were also surveyed for target macroinvertebrates, and 3 autonomous reef monitoring structures (ARMS) were recovered and redeployed at MAI-01 (Table C.2.1).

At 5 select REA sites, 23 microbial water samples were collected, with four 2-L samples at each site and three 20-L samples at MAI-07. For information about collections of algal voucher specimens, see Table I.1.1 in Appendix I: "Biological Collections."

In total, the benthic team conducted 88 individual dives around Maui Island.

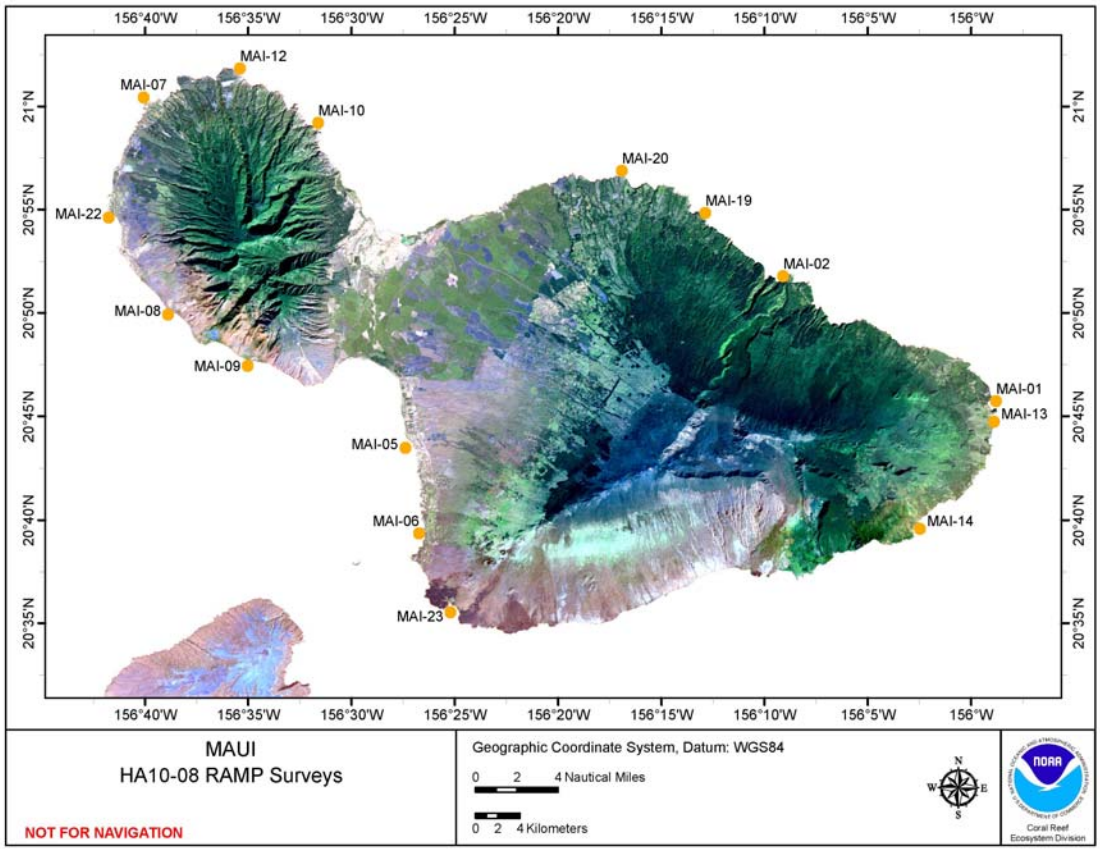


Figure C.2.1.--Locations of REA benthic sites surveyed at Maui Island during cruise HA-10-08.

Table C.2.1. Summary of REA benthic surveys and ARMS retrievals (Ret.) and deployments (Dep.) performed as well as algal voucher specimens and microbial water samples collected at Maui Island during cruise HA-10-08. Photoquadrat images were collected in concert with LPI surveys, after which roving-diver algal surveys were conducted if time permitted. For more details, see Appendix A: "Methods."

REA Site	Date	Latitude	Longitude	REA Surveys			Installations and Collections		
				LPI	Corals	Inverts	ARMS Ret/Dep	Algae	Microbial Samples
MAI-01	15-Oct	20.762300	–155.979800	×	×	–	3/3	1	–
MAI-13	15-Oct	20.745567	–155.981317	×	×	–	–	–	–
MAI-14	15-Oct	20.659700	–156.041100	×	×	–	–	–	4 × 2 L
MAI-02	16-Oct	20.863133	–156.151317	×	×	×	–	–	4 × 2 L
MAI-19	16-Oct	20.914100	–156.214400	×	×	×	–	1	–
MAI-20	16-Oct	20.948000	–156.281700	×	×	×	–	–	–
MAI-07	18-Oct	21.007433	–156.667717	×	×	×	–	–	4 × 2 L; 3 × 20 L
MAI-10	18-Oct	20.986900	–156.526900	×	×	×	–	–	–
MAI-12	18-Oct	21.030550	–156.589983	×	×	×	–	–	–
MAI-08	19-Oct	20.832000	–156.648100	×	×	×	–	–	–
MAI-09	19-Oct	20.790700	–156.583800	×	×	×	–	–	4 × 2 L
MAI-22	19-Oct	20.910083	–156.695633	×	×	×	–	–	–
MAI-05	20-Oct	20.724800	–156.456500	×	×	×	–	–	–
MAI-06	20-Oct	20.655417	–156.444900	×	×	×	–	–	4 × 2 L
MAI-23	20-Oct	20.592236	–156.419943	×	×	×	–	–	–

CRED completed a total of 24 towed-diver surveys at Maui Island, covering a total length of 55.6 km (an area of 55.6 ha) on the ocean floor (Fig. C.2.2). The mean survey length was 2.3 km with a range of 1.8–2.6 km. The mean survey depth was 13.4 m with a range of 6.2–17.1 m. The mean temperature from data recorded during these surveys was 25.8°C with a range of 25.2°C–26.3°C.

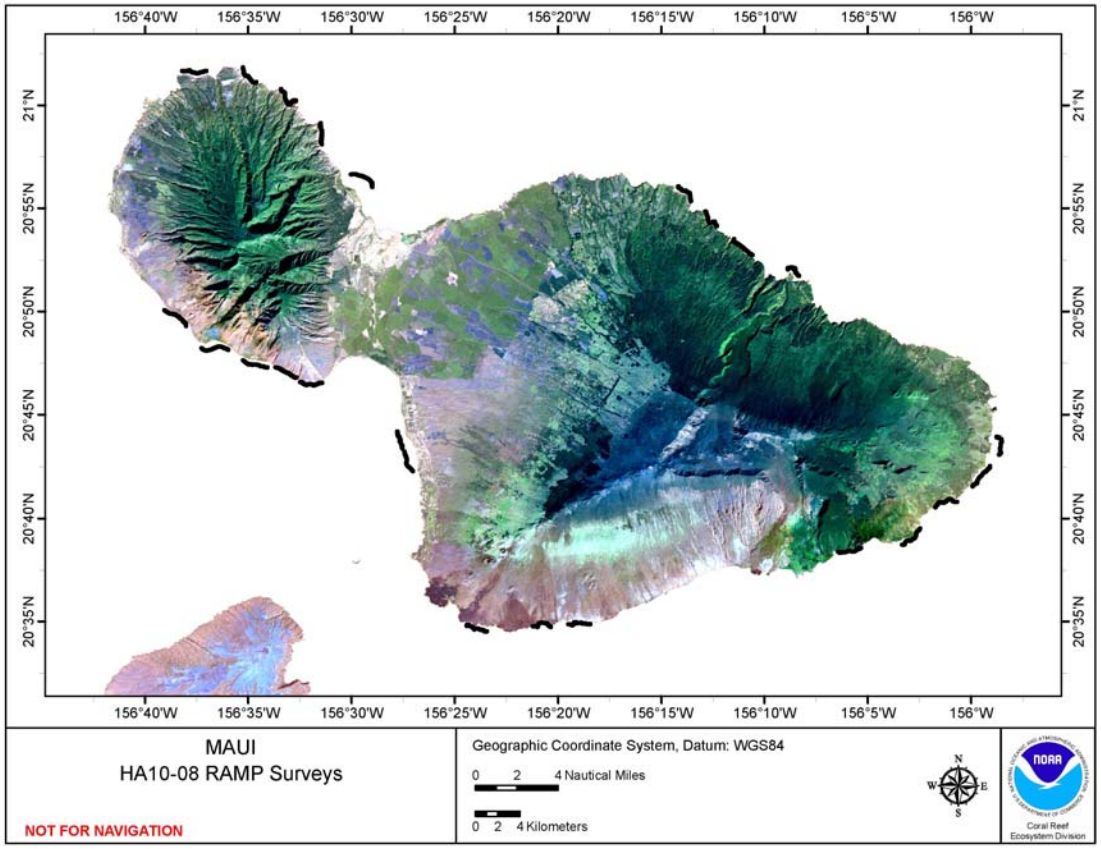


Figure C.2.2.--Track locations of towed-diver surveys conducted at Maui Island during cruise HA-10-08.

C.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary point count surveys were conducted at 33 REA sites at Maui Island in the deep, moderate, and shallow forereef strata (Table C.3.1 and Fig. C.3.1). No fishes were collected during these surveys.

In addition, CRED completed a total of 24 towed-diver surveys at Maui Island, as described previously in Section C.2 of this appendix.

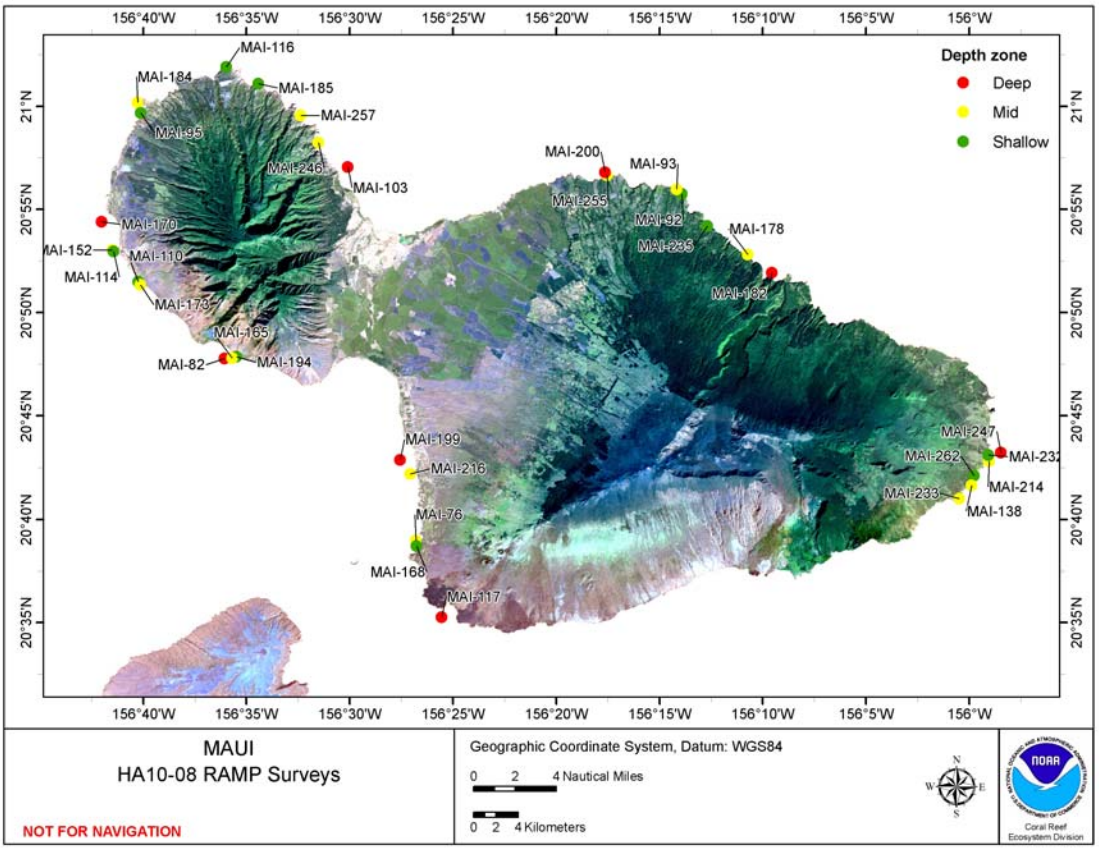


Figure C.3.1.--Locations of REA fish sites surveyed at Maui Island during cruise HA-10-08. All of these REA sites were selected using a stratified random design.

Table C.3.1.--Summary of sites where REA fish surveys were conducted at Maui Island during cruise HA-10-08.

REA Site	Date	Depth Zone	Stratum	Depth (m)	Latitude	Longitude
MAI-138	15-Oct	Mid	Forereef	15	20.69431	–155.998
MAI-214	15-Oct	Mid	Forereef	15	20.71383	–155.984
MAI-232	15-Oct	Shallow	Forereef	6	20.7187	–155.984
MAI-233	15-Oct	Mid	Forereef	14	20.6837	–156.008
MAI-247	15-Oct	Deep	Forereef	28	20.72091	–155.974
MAI-262	15-Oct	Shallow	Forereef	6	20.70219	–155.996
MAI-92	16-Oct	Shallow	Forereef	5	20.92914	–156.232
MAI-93	16-Oct	Mid	Forereef	15	20.9328	–156.236
MAI-178	16-Oct	Mid	Forereef	15	20.88027	–156.179
MAI-182	16-Oct	Deep	Forereef	23	20.86563	–156.159
MAI-200	16-Oct	Deep	Forereef	24	20.94687	–156.294
MAI-235	16-Oct	Shallow	Forereef	6	20.90331	–156.211
MAI-255	16-Oct	Mid	Forereef	15	20.94429	–156.292
MAI-95	18-Oct	Shallow	Forereef	3	20.99471	–156.668
MAI-103	18-Oct	Deep	Forereef	24	20.95085	–156.502
MAI-116	18-Oct	Shallow	Forereef	6	21.03183	–156.6
MAI-184	18-Oct	Mid	Forereef	17	21.00307	–156.671
MAI-185	18-Oct	Shallow	Forereef	6	21.01818	–156.574
MAI-246	18-Oct	Mid	Forereef	14	20.9708	–156.525
MAI-257	18-Oct	Mid	Forereef	16	20.99273	–156.54
MAI-82	19-Oct	Deep	Forereef	22	20.7962	–156.601
MAI-110	19-Oct	Shallow	Forereef	3	20.85815	–156.671
MAI-114	19-Oct	Shallow	Forereef	4	20.88291	–156.691
MAI-152	19-Oct	Mid	Forereef	10	20.88389	–156.691
MAI-165	19-Oct	Mid	Forereef	13	20.7965	–156.595
MAI-170	19-Oct	Deep	Forereef	24	20.90675	–156.7
MAI-173	19-Oct	Mid	Forereef	9	20.85586	–156.669
MAI-194	19-Oct	Shallow	Forereef	3	20.79761	–156.591
MAI-76	20-Oct	Mid	Forereef	11	20.64991	–156.447
MAI-117	20-Oct	Deep	Forereef	26	20.58783	–156.426
MAI-168	20-Oct	Shallow	Forereef	3	20.6452	–156.446
MAI-199	20-Oct	Deep	Forereef	22	20.71491	–156.459
MAI-216	20-Oct	Mid	Forereef	13	20.70373	–156.451

(This page is left blank intentionally.)

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. Oceanography and Water Quality

Oceanographic operations during HA-10-08 at Lāna`i Island entailed numerous retrievals and deployments of oceanographic moored instruments, nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, and shipboard water sampling and CTD casts offshore to a depth of 500 m.

Two subsurface temperature recorders (STRs) were retrieved, and 2 were deployed at Lāna`i Island (Fig. D.1.1). In addition, 4 shallow-water CTD casts were performed at nearshore locations at Lāna`i Island at REA sites LAN-03, LAN-05, LAN-07, and LAN-08 (Fig. D.1.2), all of which have been identified as possible locations for future installations of calcification acidification units (CAUs). In concert with the CTD cast at each of these REA sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, and nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. A total of 8 DIC and TA, 8 salinity, 8 nutrient, and 8 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each site.

From the NOAA Ship *Hi`ialakai*, ~ 50 km of ADCP transect lines were run away from this island during night operations. On the reciprocal course, shipboard CTD casts to depths of 500 m were conducted per transect line every 5 km for a total of 10 deepwater CTD casts (Fig. C.1.3). Water samples were collected concurrently with 3 select *shipboard* CTD casts 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, 15 nutrient and 15 Chl-*a* shipboard water samples were collected.

Table D.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments retrieved or deployed at Lāna`i Island during cruise HA-10-08.

Mooring Site	Instrument Type	Latitude	Longitude	Depth (m)	Retrieval	Deployment
LAN-001	STR	20.74155274	–156.8752466	11.6	×	×
LAN-004	STR	20.87185529	–156.8370840	13.1	–	×
LAN-005	STR	20.87052039	–156.8346599	14.6	×	–

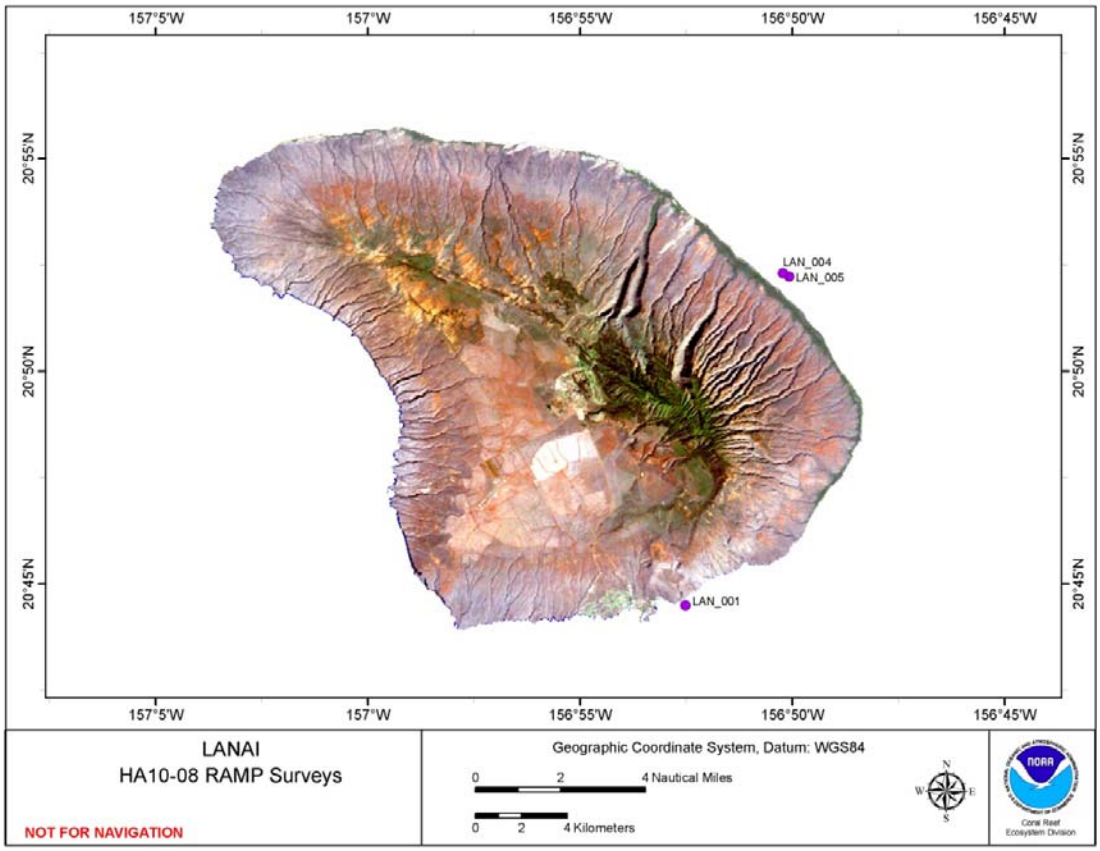


Figure D.1.1.--Locations of moored instruments retrieved and deployed at Lāna`i Island during cruise HA-10-08. Landsat satellite imagery data used in this map and the other maps in this appendix are available from the U.S. Geological Survey.

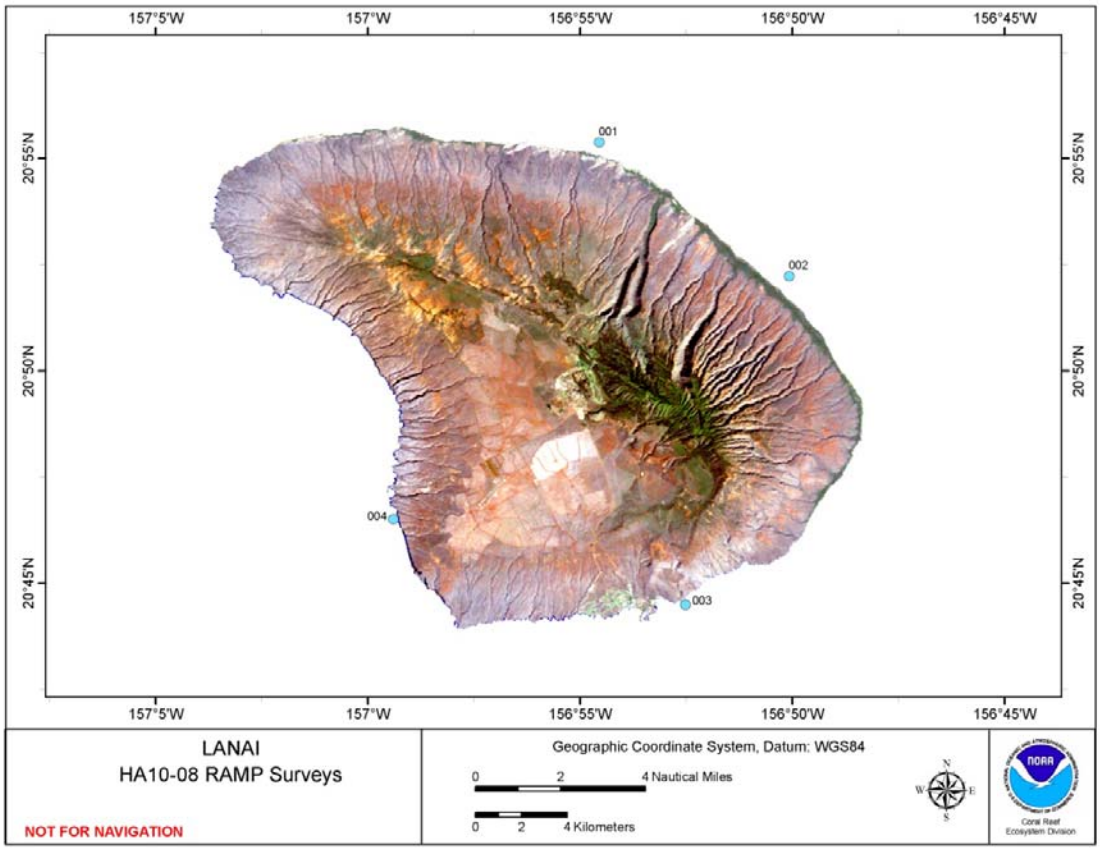


Figure D.1.2.--Locations of shallow-water CTD casts performed at Lāna`i Island during cruise HA-10-08. At all 4 nearshore cast locations, water samples for analyses of DIC, TA, salinity, nutrient, and Chl-*a* concentrations were collected.

D.2. Benthic Environment

Belt-transect and line-point-intercept (LPI) surveys were conducted and photoquadrat images were collected at 6 REA sites at Lānai to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. D.2.1 and Table D.2.1). At the end of LPI surveys, roving-diver algal surveys were conducted if time permitted. All 6 REA sites were also surveyed for target macroinvertebrates; no autonomous reef monitoring structures (ARMS) were recovered or deployed.

At 2 select REA sites, 11 microbial water samples were collected, with four 2-L samples at each site and three 20-L samples at LAN-03. For information about collections of algal voucher specimens, see Table I.1.1 in Appendix I: "Biological Collections."

In total, the benthic team conducted 36 individual dives around Lāna`i Island.

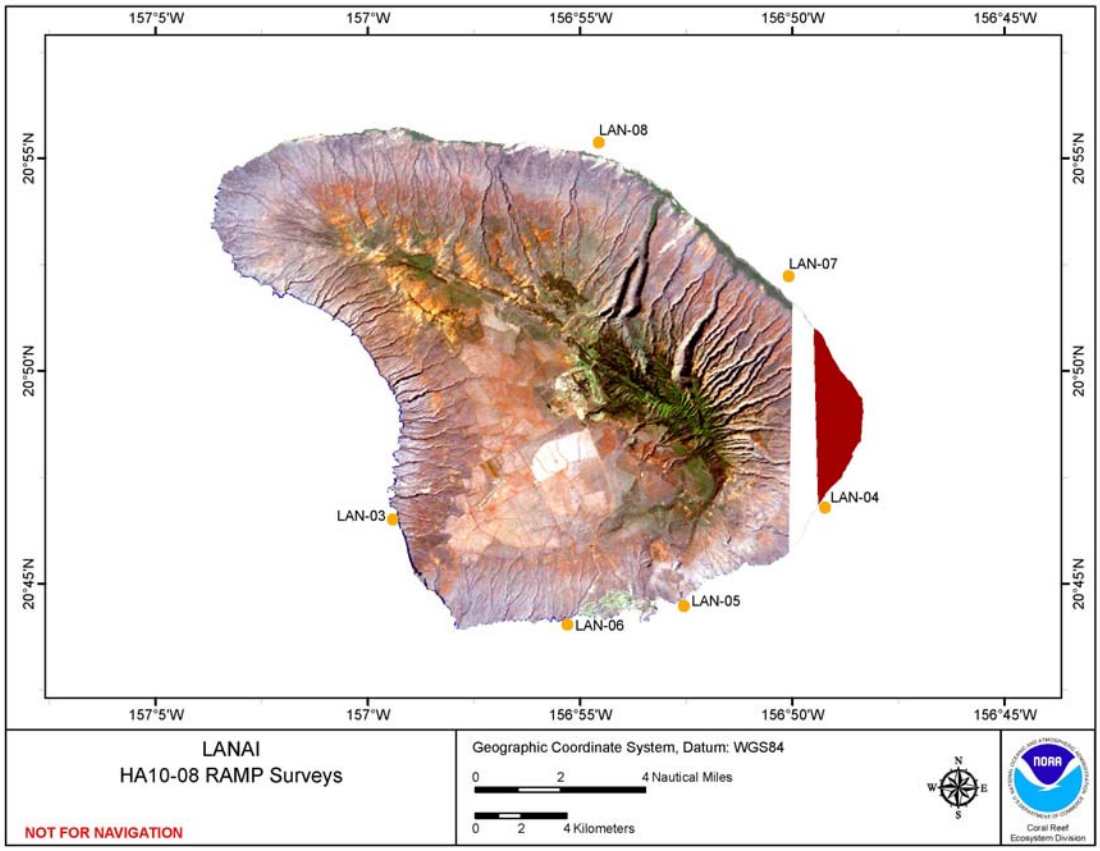


Figure D.2.1.--Locations of REA benthic sites surveyed at Lāna`i Island during cruise HA-10-08.

Table D.2.1.--Summary of REA benthic surveys and ARMS retrievals (Ret.) and deployments (Dep.) performed as well as algal voucher specimens and microbial water samples collected at Lāna`i Island during cruise HA-10-08. Photoquadrat images were collected in concert with LPI surveys, after which roving-diver algal surveys were conducted if time permitted. For more details, see Appendix A: "Methods."

REA Site	Date	Latitude	Longitude	REA Surveys			Collections	
				LPI	Corals	Inverts	Algae	Microbial Samples
LAN-04	21-Oct	20.780000	–156.820300	×	×	×	–	–
LAN-07	21-Oct	20.870600	–156.834800	×	×	×	2	4 × 2 L
LAN-08	21-Oct	20.923033	–156.909367	×	×	×	1	–
LAN-03	22-Oct	20.775100	–156.989700	×	×	×	1	4 × 2 L; 3 × 20 L
LAN-05	22-Oct	20.741200	–156.875800	×	×	×	1	–
LAN-06	22-Oct	20.733700	–156.921300	×	×	×	2	–

CRED completed a total of 10 towed-diver surveys at Lāna`i Island, covering a total length of 26.4 km (an area of 26.4 ha) on ocean floor (Fig. D.2.1). The mean survey length was 2.6 km with a range of 2.3–3.1 km. The mean survey depth was 12.6 m with a range of 10.7–15.1 m. The mean temperature from data recorded during these surveys was 26.1°C with a range of 25.9°C–26.5°C.

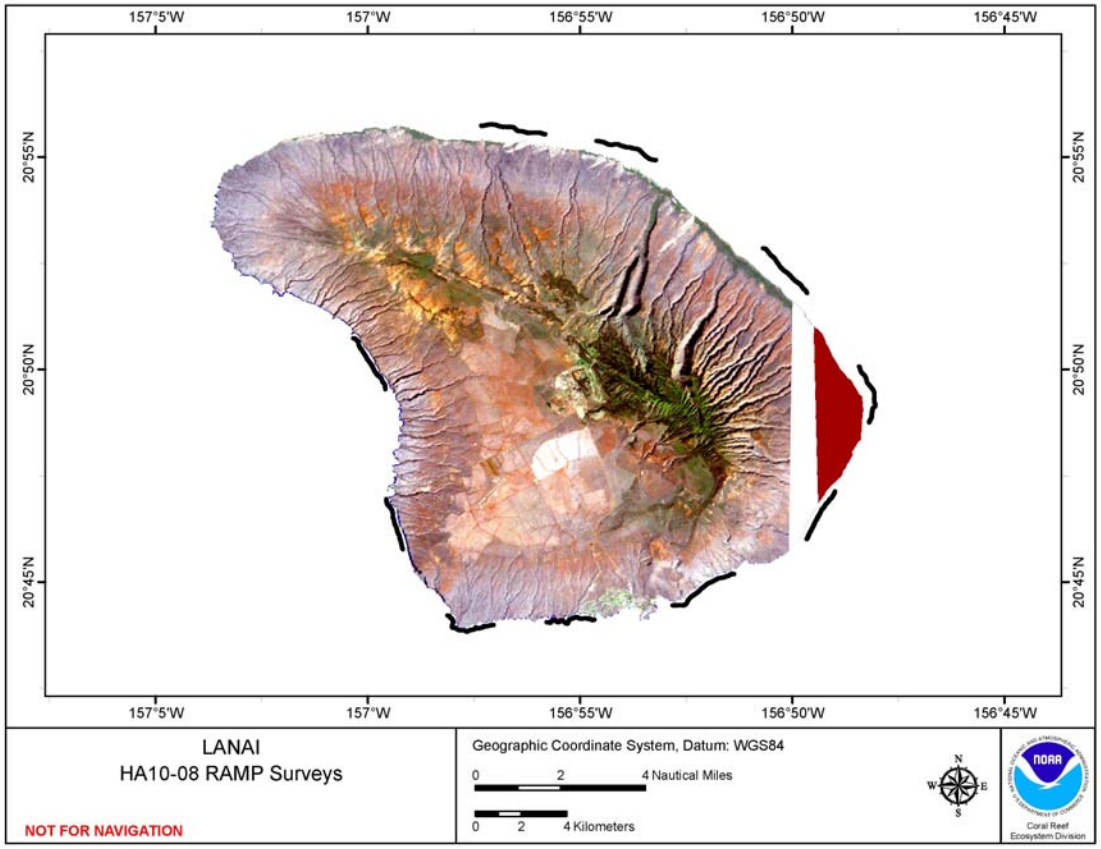


Figure D.2.2.--Track locations of towed-diver surveys conducted at Lāna`i Island during cruise HA-10-08.

D.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary point count surveys were conducted at 16 REA sites at Lāna`i Island in the deep, moderate, and shallow forereef strata (Table D.3.1 and Fig. D.3.1). No fishes were collected during these surveys.

In addition, CRED completed a total of 10 towed-diver surveys at Lāna`i Island, as described previously in Section D.2 of this appendix.

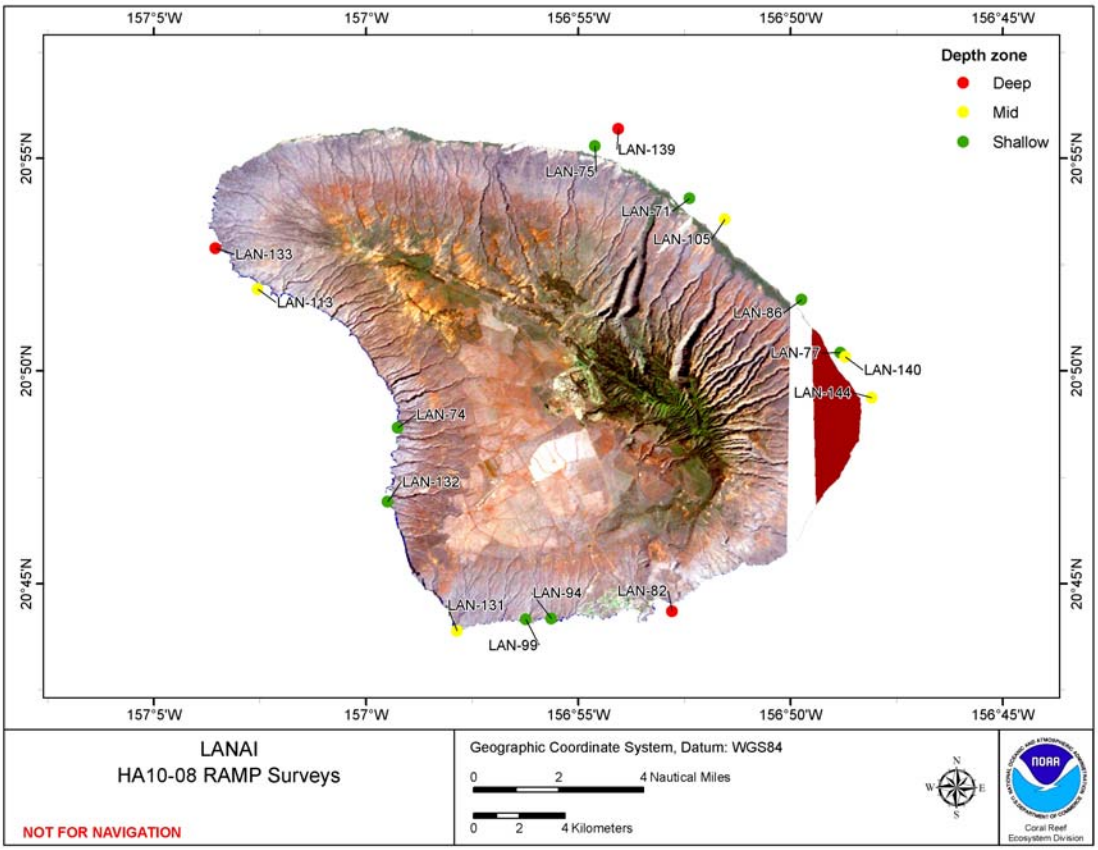


Figure D.3.1.--Locations of REA fish sites surveyed at Lāna`i Island during cruise HA-10-08. All of these REA sites were selected using a stratified random design.

Table D.3.1.--Summary of sites where REA fish surveys were conducted at Lāna`i Island during cruise HA-10-08.

REA Site	Date	Depth Zone	Stratum	Depth (m)	Latitude	Longitude
LAN-71	21-Oct	Shallow	Forereef	4	20.90103	–156.873
LAN-75	21-Oct	Shallow	Forereef	4	20.92159	–156.91
LAN-77	21-Oct	Shallow	Forereef	5	20.8404	–156.814
LAN-86	21-Oct	Shallow	Forereef	4	20.86122	–156.829
LAN-105	21-Oct	Mid	Forereef	12	20.89274	–156.859
LAN-139	21-Oct	Deep	Forereef	30	20.92825	–156.901
LAN-140	21-Oct	Mid	Forereef	12	20.83885	–156.812
LAN-144	21-Oct	Mid	Forereef	13	20.82282	–156.801
LAN-74	22-Oct	Shallow	Forereef	4	20.81103	–156.988
LAN-82	22-Oct	Deep	Forereef	17	20.73919	–156.88
LAN-94	22-Oct	Shallow	Forereef	4	20.73623	–156.927
LAN-99	22-Oct	Shallow	Forereef	5	20.73601	–156.937
LAN-113	22-Oct	Mid	Forereef	12	20.86534	–157.042
LAN-131	22-Oct	Mid	Forereef	16	20.73143	–156.964
LAN-132	22-Oct	Shallow	Forereef	5	20.78225	–156.991
LAN-133	22-Oct	Deep	Forereef	26	20.88147	–157.059

(This page is left blank intentionally.)

APPENDIX E: KAUA`I ISLAND

The island of Kaua`i is located at 22.09^{o} N, 159.53^{o} 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. Oceanography and Water Quality

Oceanographic operations around Kaua`i Island, during HA-10-08, entailed numerous retrievals and deployments of oceanographic moored instruments, nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, and shipboard water sampling and CTD casts offshore to a depth of 500 m.

Two subsurface temperature recorders (STRs) were retrieved and deployed at Kaua`i Island, one of which was deployed on an Environmental Acoustic Recorder (EAR) mooring (Fig. E.1.1). One EAR unit was retrieved and replaced. One wave-and-tide recorder (WTR) mooring, including instrument and anchor, was removed and not replaced (Table E.1.1).

In addition to the usual suite of mooring replacements, the oceanography team attempted to retrieve 4 of 3 fish tag receivers for Carl Meyer of the Hawai`i Institute of Marine Biology (HIMB), University of Hawai`i. One receiver was retrieved from the east side of Kaua`i Island. The receiver mooring on the south shore was not found, and the receiver was missing from the mooring on the north shore.

At nearshore locations around Kaua`i Island, 5 shallow-water CTD casts were performed at 5 REA sites (Fig. E.1.2) that have been identified as possible locations sites for future installations of calcification acidification units (CAUs). In concert with the CTD cast at each of those same sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, and nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. Including nutrient samples taken at REA sites without a CTD cast, a total of 10 DIC and TA, 10 salinity, 12 nutrient, and 10 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each site.

From the NOAA Ship *Hi`ialakai*, ~ 65 km of ADCP transect lines were run during night operations. On the reciprocal course, shipboard CTD casts to depths of 500 m were conducted per transect line every 5 km for a total of 14 deepwater CTD casts (Fig. E.1.3). Water samples were collected concurrently with select shipboard CTD casts 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, a total of 30 nutrient and 30 Chl-*a* shipboard water samples were collected.

Table E.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments retrieved or deployed at Kaua`i Island during cruise HA-10-08.

Mooring Site	Instrument Type	Latitude	Longitude	Depth (m)	Retrieval	Deployment
KAU-002	STR	21.86883816	–159.4474589	6.1	×	×
KAU-003	Anchor	22.12336195	–159.7770823	25.9	–	×
KAU-003	WTR	22.12336195	–159.7770823	25.9	–	×
KAU-007	EAR	22.13798669	–159.7613377	17.7	×	×
KAU-007	STR	22.13798669	–159.7613377	17.7	×	×

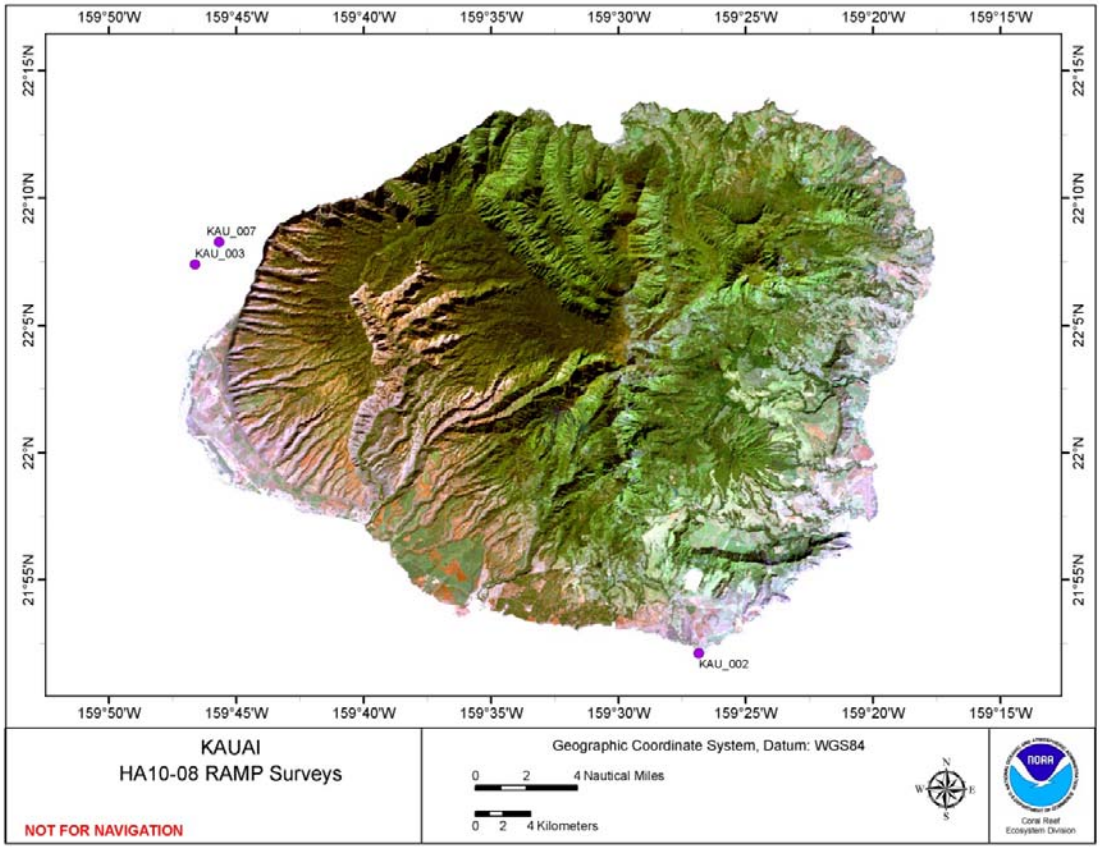


Figure E.1.1.--Locations of moored instruments retrieved and deployed at Kaua`i Island during cruise HA-10-08. Landsat satellite imagery data used in this map and the other maps in this appendix are available from the U.S. Geological Survey.

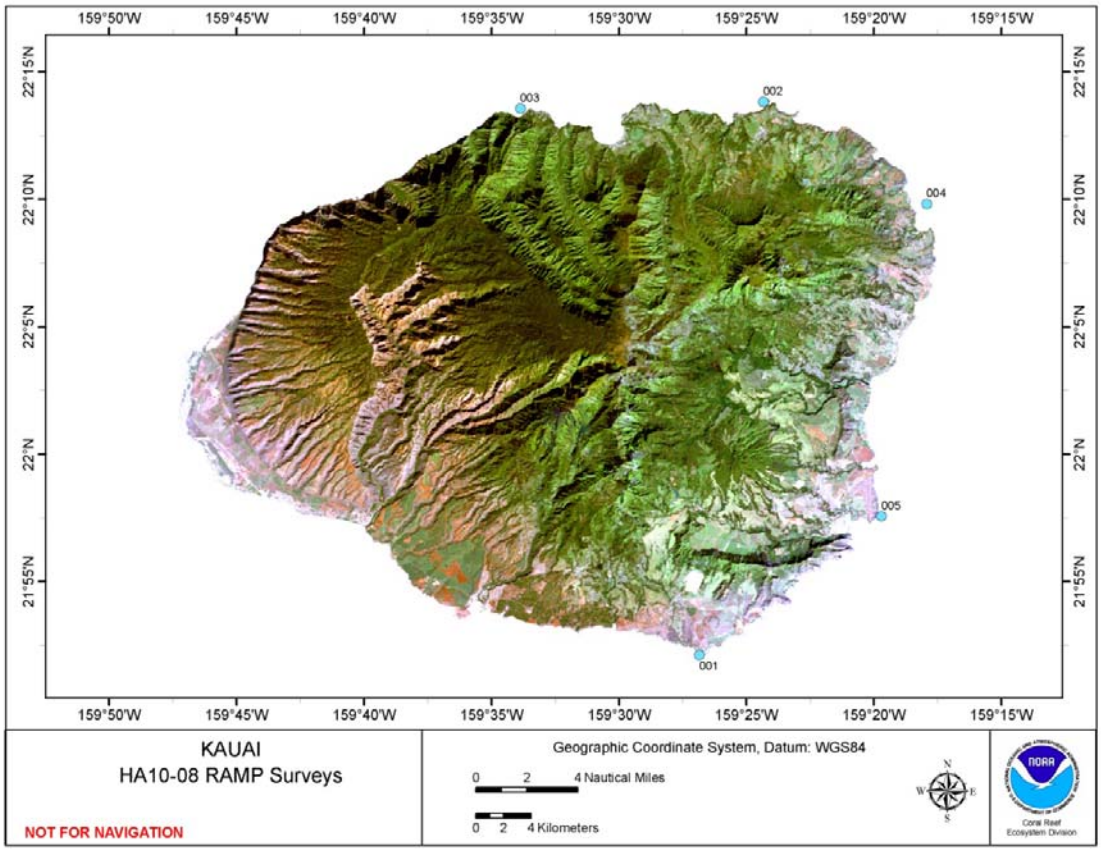


Figure E.1.2.--Locations of shallow-water CTD casts performed at Kaua`i Island during cruise HA-10-08. At all 5 nearshore cast locations, water samples for analyses of DIC, TA, salinity, nutrient, and Chl-*a* concentrations were collected.

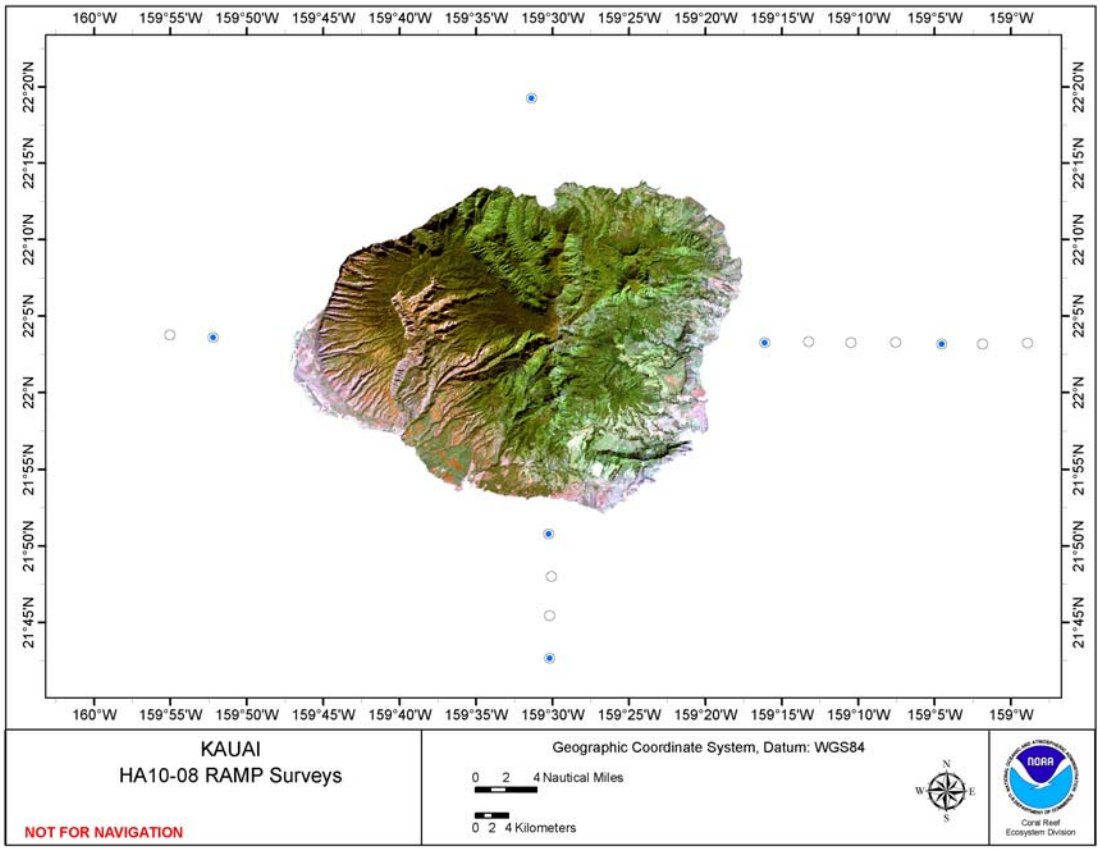


Figure E.1.3.--Locations of deepwater CTD casts conducted at Kaua`i Island from the NOAA Ship *Hi`ialakai* to a depth of 500 m. Shipboard water samples for analyses of nutrient and Chl-*a* concentrations were collected in concert with the casts conducted at the 6 locations displayed in blue.

E.2. Benthic Environment

Belt-transect and line-point-intercept (LPI) surveys were conducted and photoquadrat images were collected at 12 REA sites around Kaua`i Island to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig E.2.1 and Table E.2.1). At the end of LPI surveys, roving-diver algal surveys were conducted if time permitted. No surveys of target macroinvertebrates were completed at Kaua`i Island. Ten autonomous reef monitoring structures (ARMS) were recovered from REA sites KAU-08, KAU-14, KAU-12, KAU-06, and KAU-02, and 6 ARMS were redeployed at KAU-08, KAU-06, and KAU0-02 (Table E.2.1).

At 4 select REA sites, 19 microbial water samples were collected, with four 2-L samples at each site and three 20-L samples at KAU-13. For information about collections of algal voucher specimens, see Table I.1.1 in Appendix I: "Biological Collections."

In total, the benthic team conducted 56 individual dives around Kaua`i Island.

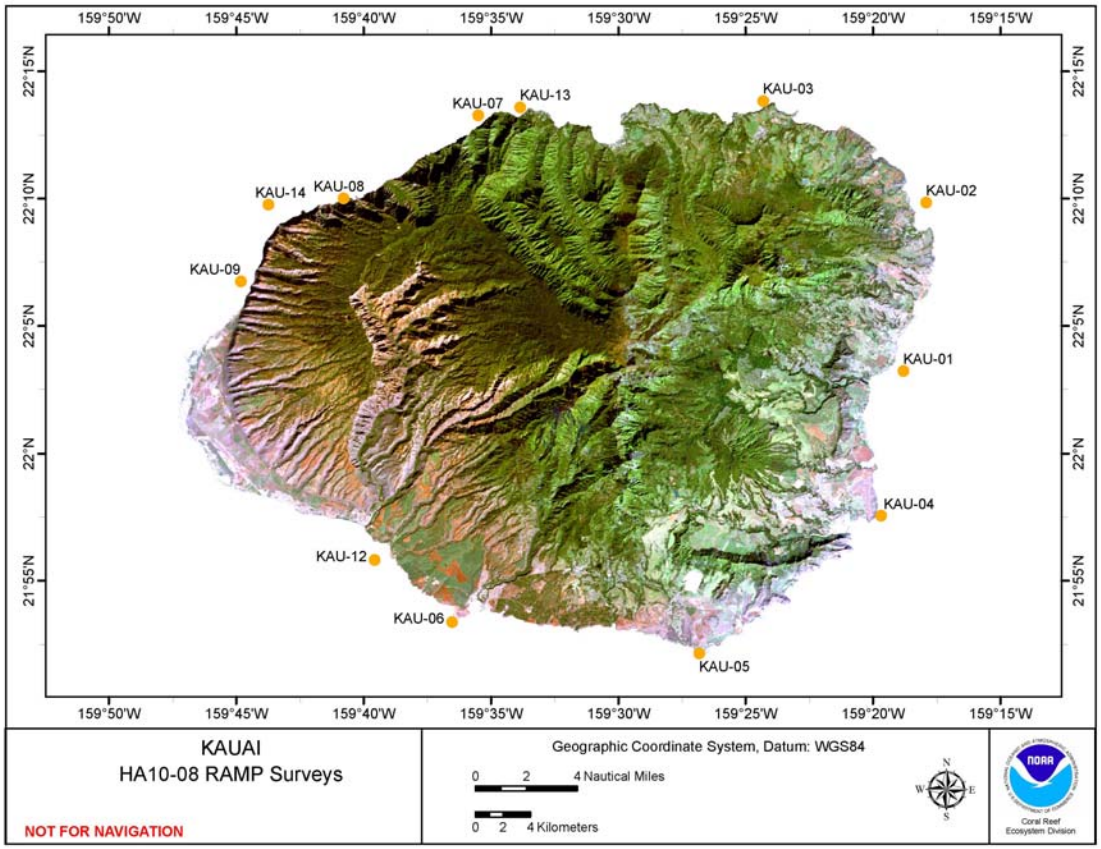


Figure E.2.1.--Locations of REA benthic sites surveyed at Kaua`i Island during cruise HA-10-08.

Table E.2.1. Summary of REA benthic surveys and ARMS retrievals (Ret.) and deployments (Dep.) performed as well as algal voucher specimens and microbial water samples collected at Kaua`i Island during cruise HA-10-08. Photoquadrat images were collected in concert with LPI surveys, after which roving-diver algal surveys were conducted if time permitted. For more details, see Appendix A: "Methods."

REA Site	Date	Latitude	Longitude	REA Surveys		Installations and Collections		
				LPI	Corals	ARMS Ret/Dep	Algae	Microbial Samples
KAU-08	27-Oct	22.166900	–159.680200	×	×	2/2	–	4 × 2 L
KAU-09	27-Oct	22.112500	–159.746900	×	×	–	1	–
KAU-14	27-Oct	22.162717	–159.729133	×	×	2/0	–	–
KAU-05	29-Oct	21.868900	–159.447200	×	×	–	–	–
KAU-06	29-Oct	21.889700	–159.608800	×	×	2/2	–	–
KAU-12	29-Oct	21.930400	–159.659500	×	×	2/0	–	4 × 2 L
KAU-03	30-Oct	22.230600	–159.405400	×	×	–	1	–
KAU-07	30-Oct	22.221100	–159.591700	×	×	–	1	–
KAU-13	30-Oct	22.226500	–159.564600	×	×	–	2	4 × 2 L; 3 × 20 L
KAU-01	31-Oct	22.053900	–159.313400	×	×	–	–	–
KAU-02	31-Oct	22.164200	–159.298933	×	×	2/2	–	4 × 2 L
KAU-04	31-Oct	21.959400	–159.328300	×	×	–	–	–

CRED completed a total of 22 towed-diver surveys at Kaua`i Island, covering a total length of 55.5 km (an area of 55.5 ha) on the ocean floor (Fig. E.2.2). The mean survey length was 2.5 km with a range of 1.9–3.5 km. The mean survey depth was 14.9 m with a range of 12–20.7 m. The mean temperature from data recorded during these surveys was 25.9°C with a range of 25.6°C –26.4°C.

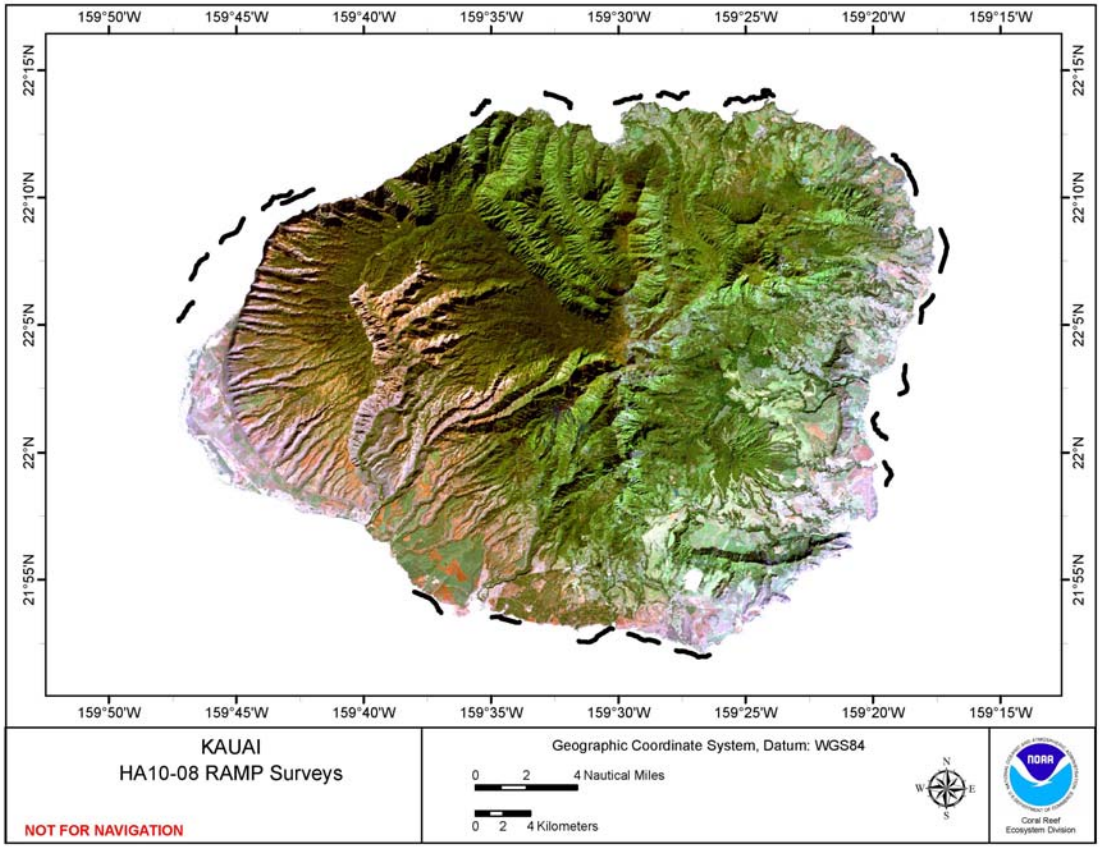


Figure E.2.2.--Track locations of towed-diver surveys conducted at Kaua`i Island during cruise HA-10-08.

E.3. 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 Kaua`i Island in the deep, moderate, and shallow forereef strata (Table E. 3.1 and Fig. E.3.1). No fishes were collected during these surveys.

In addition, CRED completed a total of 22 towed-diver surveys at Kaua`i Island, as described previously in Section E.2 of this appendix.

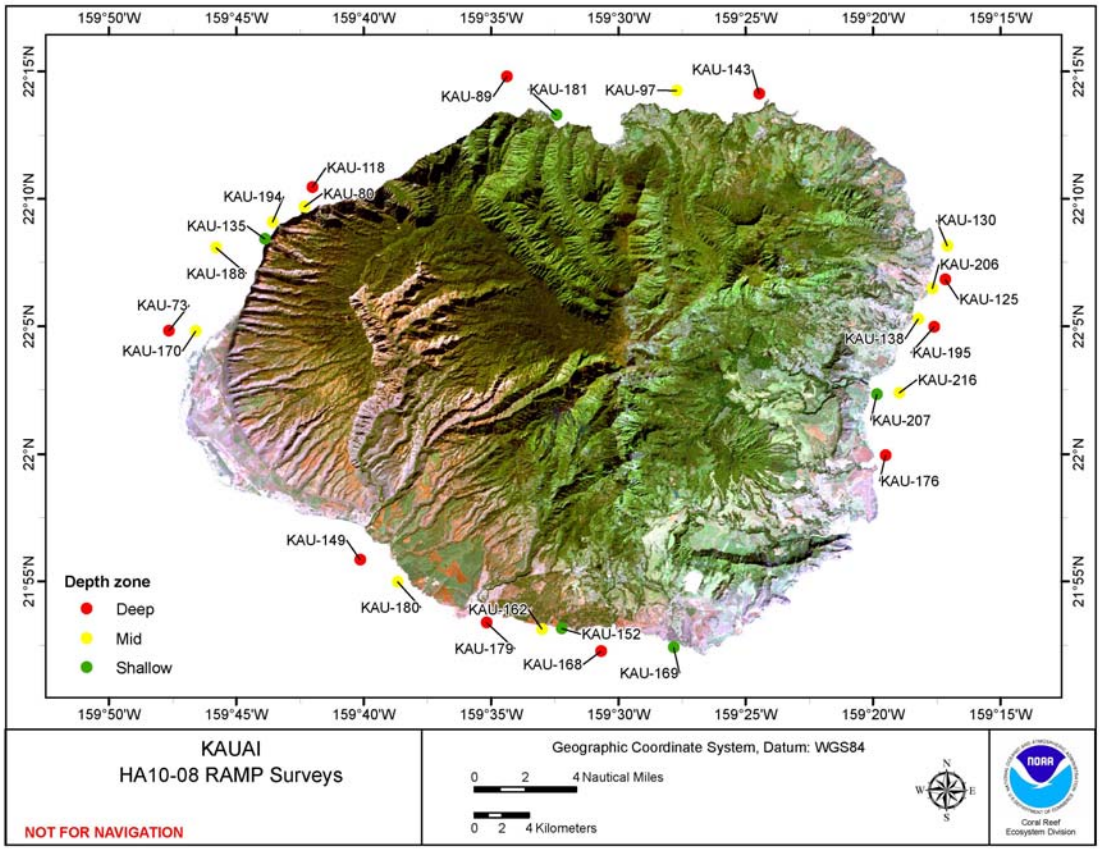


Figure E.3.1.--Locations of REA fish sites surveyed at Kaua`i Island during cruise HA-10-08. All of these REA sites were selected using a stratified random design.

Table E.3.1. Summary of sites where REA fish surveys were conducted at Kaua`i Island during cruise HA-10-08.

REA Site	Date	Depth Zone	Stratum	Depth (m)	Latitude	Longitude
KAU-73	27-Oct	Deep	Forereef	25	22.08031	–159.794
KAU-80	27-Oct	Mid	Forereef	11	22.16161	–159.706
KAU-118	27-Oct	Deep	Forereef	23	22.17425	–159.7
KAU-135	27-Oct	Shallow	Forereef	6	22.14039	–159.731
KAU-170	27-Oct	Mid	Forereef	16	22.08022	–159.777
KAU-188	27-Oct	Mid	Forereef	18	22.13478	–159.763
KAU-194	27-Oct	Mid	Forereef	9	22.15153	–159.726
KAU-149	29-Oct	Deep	Forereef	22	21.93094	–159.669
KAU-152	29-Oct	Shallow	Forereef	7	21.88599	–159.537
KAU-162	29-Oct	Mid	Forereef	13	21.88554	–159.55
KAU-168	29-Oct	Deep	Forereef	29	21.87106	–159.511
KAU-169	29-Oct	Shallow	Forereef	7	21.87361	–159.464
KAU-179	29-Oct	Deep	Forereef	23	21.88978	–159.586
KAU-180	29-Oct	Mid	Forereef	10	21.9167	–159.645
KAU-89	30-Oct	Deep	Forereef	25	22.24684	–159.573
KAU-97	30-Oct	Mid	Forereef	17	22.23749	–159.462
KAU-143	30-Oct	Deep	Forereef	24	22.23549	–159.408
KAU-181	30-Oct	Shallow	Forereef	5	22.22163	–159.541
KAU-125	31-Oct	Deep	Forereef	20	22.11411	–159.286
KAU-130	31-Oct	Mid	Forereef	14	22.13601	–159.285
KAU-138	31-Oct	Mid	Forereef	9	22.08828	–159.304
KAU-176	31-Oct	Deep	Forereef	22	21.99936	–159.325
KAU-195	31-Oct	Deep	Forereef	22	22.08299	–159.293
KAU-206	31-Oct	Mid	Forereef	12	22.10802	–159.295
KAU-207	31-Oct	Shallow	Forereef	5	22.0388	–159.331
KAU-216	31-Oct	Mid	Forereef	18	22.03985	–159.316

(This page is left blank intentionally.)

APPENDIX F: NI`IHAU ISLAND AND LEHUA ROCK

The island of Ni`ihau Island and Lehua Rock, located at 21.89^{o} N, 160.16^{o} W and 22.02^{o} N, 160.10^{o} W respectively 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. Oceanography and Water Quality

Oceanographic operations during HA-10-08 at Ni`ihau Island and Lehua Rock entailed numerous retrievals and deployments of oceanographic moored instruments, nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, and shipboard water sampling and CTD casts offshore to a depth of 500 m.

Two subsurface temperature recorders (STRs) were retrieved, and 2 STRs were deployed, 1 at Ni`ihau Island and 1 at Lehua Rock (Fig. F.1.1 and Table F.1.1).

At nearshore locations around Ni`ihau Island, 3 shallow-water CTD casts were performed at REA sites NII-01, NII-03, and NII-05 (Fig. F.1.2), which have been identified as possible locations for future installations of calcification acidification units (CAUs). In concert with the CTD cast at each of these REA sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, and nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. A total of 6 DIC and TA, 6 salinity, 6 nutrient, and 6 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each site.

From the NOAA Ship *Hi`ialakai*, ~ 40 km of ADCP transect lines were run away from these islands during night operations. On the reciprocal course, shipboard CTD casts to depths of 500 m were conducted per transect line every 5 km for a total of 7 deepwater CTD casts. Water samples were collected concurrently with 2 select shipboard CTD casts 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 and Lehua Rock, 10 nutrient and 10 Chl-*a* shipboard water samples were collected.

Table F.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments retrieved or deployed at Ni`ihau Island or Lehua Rock during cruise HA-10-08.

Mooring Site	Instrument Type	Latitude	Longitude	Depth (m)	Retrieval	Deployment
NII-002	STR	21.95128114	–160.0617623	12.5	×	×
LEH-002	STR	22.01449393	–160.0970466	7	–	×
LEH-003	STR	22.01659419	–160.0913898	12.5	×	–

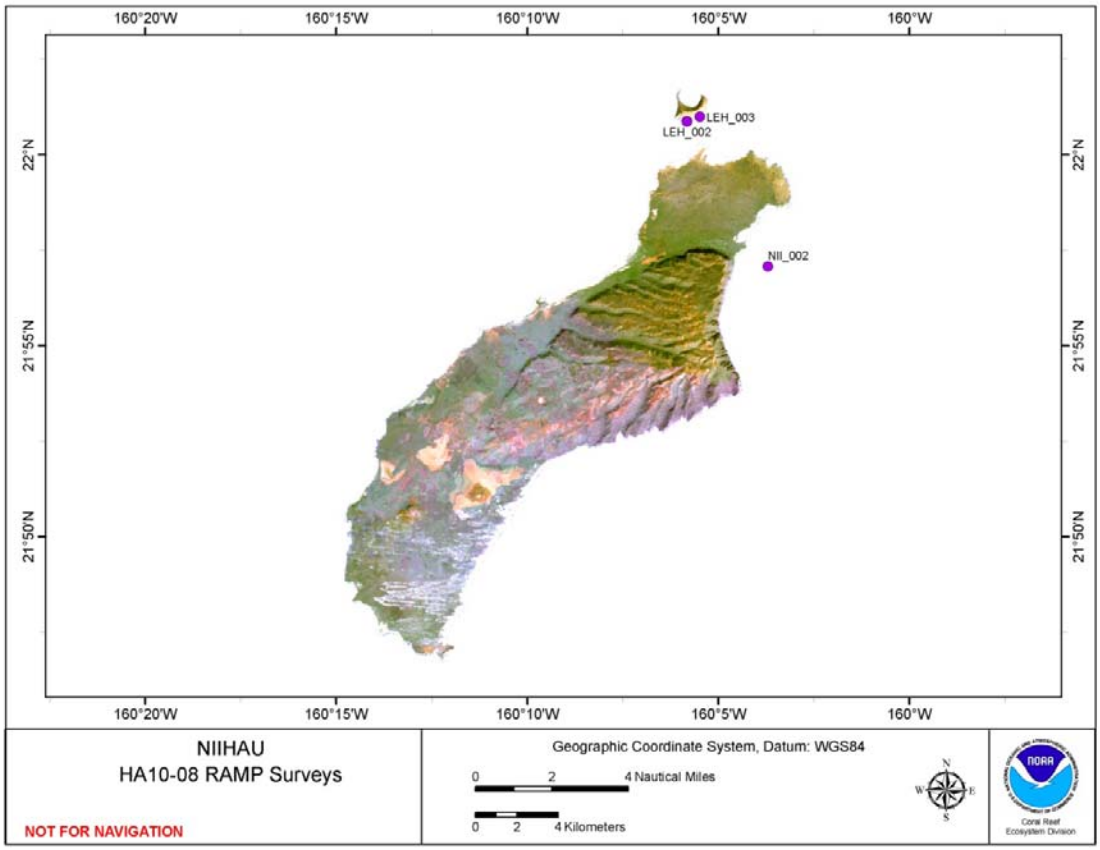


Figure F.1.1.--Locations of moored instruments retrieved and deployed at Ni`ihau Island and Lehua Rock during cruise HA-10-08. Landsat satellite imagery data used in this map and the other maps in this appendix are available from the U.S. Geological Survey.

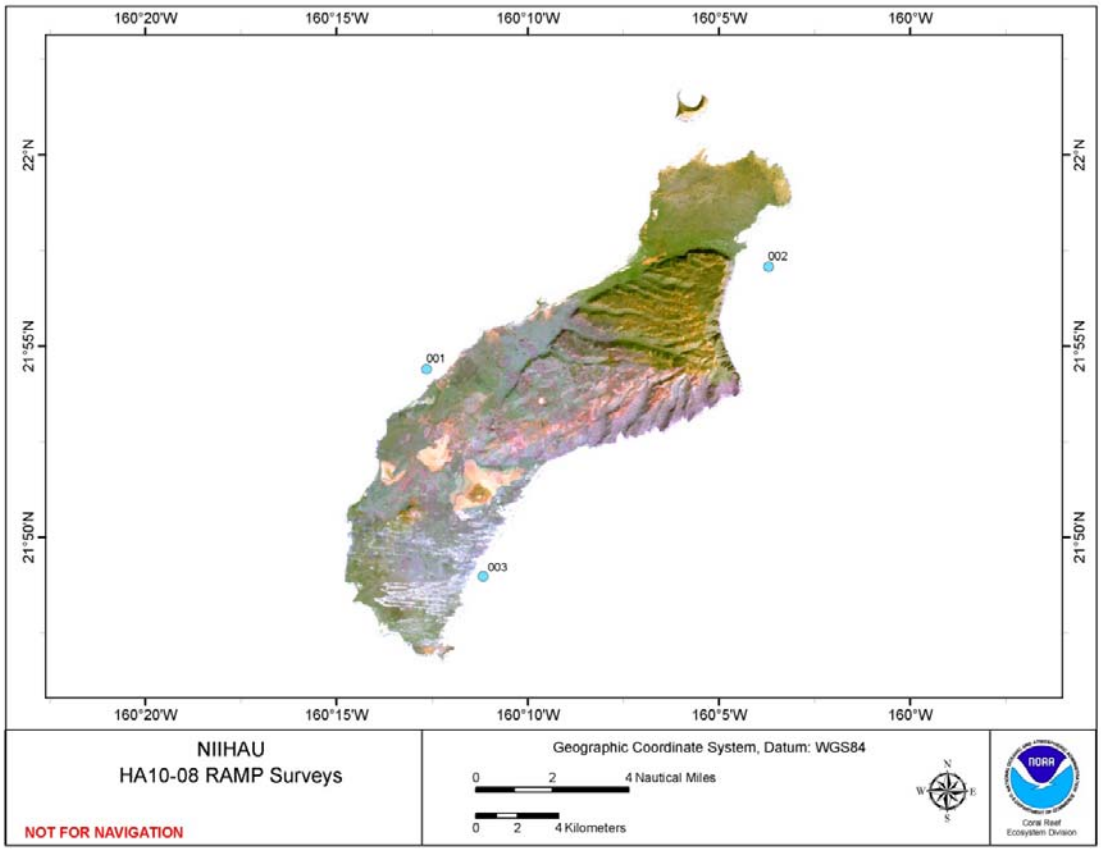


Figure F.1.2.--Locations of shallow-water CTD casts performed at Ni`ihau Island during cruise HA-10-08. At all 3 nearshore cast locations, water samples for analyses of DIC, TA, salinity, nutrient, and Chl-*a* concentrations were collected.

F.2. Benthic Environment

Belt-transect and line-point-intercept (LPI) surveys were conducted and photoquadrat images were collected at 6 REA sites around Ni`ihau Island to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. F.2.1 and Table F.2.1). At the end of LPI surveys, roving-diver algal surveys were conducted if time permitted. No surveys of target macroinvertebrates were completed, and no autonomous reef monitoring structures (ARMS) were deployed or recovered.

At 2 select REA sites, 8 microbial water samples were collected, with four 2-L samples at each site. For information about collections of algal voucher specimens, see Table I.1.1 in Appendix I: "Biological Collections."

In total, the benthic team conducted 24 individual dives around Ni`ihau Island.

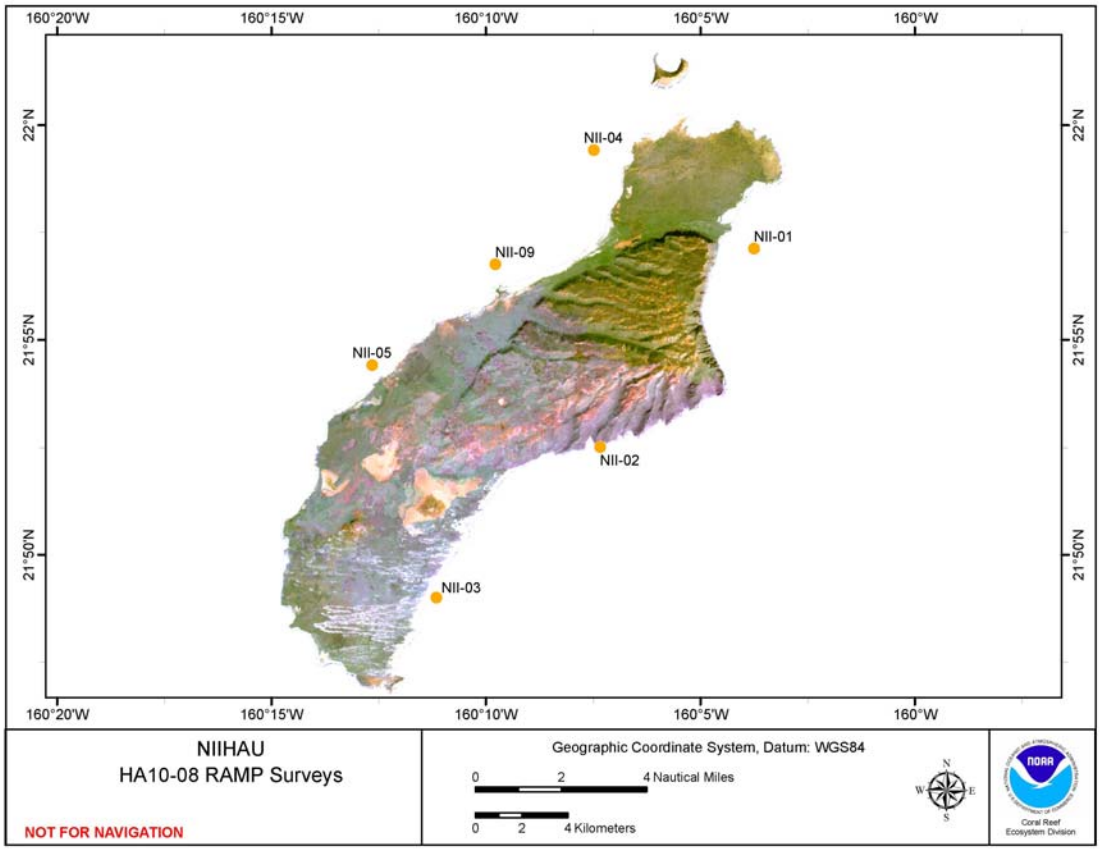


Figure E.2.1.--Locations of REA benthic sites surveyed at Ni`ihau Island during cruise HA-10-08.

Table F.2.1. Summary of REA benthic surveys performed and algal voucher specimen and microbial water samples collected at Ni`ihau Island during cruise HA-10-08. Photoquadrat images were collected in concert with LPI surveys, after which roving-diver algal surveys were conducted if time permitted. For more details, see Appendix A: "Methods."

REA Site	Date	Latitude	Longitude	REA Surveys		Collections	
				LPI	Corals	Algae	Microbial Samples
NII-04	28-Oct	21.990383	–160.124833	×	×	–	–
NII-05	28-Oct	21.906900	–160.210900	×	×	–	4 × 2 L
NII-09	28-Oct	21.945800	–160.163300	×	×	–	–
NII-01	1-Nov	21.952000	–160.062400	×	×	–	–
NII-02	1-Nov	21.875300	–160.122400	×	×	1	–
NII-03	1-Nov	21.816700	–160.185900	×	×	–	4 × 2 L

CRED completed a total of 9 towed-diver surveys at Ni`ihau Island and Lehua Rock, covering a combined total length of 19.6 km (an area of 19.6 ha) on the ocean floor (Fig. F.2.2). The mean survey length was 2.2 km with a range of 0.9–2.7 km. The mean survey depth was 13.8 m with a range of 9.1–16.6 m. The mean temperature from data recorded during these surveys was 26.2°C with a range of 25.9°C–26.5°C.

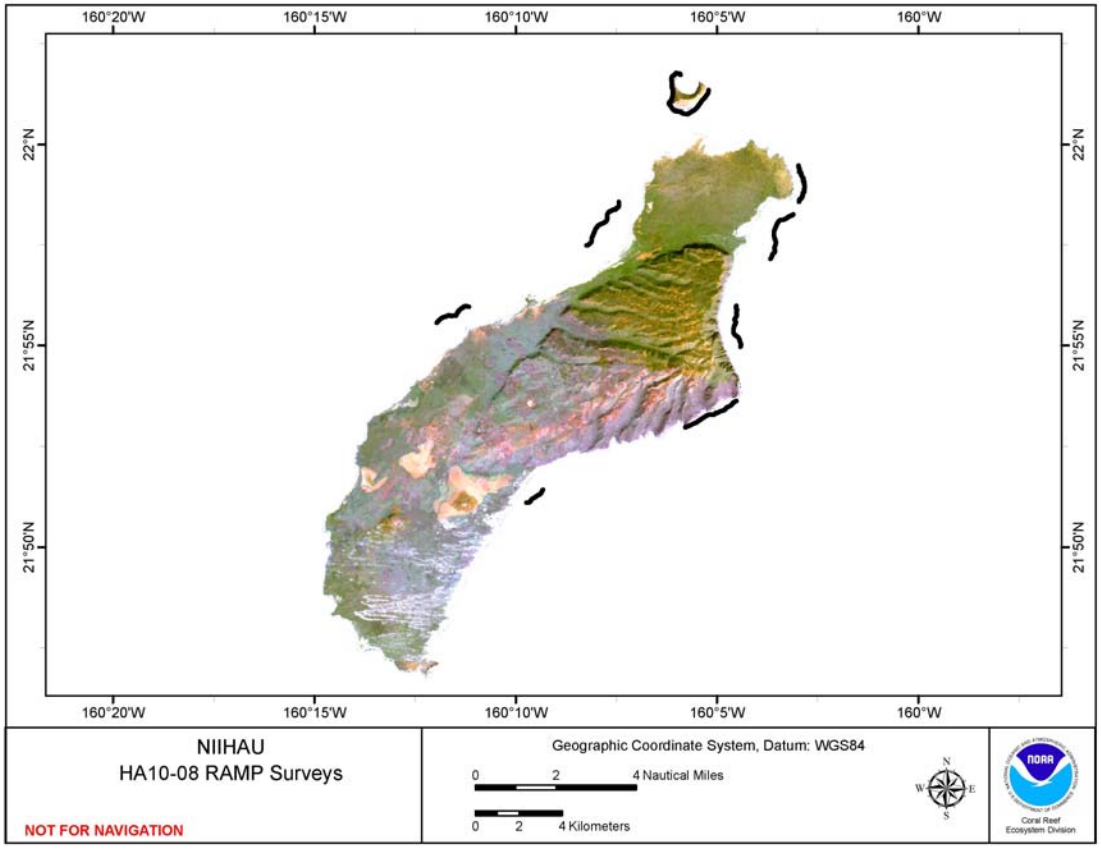


Figure F.2.2.--Track locations of towed-diver surveys conducted at Ni`ihau Island and Lehua Rock during cruise HA-10-08.

F.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary point count surveys were conducted at 16 REA sites at Ni`ihau Island in the deep, moderate, and shallow forereef strata (Table F.3.1 and Fig. F.3.1). No fishes were collected during these surveys.

In addition, CRED completed a total of 9 towed-diver surveys at Ni`ihau Island and Lehua Rock, as described in Section F.2 of this appendix.

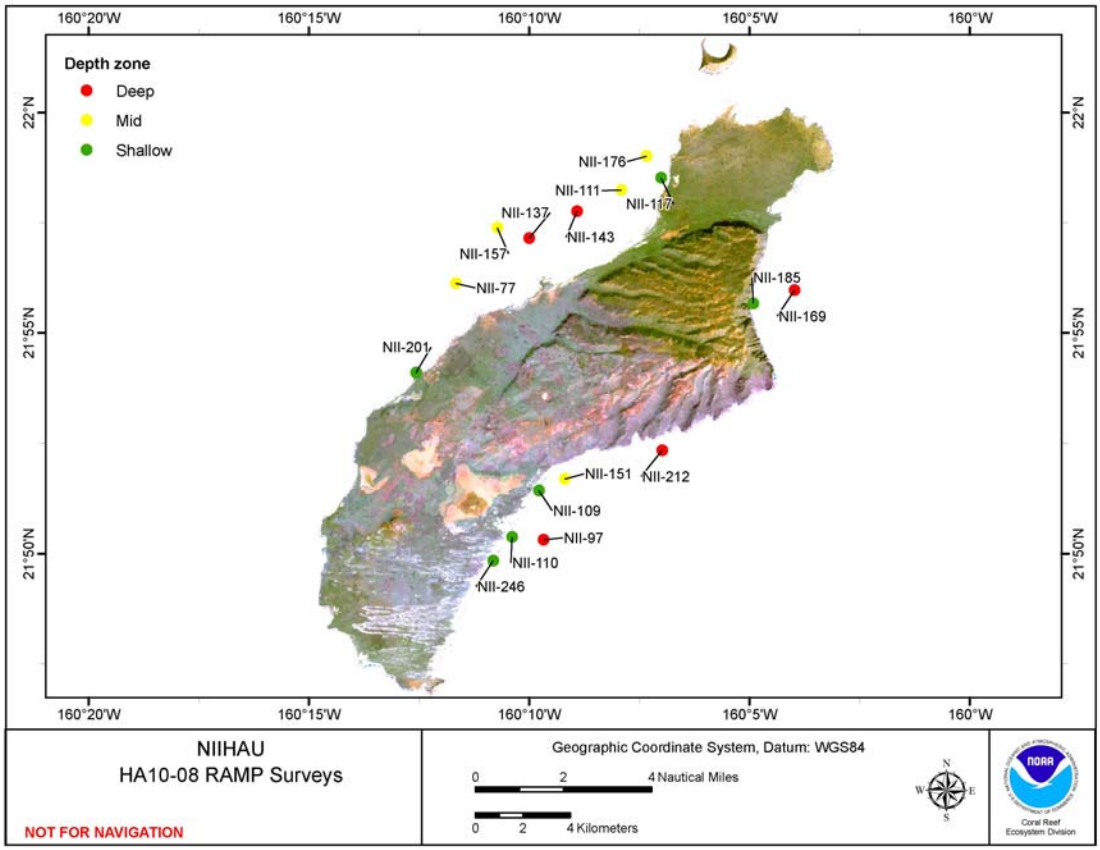


Figure F.3.1.--Locations of REA fish sites surveyed at Ni`ihau Island during cruise HA-10-08. All of these REA sites were selected using a stratified random design.

Table F.3.1.--Summary of sites where REA fish surveys were conducted at Ni`ihau Island during cruise HA-10-08.

REA Site	Date	Depth Zone	Stratum	Depth (m)	Latitude	Longitude
NII-77	28-Oct	Mid	Forereef	15	21.9355005	–160.194437
NII-111	28-Oct	Mid	Forereef	19	21.9707030	–160.131867
NII-117	28-Oct	Shallow	Forereef	5	21.9752800	–160.116829
NII-137	28-Oct	Deep	Forereef	21	21.9524174	–160.166668
NII-143	28-Oct	Deep	Forereef	23	21.9626701	–160.148553
NII-157	28-Oct	Mid	Forereef	17	21.9564564	–160.178729
NII-176	28-Oct	Mid	Forereef	16	21.9835540	–160.122299
NII-201	28-Oct	Shallow	Forereef	5	21.9016154	–160.209490
NII-97	1-Nov	Deep	Forereef	28	21.8386418	–160.161300
NII-109	1-Nov	Shallow	Forereef	6	21.8571895	–160.163003
NII-110	1-Nov	Shallow	Forereef	4	21.8397460	–160.173163
NII-151	1-Nov	Mid	Forereef	14	21.8616376	–160.153273
NII-169	1-Nov	Deep	Forereef	26	21.9327716	–160.066355
NII-185	1-Nov	Shallow	Forereef	6	21.9278369	–160.081929
NII-212	1-Nov	Deep	Forereef	23	21.8724317	–160.116435
NII-246	1-Nov	Shallow	Forereef	6	21.8307340	–160.180314

(This page is left blank intentionally.)

APPENDIX G: O`AHU ISLAND

The island of O`ahu, located at 21.44^{o} N, 158.00^{o} W in the north Pacific, 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."

G.1. Oceanography and Water Quality

Oceanographic operations around O`ahu Island during HA-10-08 entailed numerous retrievals and deployments of oceanographic moored instruments, nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, and shipboard water sampling and CTD casts offshore to a depth of 500 m.

No oceanographic moorings were retrieved or deployed at O`ahu Island during cruise HA-10-08 because of high surf and poor weather conditions. At nearshore locations around O`ahu Island, 3 shallow-water CTD casts were performed at REA sites OAH-01, OAH-05, and OAH-12 (Fig. G.1.1), which have been identified as possible locations for future installations of calcification acidification units (CAUs). In concert with the CTD cast at each of those same REA sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, and nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. A total of 8 DIC and TA, 8 salinity, 8 nutrient, and 8 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each CTD cast location and 2 additional samples for replicate analyses.

From the NOAA Ship *Hi`ialakai*, ~ 90 km of ADCP transect lines were run in one cardinal direction (south) away from this island during night operations. On the reciprocal course, shipboard CTD casts to depths of 500 m were conducted per transect line every 5 km for a total of 18 deepwater CTD casts (Fig. G.1.3). Water samples were collected concurrently with select shipboard CTD cast at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. A total of 25 nutrient and 25 Chl-*a* deepwater samples were collected near O`ahu Island.

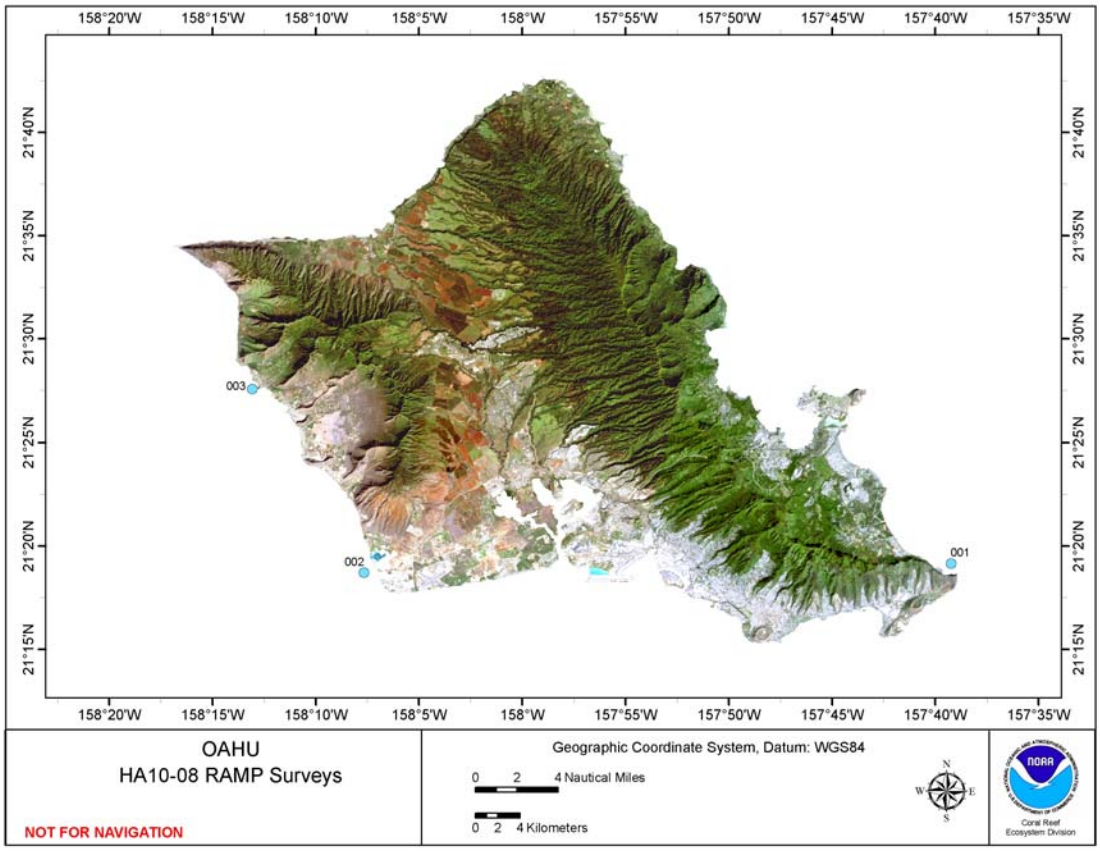


Figure G.1.1.--Locations of shallow-water CTD casts performed at O`ahu Island during cruise HA-10-08. At all 3 nearshore cast locations, water samples for analyses of DIC, TA, salinity, nutrient, and Chl-*a* concentrations were collected. Landsat satellite imagery data used in this map and the other maps in this appendix are available from the U.S. Geological Survey.

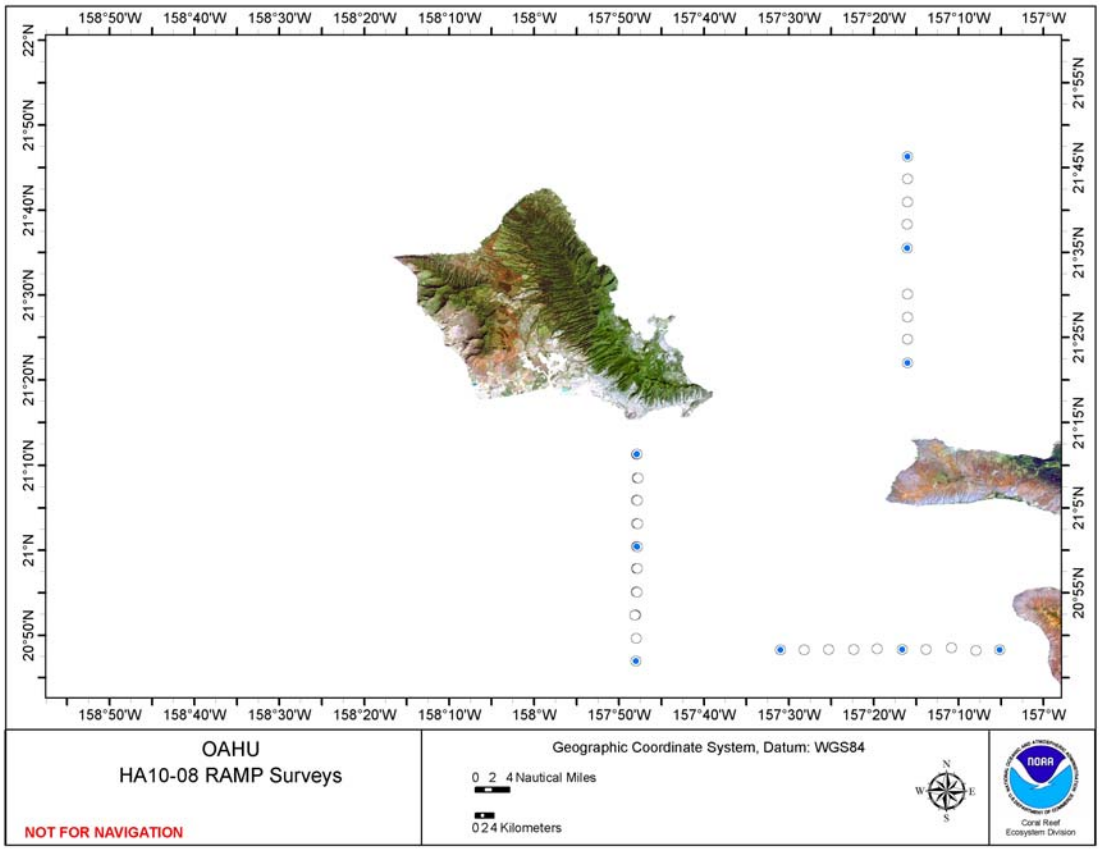


Figure G.1.2.--Locations of deepwater CTD casts conducted at O`ahu Island from the NOAA Ship *Hi`ialakai* to a depth of 500 m. Shipboard water samples for analyses of nutrient and Chl-*a* concentrations were collected in concert with the casts conducted at the 3 locations near O`ahu displayed in blue.

G.2. Benthic Environment

Belt-transect and line-point-intercept (LPI) surveys were conducted and photoquadrat images were collected at 8 REA sites at O`ahu Island to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. G.2.1 and Table G.2.1). At the end of LPI surveys, roving-diver algal surveys were conducted if time permitted. One survey for target macroinvertebrates was completed at site OAH-17, and 6 autonomous reef monitoring structures (ARMS) were recovered from OAH-12, OAH-15, and OAH-14 (Table G.2.1); 3 ARMS were redeployed at OAH-12.

At 3 select REA sites, 12 microbial water samples were collected, with four 2-L samples at each site and three 20-L samples at OAH-05.

In total, the benthic team conducted 49 individual dives around O`ahu Island.

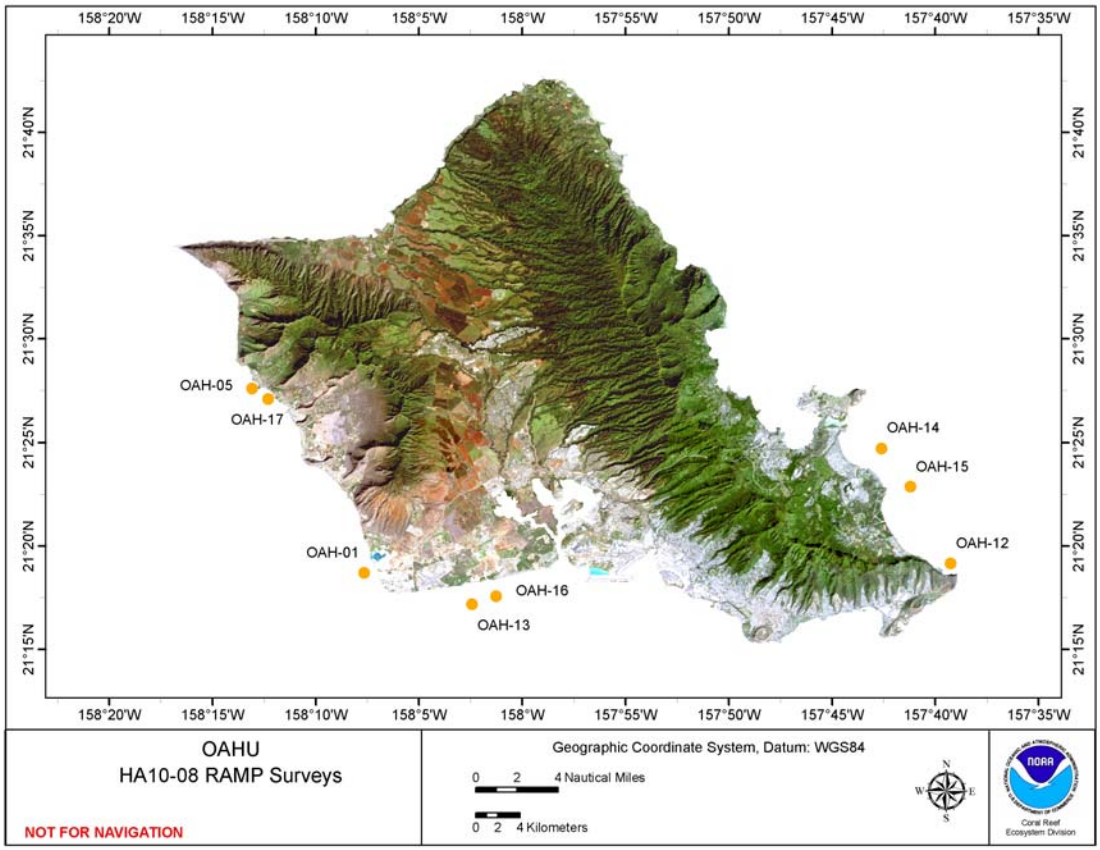


Figure G.2.1.--Locations of REA benthic sites surveyed at O`ahu Island during cruise HA-10-08.

Table G.2.1.--Summary of REA benthic surveys, ARMS retrievals (Ret.) and deployments (Dep.), and microbial water sampling performed at O`ahu Island during cruise HA-10-08. Photoquadrat images were collected in concert with LPI surveys, after which roving-diver algal surveys were conducted if time permitted. For more details, see Appendix A: "Methods."

				REA Surveys			Installations and Collections	
Site ID	Date	Latitude	Longitude	LPI	Corals	Inverts	ARMS Ret/Dep	Microbial Samples
OAH-12	24-Oct	21.319200	–157.654100	×	×	–	3/3	4 × 2 L
OAH-14	24-Oct	21.412217	–157.709800	×	×	–	1/0	–
OAH-15	24-Oct	21.381300	–157.686750	×	×	–	2/0	–
OAH-01	25-Oct	21.311800	–158.127300	×	×	–	–	4 × 2 L
OAH-13	25-Oct	21.286400	–158.040500	×	×	–	–	–
OAH-16	25-Oct	21.292951	–158.021057	×	×	–	–	–
OAH-05	2-Nov	21.459900	–158.217800	–	–	–	–	4 × 2 L; 3 × 20 L
OAH-17	2-Nov	21.451513	–158.205013	×	×	×	–	–

CRED completed a total of 14 towed-diver surveys at O`ahu Island, covering a total length of 30.4 km (an area of 30.4 ha) on the ocean floor (Fig. G.2.2). The mean survey length was 2.2 km with a range of 1.5-2.7 km. The mean survey depth was 13.5 m with a range of 10.8–16.7 m. The mean temperature from data recorded during these surveys was 26.1°C with a range of 25.8°C –26.4°C.

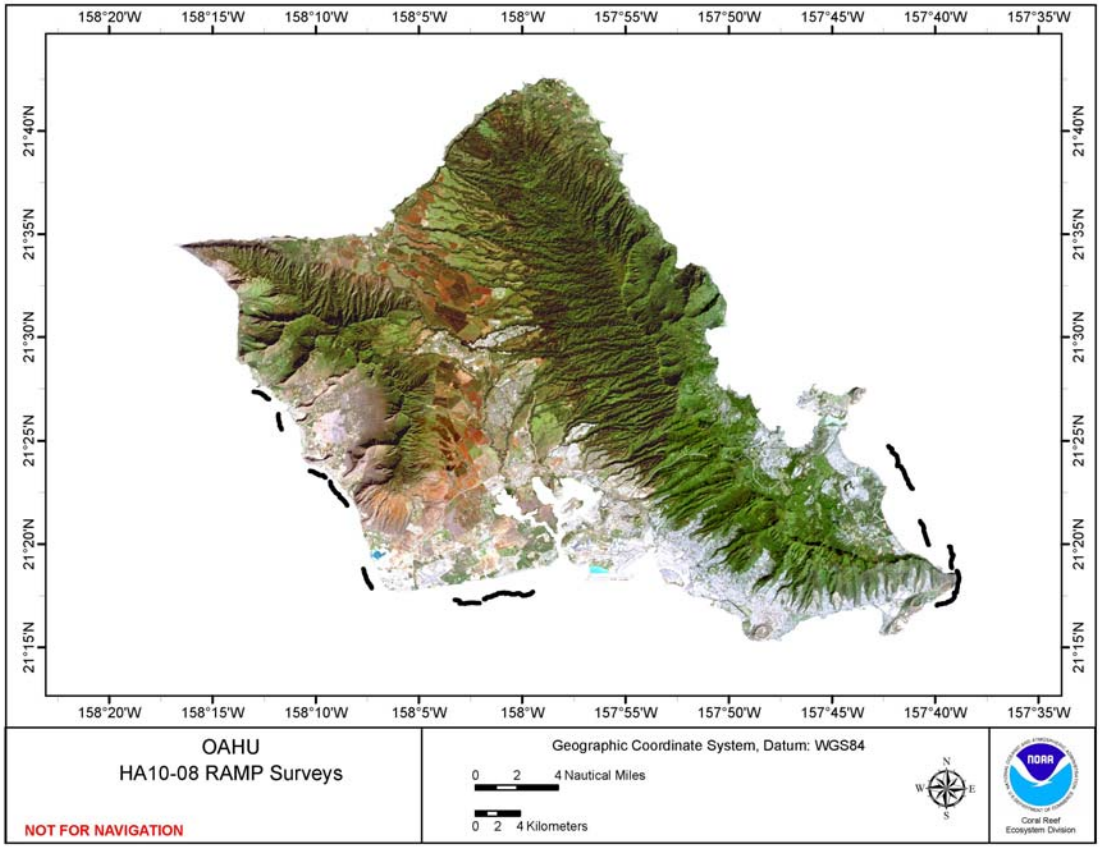


Figure G.2.2.--Track locations of towed-diver surveys conducted at O`ahu Island during cruise HA-10-08.

G.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary point count surveys were conducted at 15 REA sites at O`ahu Island in the deep, moderate, and shallow forereef strata (Table G.3.1 and Fig. G.3.1 and). No fishes were collected during these surveys.

In addition, CRED completed a total of 14 towed-diver surveys at O`ahu Island, as described previously in Section G.2 of this appendix.

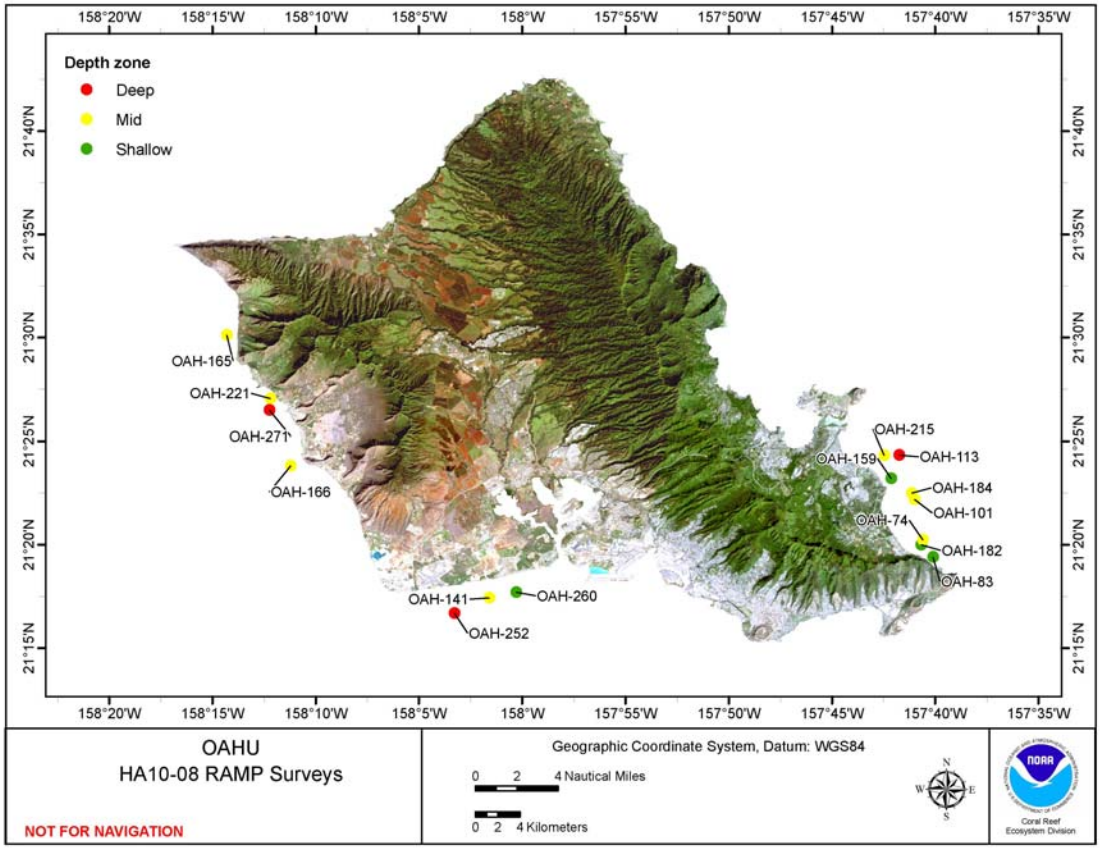


Figure G.3.1.--Locations of REA fish sites surveyed at O`ahu Island during cruise HA-10-08. All of these REA sites were selected using a stratified random design.

Table G.3.1. Summary of sites where REA fish surveys were conducted at O`ahu Island during cruise HA-10-08.

REA Site	Date	Depth Zone	Stratum	Depth (m)	Latitude	Longitude
OAH-74	24-Oct	Mid	Forereef	9	21.3373548	–157.676745
OAH-83	24-Oct	Shallow	Forereef	3	21.3235105	–157.668437
OAH-101	24-Oct	Mid	Forereef	12	21.3700119	–157.683469
OAH-113	24-Oct	Deep	Forereef	20	21.4057210	–157.695834
OAH-159	24-Oct	Shallow	Forereef	3	21.3870305	–157.702372
OAH-182	24-Oct	Shallow	Forereef	4	21.3333642	–157.678072
OAH-184	24-Oct	Mid	Forereef	13	21.3751388	–157.685668
OAH-215	24-Oct	Mid	Forereef	13	21.4056232	–157.707900
OAH-141	25-Oct	Mid	Forereef	15	21.2906891	–158.026609
OAH-252	25-Oct	Deep	Forereef	26	21.2782175	–158.054759
OAH-260	25-Oct	Shallow	Forereef	6	21.2950655	–158.004920
OAH-165	2-Nov	Mid	Forereef	16	21.5023114	–158.238338
OAH-166	2-Nov	Mid	Forereef	13	21.3971015	–158.186970
OAH-221	2-Nov	Mid	Forereef	7	21.4510562	–158.203131
OAH-271	2-Nov	Deep	Forereef	23	21.4416605	–158.203980

(This page is left blank intentionally.)

APPENDIX H: MOLOKA`I ISLAND

The island of Moloka`i, 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."

H.1. Oceanography and Water Quality

Oceanographic operations around Moloka`i Island during HA-10-08 entailed numerous retrievals and deployments of oceanographic moored instruments, nearshore water sampling and conductivity, temperature, and depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, and shipboard water sampling and CTD casts offshore to a depth of 500 m.

Two subsurface temperature recorders (STRs) were retrieved, and 2 were deployed at Moloka`i Island (Fig. H.1.1 and Table H.1.1).

At nearshore locations around Moloka`I, 6 shallow-water CTD casts were performed at REA sites MOL-01, MOL-03, MOL-04, and MOL-09 and newly established sites MOL-13 and MOL-14, all of which have been identified as possible locations for future installations of calcification acidification units (CAUs) and potential carbonate chemistry work (Fig. H.1.1). In concert with the CTD cast at each of these REA sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, and nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. A total of 12 DIC and TA, 12 salinity, 12 nutrient, and 12 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each site.

From the NOAA Ship *Hi`ialakai*, ~ 200 km of ADCP transect lines were run away from this island during night operations. On the reciprocal course, shipboard CTD casts were conducted to depths of 500 m per transect line every 5 km for a total of 9 deepwater CTD casts (Fig. C.1.3). Water samples were collected concurrently with select shipboard CTD casts 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, 15 nutrient and 15 Chl-*a* shipboard water samples were collected.

Table H.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments retrieved or deployed at Moloka`i Island during cruise HA-10-08.

REA Site	Instrument Type	Latitude	Longitude	Depth (m)	Retrieval	Deployment
MOL-001	STR	21.20307961	–157.2523968	9.8	×	×
MOL-002	STR	21.08093566	–157.2669635	19.5	×	×

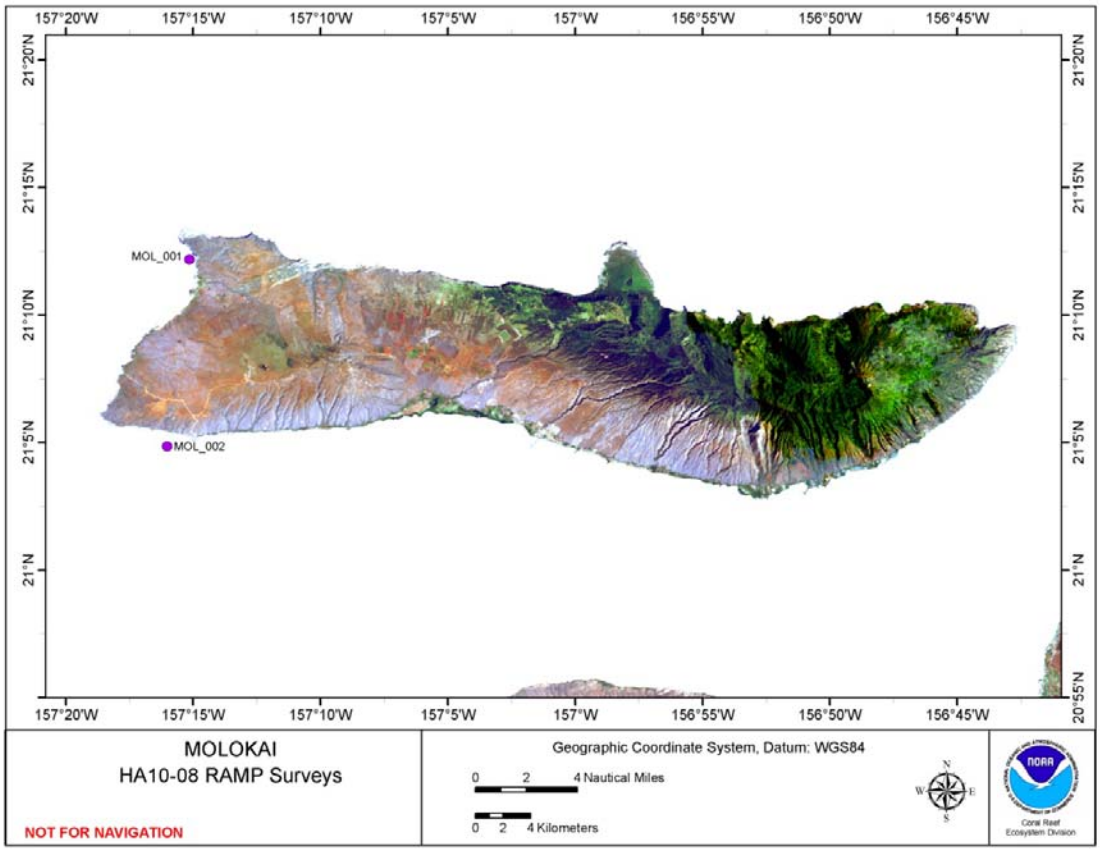


Figure H.1.1.--Locations of moored instruments retrieved and deployed at Moloka`i Island during cruise HA-10-08. Landsat satellite imagery data used in this map and the other maps in this appendix are available from the U.S. Geological Survey.

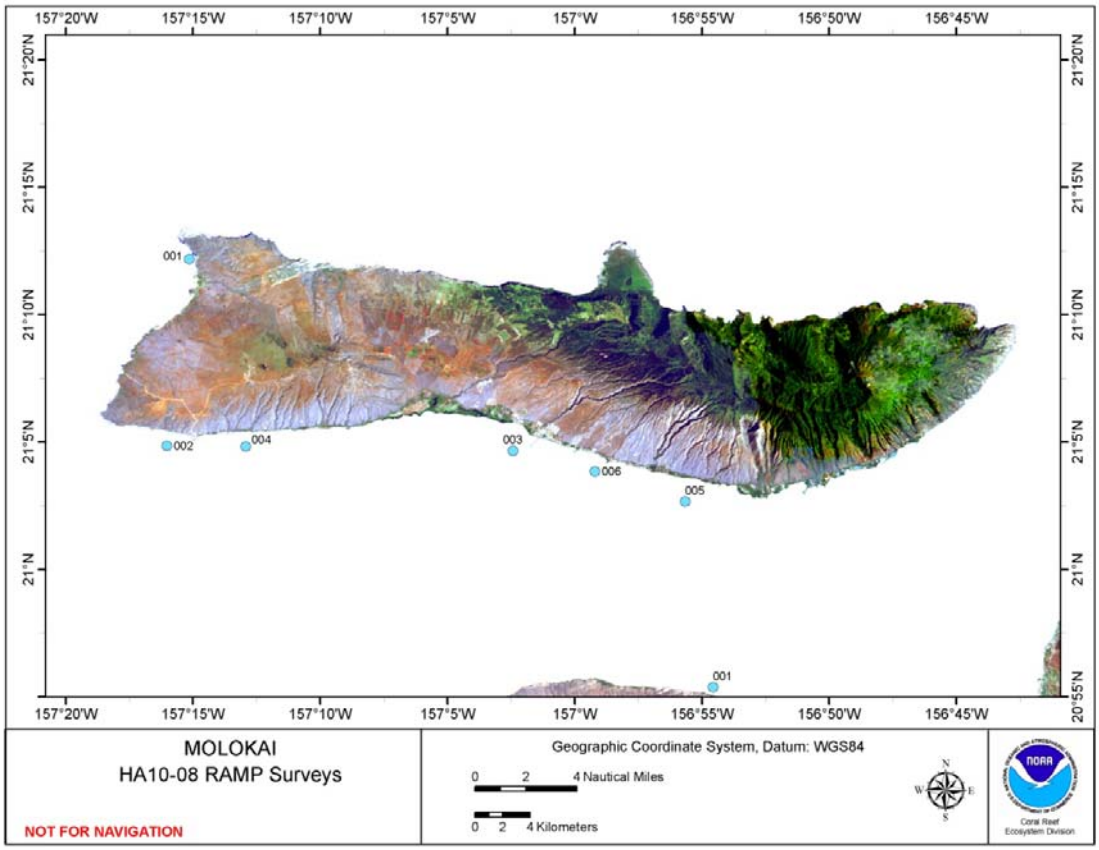


Figure H.1.2.--Locations of shallow-water CTD casts performed at Moloka`i Island during cruise HA-10-08. At all 6 nearshore cast locations, water samples for analyses of DIC, TA, salinity, nutrient, and Chl-*a* concentrations were collected

H.2. Benthic Environment

Belt-transect and line-point-intercept (LPI) surveys were conducted and photoquadrat images were collected at 9 REA sites at Moloka`i Island to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. H.2.1 and Table H.2.1). At the end of LPI surveys, roving-diver algal surveys were conducted if time permitted. A subset of 8 REA sites were also surveyed for target macroinvertebrates, with one additional site, MOL-10, surveyed to assess the magnitude and density of an outbreak of crown-of-thorns seastars. No autonomous reef monitoring structures (ARMS) were deployed or recovered around this island.

At 3 select REA sites, 12 microbial water samples were collected, with four 2-L samples at each site. For information about collections of algal voucher specimens, see Table I.1.1 in Appendix I: "Biological Collections."

In total, the benthic team conducted 56 individual dives at Moloka`i Island.

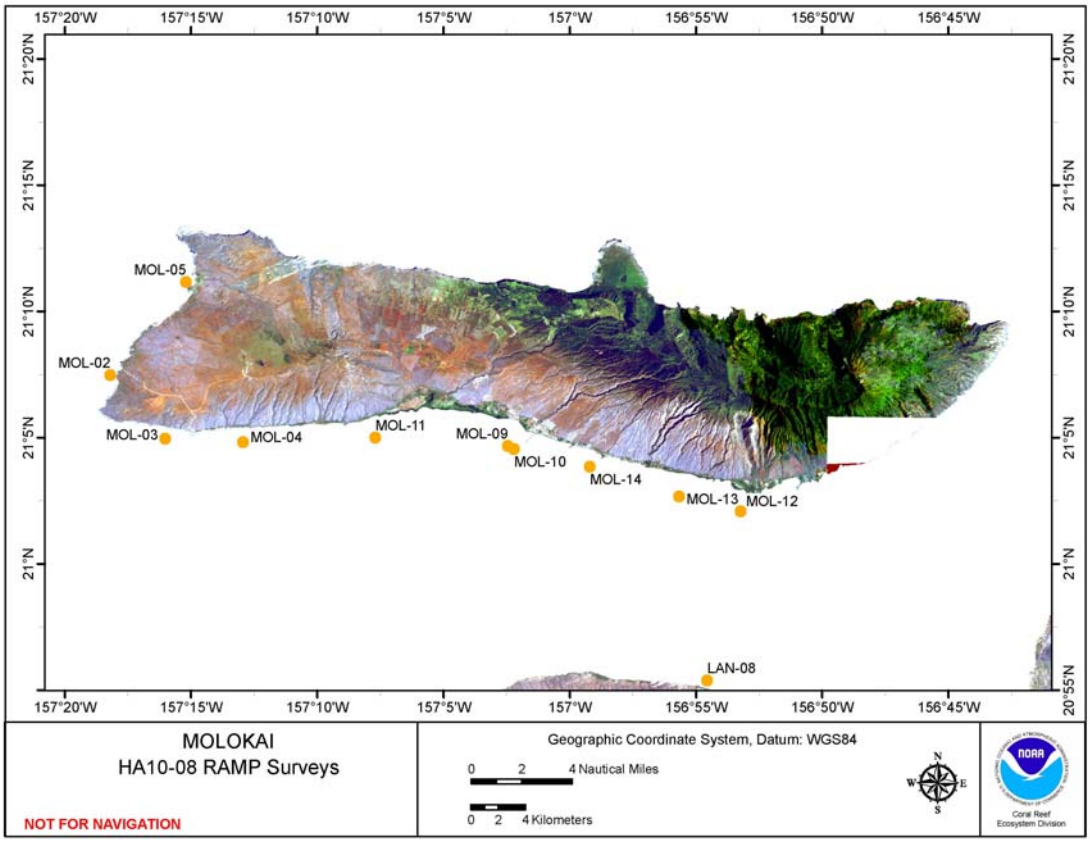


Figure H.2.1.--Locations of REA benthic sites surveyed at Moloka`i Island during cruise HA-10-08.

Table H.2.1.--Summary of REA benthic surveys performed and algal voucher specimens and microbial water samples collected at Moloka`i Island during cruise HA-10-08. Photoquadrat images were collected in concert with LPI surveys, after which roving-diver algal surveys were conducted if time permitted. For more details, see Appendix A: "Methods."

REA Site	Date	Latitude	Longitude	REA Surveys			Collections	
				LPI	Corals	Inverts	Algae	Microbial Samples
MOL-02	23-Oct	21.124900	–157.303200	×	×	×	–	–
MOL-03	23-Oct	21.083000	–157.267100	×	×	×	2	4 × 2L
MOL-05	23-Oct	21.186100	–157.253400	×	×	×	–	–
MOL-04	3-Nov	21.080500	–157.215600	×	×	×	–	4 × 2L
MOL-09	3-Nov	21.077889	–157.040851	×	×	×	2	–
MOL-10	3-Nov	21.075790	–157.036831	–	–	×	–	–
MOL-11	3-Nov	21.083414	–157.128476	×	×	–	1	–
MOL-12	4-Nov	21.034793	–156.887076	×	×	×	1	–
MOL-13	4-Nov	21.044643	–156.927768	×	×	×	–	4 × 2L
MOL-14	4-Nov	21.064287	–156.986761	×	×	×	1	–

CRED completed a total of 11 towed-diver surveys at Moloka`i Island, covering a total length of 25.7 km (an area of 25.7 ha) on the ocean floor (Fig. H.2.2). The mean survey length was 2.3 km with a range of 2–2.7 km. The mean survey depth was 13.6 m with a range of 12.5–15.4 m. The mean temperature from data recorded during these surveys was 25.6°C with a range of 25.4°C–25.8°C.

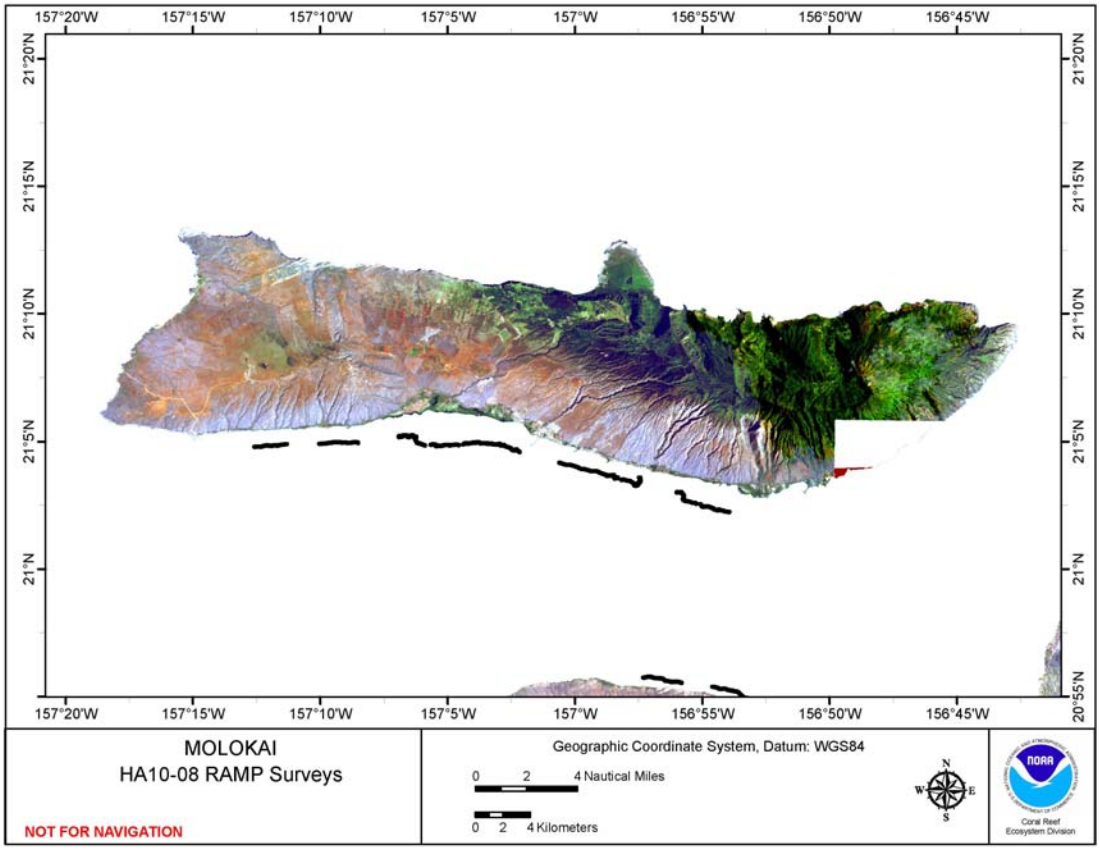


Figure H.2.2.—Track locations of towed-diver surveys conducted at Moloka`i Island during cruise HA-10-08.

H.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary point count surveys were conducted at 10 REA sites at Moloka`i Island in the deep, moderate, and shallow forereef strata (Table H.3.1 and Fig. H.3.1). No fishes were collected during these surveys.

In addition, CRED completed a total of 11 towed-diver surveys at Moloka`i Island, as described in Section H.2 of this appendix.

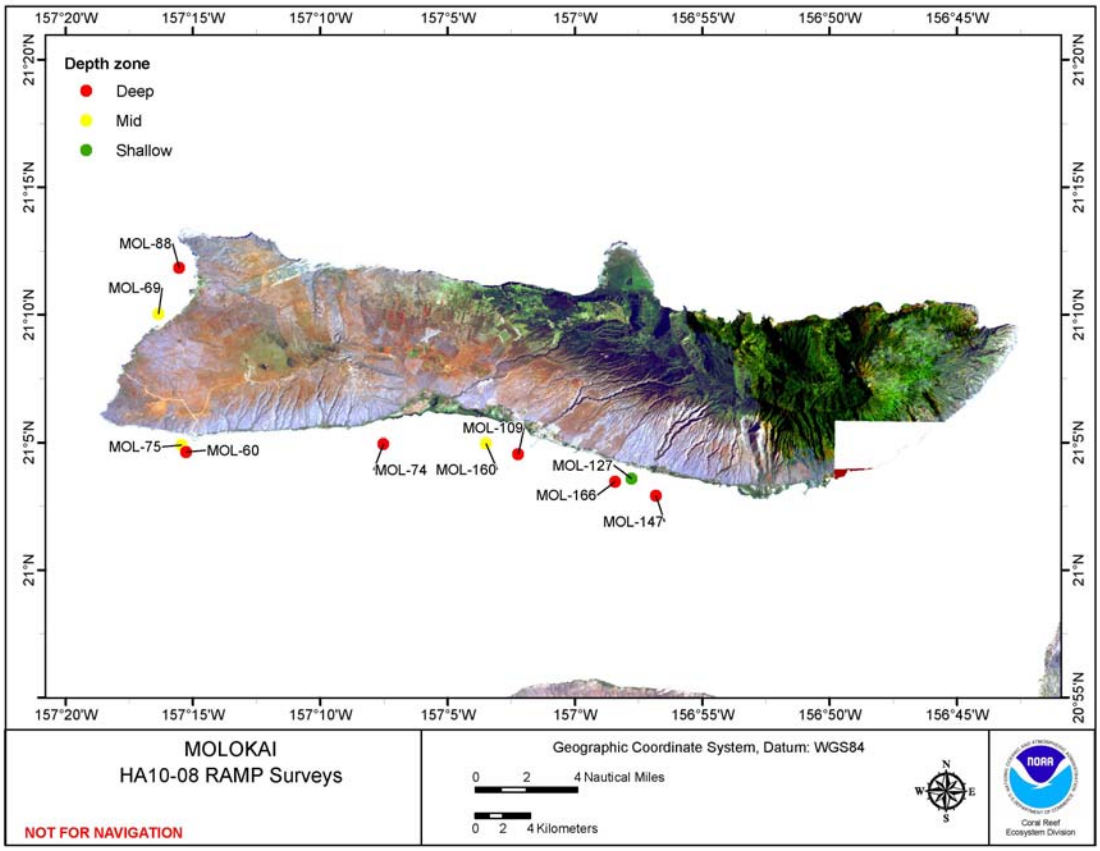


Figure H.3.1.--Locations of REA fish sites surveyed at Moloka`i Island during cruise HA-10-08. All of these REA sites were selected using a stratified random design.

TableH.3.1. Summary of sites where REA fish surveys were conducted at Moloka`i Island during cruise HA-10-08.

REA Site	Date	Depth Zone	Stratum	Depth (m)	Latitude	Longitude
MOL-60	23-Oct	Deep	Forereef	21	21.0771262	–157.254521
MOL-69	23-Oct	Mid	Forereef	12	21.1673281	–157.272442
MOL-75	23-Oct	Mid	Forereef	12	21.0817469	–157.25749
MOL-88	23-Oct	Deep	Forereef	22	21.197399	–157.259037
MOL-74	3-Nov	Deep	Forereef	22	21.0825303	–157.125438
MOL-109	3-Nov	Deep	Forereef	23	21.0758399	–157.037208
MOL-160	3-Nov	Mid	Forereef	11	21.0827687	–157.058156
MOL-127	4-Nov	Shallow	Forereef	5	21.0599595	–156.962906
MOL-147	4-Nov	Deep	Forereef	21	21.0487337	–156.947076
MOL-166	4-Nov	Deep	Forereef	25	21.0578103	–156.973771

APPENDIX I: BIOLOGICAL COLLECTIONS

Algal voucher samples were collected at the islands of Hawai`i, Maui, Lāna`i, Kaua`i, Ni`ihau, and Moloka`i and their surrounding waters for research purposes. These collections are listed here in Table I.1.

Table I.1.--Algal voucher samples collected in the main Hawaiian Islands during cruise HA-10-08, October 07–November 05, 2010.

REA Site	Island	Date	Latitude	Longitude	Specimen Collected	Number of Samples	Depth (m)
HAW-30	Hawai`i	9-Oct	20.058470	–155.366192	Red algae	1	13.7
HAW-26	Hawai`i	10-Oct	19.741449	–155.030354	*Platoma* sp.	1	13.7
HAW-26	Hawai`i	10-Oct	19.741449	–155.030354	Red algae	2	13.7
HAW-26	Hawai`i	10-Oct	19.741449	–155.030354	*Halichrysis* sp.	1	13.7
HAW-28	Hawai`i	14-Oct	19.299708	–155.084072	Red algae	1	13.7
MAI-01	Maui	15-Oct	20.762262	–155.979771	Red algae	1	13.7
MAI-19	Maui	16-Oct	20.914151	–156.214281	Red algae	1	13.7
LAN-07	Lāna`i	21-Oct	20.870461	–156.834671	Red algae	1	13.7
LAN-07	Lāna`i	21-Oct	20.870461	–156.834671	*Halichrysis* sp.	1	13.7
LAN-08	Lāna`i	21-Oct	20.922954	–156.909279	*Caulerpella* sp.	1	13.7
LAN-03	Lāna`i	22-Oct	20.775206	–156.990077	Red algae	1	10.7
LAN-05	Lāna`i	22-Oct	20.741272	–156.875833	*Caulerpa* sp.	1	13.7
LAN-06	Lāna`i	22-Oct	20.733912	–156.921508	*Halimeda kanaloana*	1	22.9
LAN-06	Lāna`i	22-Oct	20.733912	–156.921508	*Caulerpa* sp.	1	13.7
MOL-03	Moloka`i	23-Oct	21.082795	–157.267038	*Gibsmithia* sp.	1	13.7
MOL-03	Moloka`i	23-Oct	21.082795	–157.267038	Red algae	1	13.7
KAU-09	Kaua`i	27-Oct	22.166843	–159.680010	Red algae	1	11.6
NII-05	Ni`ihau	28-Oct	21.906820	-160.210974	Red algae	2	11.6
KAU-03	Kaua`i	30-Oct	22.230614	–159.405432	Red algae	1	12–15
KAU-07	Kaua`i	30-Oct	22.221131	–159.591697	Red algae	1	12–15
KAU-13	Kaua`i	30-Oct	22.226493	–159.564489	Red algae	1	7.6
KAU-13	Kaua`i	30-Oct	22.226493	–159.564489	*Caulerpa taxifolia*	1	7.6
NII-02	Ni`ihau	1-Nov	21.875143	-160.122432	Red algae	1	9.1
–	–	3-Nov	21.080150	–157.210683	Red algae	1	12–15
MOL-09	Moloka`i	3-Nov	21.077880	–157.040851	*Gibsmithia* sp.	1	13.7
MOL-09	Moloka`i	3-Nov	21.077880	–157.040851	Red algae	1	13.7
MOL-11	Moloka`i	3-Nov	21.083414	–157.128476	*Gibsmithia* sp.	1	13.7
MOL-12	Moloka`i	4-Nov	21.034793	–156.887076	*Kallymenia* sp.	1	13.7
MOL-14	Moloka`i	4-Nov	21.064287	–156.986761	*Halimeda kanaloana*	1	13.7

(This page is left blank intentionally.)