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-12-01, Leg IV

CRUISE PERIOD: 27 April–24 May 2012

AREA OF OPERATION: Jarvis Island, Palmyra Atoll, and Kingman Reef of the Pacific Remote Islands Marine National Monument

TYPE OF OPERATION: Personnel from the Coral Reef Ecosystem Division (CRED) of the NOAA Pacific Islands Fisheries Science Center, U.S Fish and Wildlife Service, San Diego State University, and the Papahānaumokuākea Marine National Monument conducted interdisciplinary Pacific Reef and Assessment Program (Pacific RAMP) surveys in waters surrounding Jarvis Island, Palmyra Atoll and Kingman Reef. All activities described in this report were covered by the following permits: Pacific Reefs National Wildlife Refuge Complex special-use permit number 12521-10001 (effective date: February 7, 2012; expiration date: December 31, 2012).

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.

27 April — Start of cruise. Embarked all scientific crew. Departed Pago Pago Harbor, American Samoa, at 1730 and began transit to Jarvis Island. This departure time was delayed by 8 hrs 30 min from the original project instructions owing to refueling and other ship related logistics.

28 April — Transit day.

29 April — Transit day.

30 April — Transit day.

[1] PIFSC Cruise Report CR-12-006
Issued 1 October 2012

1 May Transit day.

2 May Arrived at Jarvis Island. Disembarked U.S. Fish and Wildlife personnel Amanda Meyer and Videographer Stephani Gordon for terrestrial surveys of seabirds and vegetation. No field operations were performed due to a 1700 arrival at Jarvis Island.

3 May Began field operations at Jarvis Island. Deployed and retrieved the following types of instruments: subsurface temperature recorder (STR), acoustic Doppler profiler (ADP), temperature and salinity sensor (SBE37), moored conductivity, temperature, depth (CTD) recorder, autonomous reef monitoring structure (ARMS), and calcification acidification unit (CAU). Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. Nearshore water samples were collected for chlorophyll-*a* (Chl-*a*), nutrient, dissolved inorganic carbon (DIC), total alkalinity (TA) salinity, and microbial community analyses. Nearshore CTD profiles were collected, and shipboard operations included acoustic Doppler current profiler (ADCP) transects, deepwater CTD casts, and water sampling for Chl-*a* and nutrient concentrations.

4 May Continued field operations at Jarvis Island. Deployed and retrieved the following types of instruments: STR, ARMS, CAU, Ecological Acoustic Recorder (EAR). Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. 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 water sampling for Chl-*a* and nutrient concentrations.

5 May Continued field operations at Jarvis Island. Deployed and retrieved the following types of instruments: STR, CAU. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. Pneumatic coral cores were collected. 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 water sampling for Chl-*a* and nutrient concentrations.

6 May Continued field operations at Jarvis Island. Deployed and retrieved the following types of instruments: ARMS, CTD, ADP. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. Hydraulic coral cores were collected. 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 water sampling for Chl-*a* and nutrient concentrations. No towed-diver surveys

were performed owing to hydraulic coral coring. Embarked Amanda Meyer and Stephani Gordon. Began transit to Kingman Reef.

7 May Transit day.

8 May Transit day.

9 May Arrived at Kingman Reef and began field operations. Deployed and retrieved the following types of instruments: STR, CAU, ARMS. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. 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 water sampling for Chl-*a* and nutrient concentrations.

10 May Continued field operations at Kingman Reef. Deployed and retrieved the following types of instruments: STR, single point current sensor (RCM), sea surface temperature (SST) buoy, CAU, ARMS, EAR. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. 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 and deepwater CTD casts.

11 May Continued field operations at Kingman Reef. Deployed and retrieved the following types of instruments: STR, CAU. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. 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 water sampling for Chl-*a* and nutrient concentrations.

12 May Continued field operations at Kingman Reef. Deployed and retrieved the following types of instruments: CAU, ARMS. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. Pneumatic coral cores were collected. 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 water sampling for Chl-*a* and nutrient concentrations. The total number of deepwater CTD casts was limited owing to inclement weather.

13 May Continued field operations at Kingman Reef. Deployed and retrieved the following types of instruments: CAU, ARMS. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. Hydraulic

coral cores were collected. 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 water sampling for Chl-*a* and nutrient concentrations. No towed-diver surveys were performed owing to hydraulic coral coring. The total number of deepwater CTD casts was limited owing to inclement weather. Departed Kingman Reef en route to Palmyra Atoll.

14 May Arrived at Palmyra Atoll and began field operations. Disembarked U.S. Fish and Wildlife personnel Amanda Meyer and Videographer Stephani Gordon for terrestrial surveys of seabirds and vegetation. Deployed and retrieved the following types of instruments: STR, ADP, SBE37, CAU, ARMS. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. 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 water sampling for Chl-*a* and nutrient concentrations. The total number of deepwater CTD casts was limited owing to inclement weather.

15 May Continued field operations at Palmyra Atoll. Deployed and retrieved the following types of instruments: STR, ADP, SBE37, CAU, EAR. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. 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 water sampling for Chl-*a* and nutrient concentrations. The total number of deepwater CTD casts was limited owing to inclement weather.

16 May Continued field operations at Palmyra Atoll. Embarked Stephani Gordon. Deployed and retrieved the following types of instruments: STR, ADP, SBE37, CAU, ARMS. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. 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 water sampling for Chl-*a* and nutrient concentrations. The total number of deepwater CTD casts was limited owing to inclement weather.

17 May Continued field operations at Palmyra Atoll. No diving was conducted owing to the NOAA Dive Center’s policy on consecutive dive days. The Oceanography team conducted snorkel operations, retrieving two wave and tide recorders (WTRs) and two STRs. ADCP transects, deepwater

CTD casts, and water sampling for Chl-*a* and nutrient concentrations were collected.

18 May Continued field operations at Palmyra Atoll. Deployed and retrieved the following types of instruments: STR, ADP, SBE37, CAU, ARMS. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. 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 water sampling for Chl-*a* and nutrient concentrations.

19 May Continued field operations at Palmyra Atoll. Deployed and retrieved the following types of instruments: STR, SST. Samples of the algal genus *Halimeda* were collected for calcification and isotope analyses. Departed Palmyra Atoll en route to Pearl Harbor, Honolulu, Hawaii.

20 May Transit day.

21 May Transit day.

22 May Transit day.

23 May Transit day.

24 May Arrived at Pearl Harbor, Honolulu, Hawai´i. Disembarked all scientific personnel. End of HA-12-01, Leg IV.

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 U.S. Line Islands: Jarvis Island, Palmyra Atoll and Kingman Reef.

B. Deployed and retrieved a suite of instruments and installations—including SST buoys, STRs, CTD sensor, ADP, RCM, SBE37, ARMS, CAUs, and EARs—to allow for remote, long-term monitoring of oceanographic, environmental, and ecological conditions of the coral reef ecosystems of the U.S. Line Islands.

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

D. Conducted shipboard oceanographic and meteorological observations to examine physical and biological linkages supporting and maintaining these island ecosystems, using CTD casts deployed to a depth of 500 m with concurrent water samples taken at select locations and depths, collecting continuous ADCP, SST, salinity, and partial pressure of carbon dioxide (pCO_2) data around reef ecosystems and fundamental meteorological data, such as air temperature, wind speed and direction, barometric pressure, and relative humidity.

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

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

G. Conducted terrestrial surveys of seabirds and vegetation on Jarvis Island and Palmyra Atoll (representatives of the U.S. Fish and Wildlife Service completed this mission).

H. Supported the collection of video footage by Stephani Gordon of Open Boat Films for the purpose of producing an outreach and education video highlighting NOAA's research activities within the Marine National Monument.

RESULTS:

This section provides tallies of research activities (Table 1), a list of data collected during cruise HA-12-01, Leg IV, and a summary of important observations. For more information pertaining to the data collected, methodology employed, and preliminary findings at the islands visited, see Appendices A–E.

Table 1.--Statistics for the Pacific RAMP 2012 cruise to the U.S. Line Islands (cruise HA-12-01, Leg IV), including Jarvis Island, Kingman Reef and Palmyra Atoll. The numbers for REA sites include sites where REA benthic or fish surveys were conducted. The numbers in the first row for towed-diver surveys include calibration surveys, but the numbers in the separate rows for benthic and fish surveys do not. The totals for scuba dives include all dives carried out for all activities at each island.

ResearchActivity	Jarvis	Kingman	Palmyra	Total
Scuba Dives	233	304	291	828
Biological Surveys				
Towed-diver Surveys: Benthic and Fish	11	22	22	55
Combined Length (km) of Towed-diver Surveys	23.2	43.9	44.9	112
Towed-diver Surveys: Benthic	10	22	22	54
Towed-diver Surveys: Fish	10	22	22	54
REA Sites: Benthic	10	15	15	40
REA Sites: Fish	42	49	42	133
Biological Sample Collections				
Algal Voucher Specimens	3	6	11	20
Halimeda Samples (calcification analysis)	50	120	170	340
Halimeda Samples (isotope analysis)	30	24	36	90
Coral Core Samples	3	4	0	7
Microbial Water Samples	21	26	24	71
Microbial Benthic Samples	10	13	20	43
Biological Monitoring Installations				
ARMS Retrieved	9	9	9	27
ARMS Deployed	9	9	9	27
CAUs Retrieved	24	40	40	104
CAUs Deployed	25	40	40	105
EARs Retrieved	1	1	1	3
EARs Deployed	1	1	1	3
Oceanographic Moored Instruments				
RCMs Retrieved	0	1	0	1
SST Buoys Retrieved	0	1	0	1
STRs Retrieved	13	11	25	49
STRs Deployed	7	13	22	42
WTRs Retrieved	0	0	2	2
Temperature and Salinity Sensors (SBE 37) Retrieved	1	0	6	7
ADPs Retrieved	1	0	4	5
ADPs Deployed	1	0	2	3
CTD Sensors Retrieved	1	0	0	1
CTD Sensors Deployed	1	0	0	1
Hydrographic Surveys				
Shallow-water CTD Casts	5	8	8	21
Deepwater CTD Casts	39	27	18	84
Total Length (km) of ADCP Transects	40	58	36	134
Water-quality Sampling				
Shallow-water Nutrient Water Samples	21	16	16	53
Shallow-water Chl-*a* Water Samples	10	16	16	42
Shallow-water Salinity Water Samples	21	16	16	53
Shallow-water DIC Water Samples	21	16	16	53
Deepwater Nutrient Water Samples	120	20	15	155
Deepwater Chl-*a* Water Samples	120	20	80	220

The coral reef ecosystems of the U.S. Line Islands have historically been surveyed biennially through CRED's Pacific RAMP. The cruise HA-12-01, Leg IV, marked this program's sixth expedition around Jarvis Island, Kingman Reef and Palmyra Atoll. Here, we present highlights from our observations during this latest expedition.

Jarvis Island

- A number of large, pelagic fishes and apex predators were observed during field operations that included: a whale shark (*Rhincodon typus*) measuring approximately 25 feet in length, a new record for the island; a small number (~7) of ocean sunfish (*Mola mola*) in close proximity to shore in approximately 30 m water depth, also a new record; and scalloped hammerhead sharks (*Sphyrna lewini*). As seen in previous years, high abundances of grey reef sharks (*Carcharhinus amblyrhynchos*), manta rays (*Manta birostris*), black jacks (*Caranx lugubris*), and great barracuda (*Sphyraena barracuda*) were also observed.

Kingman Reef

- The northeast benthic backreef environment that has been impacted by a shipwreck in 2009 was quantitatively surveyed by the benthic team, including the LPI method and community structure and disease methods. The reef in this area was originally surveyed in December 2009 by James Maragos of USFWS, and again in 2010 by CRED Pacific RAMP. In both instances, surveys were qualitative. In 2010, CRED reported that cyanobacteria and *Rhodactis* sp. were not present in substantial numbers along the reef crest but that a cyanobacterial bloom was observed in the lagoon, extending from 5 m down to ~25 m. Preliminary results from the 2012 survey reveal cyanobacteria representing the highest percent cover (54.4%) of the benthic community, while hard coral was only 7.6%. Visual observations indicated high percent cover of *Rhodactis* sp. in the shallower reef crest of this site and cyanobacteria exhibiting increased dominance at ~10 m. In addition, towed-divers noted several portions of the shipwreck (metal well/decking, timbers, fiberglass, pipe work) were present in the area with the highest cyanobacteria cover (~75%).
- The remnants of a fish aggregation device (FAD) observed in 2010 were encountered by towed-divers. Netting was draped over the reef and additional line and netting extended up into the water column, ending in a series of surface floats. A large school of bigeye jacks *(Caranx sexfasciatus*) was observed in close proximity to the FAD.
- Coral stress associated with high crown-of-thorns seastar (*Acanthaster planci*) densities was recorded in two specific locations: along the northeastern lagoonal reef crest slope and a deeper section (~20 m) of the northwestern back/lagoonal reef crest.
- Unusually large numbers of twinspot snapper (*Lutjanus bohar*) were observed along the western forereef, while high abundances of grey reef sharks (*Carcharhinus amblyrhynchos*), manta rays (*Manta birostris*), black jacks (*Caranx lugubris*), and great barracuda (*Sphyraena barracuda*) were also observed.

Palmyra Atoll

- The humpback red snapper (*Lutjanus gibbus)* was seen in schools of upwards of 500 fish at several sites on the western and eastern sides of the atoll.
- Numerous napoleon wrasse (*Cheilinus undulatus*) were encountered with the greatest numbers observed along the southern terrace.
- A thresher shark (family *Alopiidae*) was observed in ~30 m of water. This sighting is especially remarkable as these sharks are typically found in water depths between 150 and 1000 m.
- Large numbers (100s) of bottlenose dolphins (*Tursiops truncatus*) were observed on the southeast corner of Palmyra.
- As seen in previous years, high abundances of grey reef sharks (*Carcharhinus amblyrhynchos*), manta rays (*Manta birostris*), black jacks (*Caranx lugubris*), and great barracuda (*Sphyraena barracuda*) were observed.

The following data and samples were collected during this expedition:

REA Benthic Surveys:

- Digital still photographs of overall site character and typical benthos
- Digital still photographs of the benthos along transect lines
- Quantitative assessments of benthic composition from line-point-intercept surveys
- Algal voucher specimens necessary for algal species identification
- Samples of the algal genus *Halimeda* to determine degree of calcification for ocean acidification research
- Field notes of algal species diversity and relative abundance
- Number, species or genus, size, and health condition of all coral colonies observed within belt transects of known area
- Digital still photographs of diseased corals and coralline algae
- Field notes on signs of coral bleaching or disease
- Quantitative assessments of target macroinvertebrate taxa
- Specimens of invertebrates collected at REA sites
- Field notes on the size and relative abundance of sea urchins and crown-of-thorns seastars
- Collection of coral cores of massive reef building corals for the assessment of calcification rates
- Water samples and benthic grabs at select REA sites for microbial analyses

REA Fish Surveys:

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

Towed-diver Surveys:

- Digital still photographs and video of benthic habitats
- Benthic habitat characterization, including visual estimates of habitat complexity, habitat type, and cover of corals, stressed corals, macroalgae, and crustose coralline red algae
- Quantitative assessments of large (≥ 50 cm in total length) reef fishes to species level
- Counts of target macroinvertebrates, including crown-of-thorns seastars, sea cucumbers, sea urchins, and giant clams
- Quantitative and qualitative assessments of key protected species and species of concern, including cetaceans, sea turtles, and rare fishes
- Temperature and depth data

Shipboard Oceanography:

- Deepwater CTD profiles to a depth of 500 m
- Nutrient and Chl-*a* concentrations from water samples collected at variable depths
- Dissolved oxygen, turbidity, fluorescence, and pH measurements recorded by CTD sensor
- Transects of profiles of ocean current velocity and direction collected using a shipboard ADCP unit
- Solar radiation, air temperature, barometric pressure, and wind speed and direction
- 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 depths ≤ 30 m, including some at all REA sites where CAUs were installed, with dissolved oxygen measurements
- Concentrations of nutrients, Chl-*a*, salinity, DIC, and TA from water samples collected in concert with shallow-water (≤ 30 m) CTD casts
- Nutrient concentrations from water samples collected at additional REA sites

Biological Monitoring Installations:

- 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
- Installation of calcification acidification units (CAUs) to allow for future assessment of calcification rates once they are retrieved in about two years

Oceanographic Moored Instruments:

- Sea-surface and subsurface temperature at variable depths
- Sea-surface and subsurface salinity at variable depths
- Wave and tidal elevation
- Single-point and directional ocean currents
- ADP current profiles and wave spectra

- Surface air temperature, wind speed and direction, barometric pressure, and ultraviolet radiation

SCIENTIFIC PERSONNEL:

Jamison Gove, Chief Scientist, Oceanography Team, University of Hawai`i (UH)-Joint Institute for Marine and Atmospheric Research (JIMAR), Pacific Islands Fisheries Science Center (PIFSC)-Coral Reef Ecosystems Division (CRED)
Jeffrey Anderson, Benthic Team, UH-JIMAR, PIFSC-CRED
Jacob Asher, Benthic Team—Towed Diver, UH-JIMAR, PIFSC-CRED
Paula Ayotte, Fish Team, UH-JIMAR, PIFSC-CRED
Annette DesRochers, Data Manager, UH-JIMAR, PIFSC-CRED
Marie Ferguson, Benthic Team—Towed Diver, UH-JIMAR, PIFSC-CRED
Kevin Lino, Fish Tea, UH-JIMAR, PIFSC-CRED
Erin Looney, Benthic Team, UH-JIMAR, PIFSC-CRED
Mark Manuel, Fish Team, UH-JIMAR, PIFSC-CRED
Kaylyn McCoy, Fish Team—Towed Diver, UH-JIMAR, PIFSC-CRED
Daniel Merritt, Oceanography Team, UH-JIMAR, PIFSC-CRED
Noah Pomeroy, Fish Team—Towed Diver, UH-JIMAR, PIFSC-CRED
Molly Timmers, Benthic Team—Invertebrates/ARMS, UH-JIMAR, PIFSC-CRED
Oliver Vetter, Oceanography Team, UH-JIMAR, PIFSC-CRED
Rodney Withall, Benthic Team, UH-JIMAR, PIFSC-CRED
Charles Young, Oceanography Team, UH-JIMAR, PIFSC-CRED
Jill Zamzow, Fish Team, UH-JIMAR, PIFSC-CRED
Scott Godwin, Benthic Team—Invertebrates/ARMS, UH-JIMAR, Papahānaumokuākea Marine National Monument
Stephani Gordon, Videographer, Open Boat Films
Amanda Meyer, Terrestrial Team, U.S. Fish and Wildlife Service
Chris Sullivan, Microbial Biologist, San Diego State University

Submitted by: ______________________
Jamison Gove
Chief Scientist

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

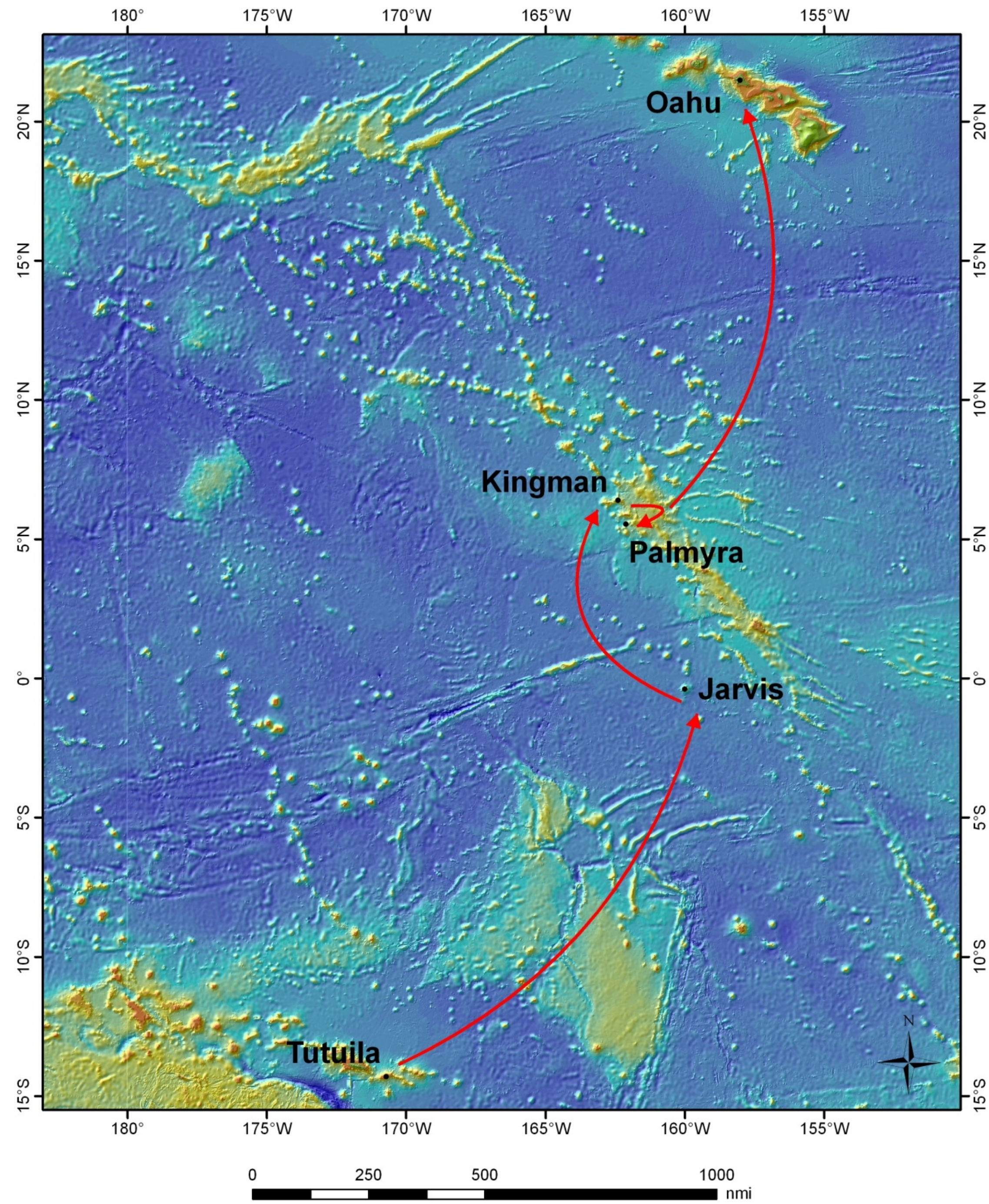

Figure 1.--Track of the NOAA Ship *Hi`ialakai* for the cruise HA-12-01, April 27–May 24, 2012, with Jarvis Island, Kingman Reef, and Palmyra Atoll surveyed during Leg IV en route from Tutuila, American Samoa, to Honolulu, O`ahu.

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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-12-01, Leg IV on the NOAA Ship *Hi`ialakai* during the period of April 27–May 24, 2012. The last coral reef assessments led by CRED at the islands of Jarvis Island, Kingman Reef and Palmyra Atoll were conducted in 2010.

A.1. Oceanography and Water Quality

(Jamison Gove, Daniel Merritt, Oliver Vetter, and Charles Young)

To assess and monitor the oceanographic and water-quality parameters influencing the coral reef ecosystems, the oceanography team performed the following activities: (1) conducted offshore oceanographic surveys characterizing prevailing water properties and ocean currents around these islands, (2) completed nearshore oceanographic and water-quality surveys, and (3) deployed and retrieved an array of subsurface moored instruments designed to provide continuous, high-resolution time-series observations. Shipboard meteorological observations, including wind speed and direction, relative humidity, air temperature, and barometric pressure, were recorded. In addition, the oceanography team retrieved and deployed ecological acoustic recorders (EARs) for monitoring the sounds of marine animals and vessel traffic and participated in installations of calcification acidification units (CAUs) for the assessment of calcification rates of crustose coralline algae and hard corals (see Section A.2.3: "Installations for Monitoring Marine Life," for information about EAR and CAU techniques).

In order to standardize NOAA's long-term monitoring across all U.S.-owned coral reefs, NOAA developed the National Coral Reef Monitoring Plan (NCRMP); a comprehensive multidisciplinary approach for assessing and monitoring coral reef ecosystems. Amongst other disciplines relevant to coral reef research, NCRMP outlines a methodological approach for assessing present and future changes to oceanographic conditions. Specifically, NCRMP focuses on ocean temperature and carbonate chemistry information, as these environmental parameters are among the primary drivers for island- and atoll-scale coral reef ecosystem variability. Details pertaining to the collection of temperature information are outlined below.

NCRMP Temperature: The overarching goals of recording reef-level temperature around coral reef systems are 1) to monitor for long-term changes in the thermal structure within the context of climate change and 2) to quantify ecologically relevant changes in the thermal structure owing to physical forcing mechanisms such as (but not limited to) waves, internal waves, tides, internal tides, and upwelling. Below are the NCRMP guidelines for thermister deployment:

1. Vertical, reef-level transects of temperature sensors will be deployed at 1, 5, 15, and 25 m water depth at each island or atoll. The number of vertical transects will depend upon the size of the island or atoll.
2. One-meter sensors are only to be deployed in backreef environments, or forereef locations that have a high likelihood of survival and retrieval. Deployment should be in water < 2 m deep, and should remain submerged through tidal variations and large wave events.
3. Five-meter sensors are to be deployed between 4 and 6 m depth range on forereef environments in a location that has a high probability of being accessible during future field missions.
4. Fifteen and 25-m deployments should be made between 13-17 m and 23-27 m depth ranges, respectively.

The guidelines stated above were implemented by CRED during ASRAMP 2012. A large majority of existing subsurface temperature recorder (STR) locations fell within these guidelines, thereby preserving the long-term temperature data set; however, there were a number of STR locations at each of the islands and atolls visited that were either moved or removed altogether in order to meet these guidelines.

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 oceanographic instruments were retrieved or deployed during this cruise.

Sea-surface Temperature (SST) Buoy: provides high-resolution SST (SBE 39 sensor, Sea-Bird Electronics Inc., Bellevue, Wash., accuracy of 0.002°C). Data are sampled at 30-min intervals and internally recorded. Subsets of these data are transmitted daily via satellite telemetry.

Subsurface Temperature Recorder (STR): provides near-real-time, high-resolution temperature data (SBE 39 sensor). 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.

Acoustic Doppler Profiler (ADP): provides directional current profiles and wave spectra using a 3-beam-configured 1-MHz Aquadopp Profiler (Nortek, Rud, Norway, accuracy of 0.005 m s^{-1} in current and 0.1% in pressure). Sample intervals for current and wave data vary depending on duration of deployment. This type of subsurface instrument is deployed at depths of 5–20 m.

CTD Sensor: provides high-resolution conductivity, pressure, and temperature data (SBE 19*plus* Seacat Profiler, accuracy of 0.005 S m^{-1} in conductivity, 0.0002°C in temperature, and 0.1% in pressure). Conductivity data is used to calculate salinity, and pressure is used to calculate depth.

A.1.2. Hydrographic Surveys

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

Shallow-water (Nearshore) Conductivity, Temperature, and Depth Casts: a CTD profiler deployed from a small boat provided data on temperature, conductivity, which is related to salinity, and pressure, which is related to depth (SBE 19*plus* Seacat Profiler). A transmissometer (C-Star, WET Labs, Philomath, Ore.) provided profiles of beam transmittance, which is related to turbidity. A dissolved oxygen sensor (SBE 43, accuracy of 2% of saturation) also was attached and measurements were made in concert with CTD measurements. A CTD cast was performed at each of the Rapid Ecological Assessment (REA) sites where CAUs were deployed. 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 $\leq$ 30 m.

Deepwater (Shipboard) CTD Casts: a ship-based CTD profiler provided high-resolution conductivity, temperature, and pressure data (SBE 911*plus* CTD, accuracy of 0.003 S m^{-1} in conductivity, 0.001°C in temperature, and 0.015% in pressure). Measurements of dissolved oxygen (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.

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 nearshore and shipboard CTD casts.

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

(Jeff Anderson, Jacob Asher, Marie Ferguson, Scott Godwin, Erin Looney, Chris Sullivan, Molly Timmers, 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 two 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, three types of monitoring installations, autonomous reef monitoring structure (ARMS), CAU, and EAR, serve as mechanisms to quantify marine invertebrates that are not easily identifiable during REA surveys, help to determine accretion rates of crustose coralline red algae and hard corals, or monitor the sounds of marine life and vessel traffic. Note that the sites where REA benthic surveys were conducted typically are different locations from the REA sites selected for fish surveys. REA sites for benthic surveys are selected for long-term monitoring of specific benthic communities over time, whereas REA sites for fish surveys are selected using a stratified random sampling design to provide representative coverage of three depth strata.

A.2.1. Benthic Composition

Using a line-point-intercept (LPI) method at REA sites, hard corals, octocorals, macroalgae, crustose coralline red algae, turf algae, cyanobacteria, and macroinvertebrates were identified to the highest possible taxonomic resolution and recorded, along with sand cover, 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 and sand at each REA site. Additionally, in concert with LPI surveys, still photographs were taken to record the benthos at intervals of 2 m along the same two transect lines with a high-resolution digital camera mounted on a pole. This work generates 30 photographs per site that are later analyzed by staff at CRED, using the computer program Coral Point Count with Excel extensions (CPCe), to determine the benthic composition at higher taxonomic levels for each REA site (similar photographs of the benthos taken at REA sites surveyed by the fish team will also be analyzed).

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

If an algal species encountered during LPI or roving-diver surveys was not identifiable in the field, an example was collected as a voucher specimen and subsequently cataloged and critically analyzed to ensure positive species identification. Provisions were made to ensure appropriate preservation and curation of each algal specimen. These voucher specimens along with the benthic photographs 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, sea cucumbers, and giant clams. 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 sensor 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% to 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 photograph 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 two 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), and severity (mild, moderate, marked, severe, or acute). 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.

A.2.3. Installations for Monitoring Marine Life

CRED accomplishes long-term monitoring of benthic biodiversity, the growth rates of corals and algae, 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 Structure (ARMS): recovered and 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 2010 U.S. Line Islands research cruise. They remained on the benthos for 2 years, enabling the recruitment and colonization of lesser known, cryptic marine invertebrates. Each ARMS was composed of 10 grey, Type 1 PVC plates (23 × 23 cm) stacked in an alternating series of open and obstructed layers attached to a base plate (35 × 45 cm) that was affixed to a reef.

ARMS previously deployed during the 2010 research cruise to the U.S. Line Islands 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 deployed onto existing stainless steel rods, with the goal of recovering them during the next research cruise to the U.S. Line Islands scheduled for 2015.

Calcification Acidification Unit (CAU): deployed at multiple sites at each island, CAUs provide mechanisms to quantify accretion rates by crustose coralline red algae and scleractinian (hard) corals. Each CAU consists of two grey PVC plates (10 × 10 cm) separated by a 1-cm spacer. CAUs were installed on the benthos by pounding stainless steel rods by hand into bare substrate and then bolting plate assemblies to those rods. It has been demonstrated that PVC encourages growth of crustose coralline red algae and recruitment of corals, and the net weight gain of calcium carbonate ($CaCO_3$) on the surfaces of the CAUs can be an indicator of net calcification. The CAUs installed during this cruise will remain on the benthos for about 2 years, enabling the recruitment and colonization of crustose coralline red algae and hard corals, upon which time they will be collected and analyzed. The data obtained from CAUs will enable a comparison of net calcification rates among islands and atolls and between archipelagos and form a baseline of accretion rates throughout the U.S. Pacific, allowing for future comparisons to determine possible consequences of increased ocean acidity and lowered aragonite saturation states.

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 or cetaceans passing nearby. 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. Coral Core Collections

In support of CRED's ocean acidification research, coral cores and tissue will be collected from *Porites* sp. at select sites to develop historical, skeletal extension (annual growth) rates and calcification rates, and gain insight into the energetic status of each sampled coral colony. In conjunction with ancillary water quality data, these cores will provide important information about the past environmental conditions in which these corals lived and how they responded. Quantification and analysis of growth banding, skeletal density and extension rate is conducted by employing a nondestructive, high resolution CT scan technique. The coral tissue collected is measured for thickness and total lipid content to validate the premise that energetics play a key role in the coral calcification response to ocean acidification.

Pneumatic Coral Coring

Up to six coral cores and tissue samples were collected at each island/atoll/reef visited. Coral cores were collected using a SCUBA diver employed, handheld, pneumatic drill. The drill is powered by compressed air from a standard Al 80 SCUBA tank. A 1.5-in diameter masonry drill bit is used to extract up to a 40 cm long coral core. The pneumatic drill can be equipped with extensions, enabling coral cores up to ~1 m. Upon extraction of a coral core sample, the remaining hole is filled with an exact fit concrete plug, positioned flush with the existing surface layer of the coral colony, and fixed in place with an underwater epoxy. This technique has been shown to have minimal impact on the long-term health and survivorship of the coral colony. Photographs of the coral colony and GPS positions will enable CRED researchers to return and monitor the coral heads drilled.

Hydraulic Coral Coring

A 3.5" diameter masonry drill bit was used to cut up to a 0.75 m long coral core segment. The hydraulic drill can be equipped with extension rods, enabling coral cores up to 8 m, extracted in 0.75 m sections. Upon extraction of the final coral core section, the remaining hole is filled with an exact fit concrete plug, positioned flush with the existing surface layer of the coral colony, and fixed in place with an underwater epoxy. Complete regeneration of coral tissue over the core plug is expected. Photographs of the coral colony and GPS positions will enable CRED researchers to return and monitor the coral heads drilled.

The hydraulic drill used during drilling operations was custom made, using seawater to power the drill, instead of oil. The hydraulic drill is hand held by a SCUBA diver and powered by a seawater hydraulic pump located in a boat on the surface. Water hoses from the hydraulic motor unit extend to the drill and operators on the seafloor for coring operations. The coral coring team constitutes a DPIC (designated person in charge), two safety divers located on the small boat and three in water SCUBA divers: a drill operator, an operator assistant and safety diver.

A.2.5. *Halimeda* Collections for Calcification Analysis

Species of the green algal genus *Halimeda* are among the most important producers of calcified sediments in reef systems. As the acidity of our oceans increases, calcification rates and the ability of *Halimeda* algae to produce sediments may fall precipitously. To gain a baseline understanding of calcification levels in species of *Halimeda*, a joint project between CRED and the Scripps Institution of Oceanography, University of California San Diego, is sampling *Halimeda* populations across the Pacific to determine ambient levels of $CaCO_3$ among different species from different geographic areas. To accomplish this research, eight individuals of three species of *Halimeda* (when present) will be collected haphazardly by hand from each established REA site visited in the U.S. Line Islands Specimens will be dried in an oven after collection and shipped to Scripps for analysis of percentage of calcification.

A.2.6. Microbial Communities and Water Chemistry

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

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

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

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

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

Collection of Microbial Water Samples: As part of the ongoing effort to understand the microbial community, two types of water samples were collected at each REA site using diver-deployable Niskin bottles (two bottles; 2 L per bottle). The Niskin bottles were filled with “reef water” collected from < 1 m above the benthos. These water samples were returned to the ship and processed for DOC, particulate organic matter (POM), nutrients, microbial (Bacteria and Archaea) and viral abundance (fluorescent microscopy), fluorescence-activated cell sorting (FACS, heterotrophs vs. autotrophs), and microbial and viral community composition (coarse analysis: 16s rRNA). In addition, at one or two REA sites per island or atoll, ~ 70 L of reef water were collected from reef crevices and surfaces for metagenomic analysis of the microbial and viral community associated with reef benthos. All microbial collections were done at select REA sites (locations with supporting fish and benthic data).

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

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

- Microbial (Bacteria and Archaea) and viral abundance: 2 replicates (0.02-µm filters, stained using SYBR Gold, Molecular Probes Inc., Eugene, Ore.)
- Microbial (Bacteria and Archaea) size structure : 2 replicates (0.2-µm filters, stained using 4',6-Diamidino-2-phenylindole (DAPI))
- Microbial community composition (FACS, heterotrophs/autotrophs): 5 replicates
- Microbial community composition (16s rRNA): 2 replicates (0.22-µm filters)

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

- Microbial community composition (metagenome): 1 sample, (3–6 filters of 0.45 µm)
- Viral community composition (metagenome): 1 sample, (3–6 vials)

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

Enumeration of microbes and viruses. Replicate 5-mL and 500-µL reef-water samples were fixed using paraformaldehyde and filtered through 0.02-µm filters. These filters were stained using the general nucleic acid stain SYBR Gold and mounted on a microscope slide. Bacteria and VLPs were counted under UV light using Image Pro software.

Microbial community size structure. Replicate 5-mL samples of reef water were fixed with glutaraldehyde and filtered through 0.2-µm filters. These filters were stained with DAPI, a general nucleic acid stain for staining double-stranded DNA (dsDNA) that allows length and width data to be obtained for individual microbes. These filters were then mounted on a microscope slide for analysis under UV light using Image Pro software. These slides can also be used to quantify the number of actively dividing microbial cells. Slide analysis will be performed at San Diego State University (SDSU). All filters were stored at –20º C for archival purposes.

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

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 SDSU for flow cytometry analysis.

Water Chemistry (DOC/POC): 30 mL of seawater were filtered through pre-combusted glass fiber filters from each of the 4 Niskin bottles, and the filtrate was collected in precombusted glass bottles. Hydrochloric acid was added to each bottle to remove DIC, and the bottles were stored upright at 4ºC. To assess POC, 500 mL of seawater were filtered through each glass fiber filter (4 replicates), and the filters were stored at – 20°C. Stable isotopes of carbon and nitrogen also will be analyzed from the filters via standard protocols at SDSU.

*Collection of DNA for metagenomics***:** The community structure of the microbes and viruses associated with the water column was assessed by metagenomic analysis. Metagenomics is a powerful tool for studying environmental populations, as < 1% of all environmental microbial diversity is currently cultivable. The steps for analysis of microbial community diversity and function involve collection of environmental DNA followed by 454 sequencing. To remove large eukaryotic organisms, reef water was filtered through a 20-µm pre-filter. This 20-µm filtrate was subsequently passed through a 0.22-µm Sterivex filter to trap microbes (two filters, ~ 2.5 L each). The filters were stored at – 20ºC. DNA isolation and metagenomic analysis will be completed at SDSU.

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

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

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

The following data items were collected at REA sites when time permitted:

- Coral rubble or sediment: 6 replicate bags
- Algae: 6 replicate bags

A.3. Surveys of Reef Fishes

(Paula Ayotte, Kevin Lino, Mark Manuel, Kaylyn McCoy, Noah Pomeroy, and Jill Zamzow)

Six divers conducted REA fish surveys using the stationary-point-count (SPC) method at preselected REA sites. Three separate teams performed these surveys. Each team consisted of two divers and conducted either one or two SPC surveys per site. All REA fish 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, the two 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 one diver at each, served as the center of a visually estimated cylindrical survey area with a radius of 7.5 m. During the first 5 min, divers only recorded the presence of species within their respective cylinders. Afterwards, divers went down their respective species lists, which were created from their work during the initial 5 min of a survey, sizing and counting all individuals within their cylinder, one species at a time. Cryptic species missed during the initial 5 min of a survey could still be counted, sized, and added to the original species list. Fish species observed at a REA site but not recorded during the SPCs were recorded for presence data.

After a survey was completed, divers recorded benthic habitat information within their respective cylindrical survey areas. Divers visually estimated habitat complexity, habitat type, and percentage of cover for hard corals, macroalgae, crustose coralline red algae, turf algae, and sand. Every 2 m along the transect line, still photographs were taken of the benthos at a distance of 1 m from the right side of the line. If only one replicate survey was completed at a REA site (because of insufficient air pressure or bottom time), benthic photographs were taken at each meter mark. Like the photographs taken along transect lines during surveys at REA benthic sites, these images will be analyzed later.

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, with one diver quantifying fish populations and the other quantifying the benthos (for more details about towed-divers surveys, see Section A.2.1: “Benthic Composition”).

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.

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APPENDIX B: JARVIS ISLAND

Jarvis Island, located at 0°22´S, 160°00´W in the central equatorial Pacific, is part of the U.S. Line Islands and is one of the islands of the Pacific Remote Islands Marine National Monument. 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 the research cruise HA-12-01, Leg IV, to Jarvis Island entailed numerous retrievals and deployments of oceanographic moored instruments, CAUs, nearshore water sampling, a designated benthic carbonate chemistry investigation, and CTD casts at select REA sites. Deepwater investigations included shipboard water sampling and CTD casts and ADCP transect lines.

Numerous oceanographic instruments were retrieved and deployed in the nearshore waters at Jarvis Island. In total, 14 STRs were retrieved and 7 deployed, 3 of which were deployed in the same location as they were retrieved while 4 additional STRs were deployed in new locations (Fig. B.1.1 and Table B.1.1). The STR deployment strategy at Jarvis is part of NOAA's newly developed National Coral Reef Monitoring Program (NCRMP). Please see Appendix A: "Methods" for more information pertaining to NCRMP. A single SST buoy that had broken free and washed ashore since the last visit to Jarvis in 2010 was recovered from the island and not replaced, owing to funding constraints. An EAR was retrieved and replaced in the same location and an SBE37 salinity/temperature logger was retrieved and not replaced (Fig. B.1.1 and Table B.1.1).

Shallow-water CTD casts were performed at each of the 5 select REA sites where CAUs were replaced (Fig. B.1.1). See section B.2: "Benthic Environment" for more information pertaining to CAU deployment and retrievals. In concert with each CTD cast, two water samples were taken (surface and near reef) to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, dissolved nutrients (NO_3^-, NO_2^-,PO_4^{3-}, $Si(OH)_4$), and chlorophyll-*a* (Chl-*a*) concentrations. Accounting for losses and microbiological nutrient samples taken alone, a total of 10 DIC and TA, 10 salinity, 10 nutrient, and 10 Chl-*a* water samples were collected at these sites.

In addition to these samples collected, a carbonate chemistry investigation was performed on the west side of the island at REA JAR-11 (Fig. B.1.1). This entailed the temporary deployment of an Aquadopp ADP and Seabird 19plus CTD logger moored to the sea floor in 15.8 m of water. Repeat water samples taken at this location totaled 11 DIC and TA, 11 nutrient and 11 salinity. These were taken in the morning (0800–0900) and the afternoon (1600–1700) and opportunistically when possible through the day. The moored CTD and ADP were removed at the end of operations at Jarvis.

An absolute total inventory of water samples from Jarvis were as follows: 10 Chl-a, 21 nutrients, 21 salinity, 21 DIC and 21 TA.

One pneumatic and two hydraulic coral cores were extracted from mounding *Porites* species around Jarvis Island. Please see Appendix A: “Methods” for more information pertaining to coral core operations and Table E.1.1 in Appendix E: “Biological Collections” for more information pertaining to coral core locations.

Deepwater CTD casts were collected during 4 nights of operations. Two CTD transects were conducted, one to the west and one to the east of the island, while on two consecutive nights, CTDs were collected in the same location to the west of Jarvis (Fig. B.1.2). Water samples for nutrients and Chl-*a* were collected at 5 depths concurrently with 24 CTD casts. ADCP data were collected concurrently along CTD transects.

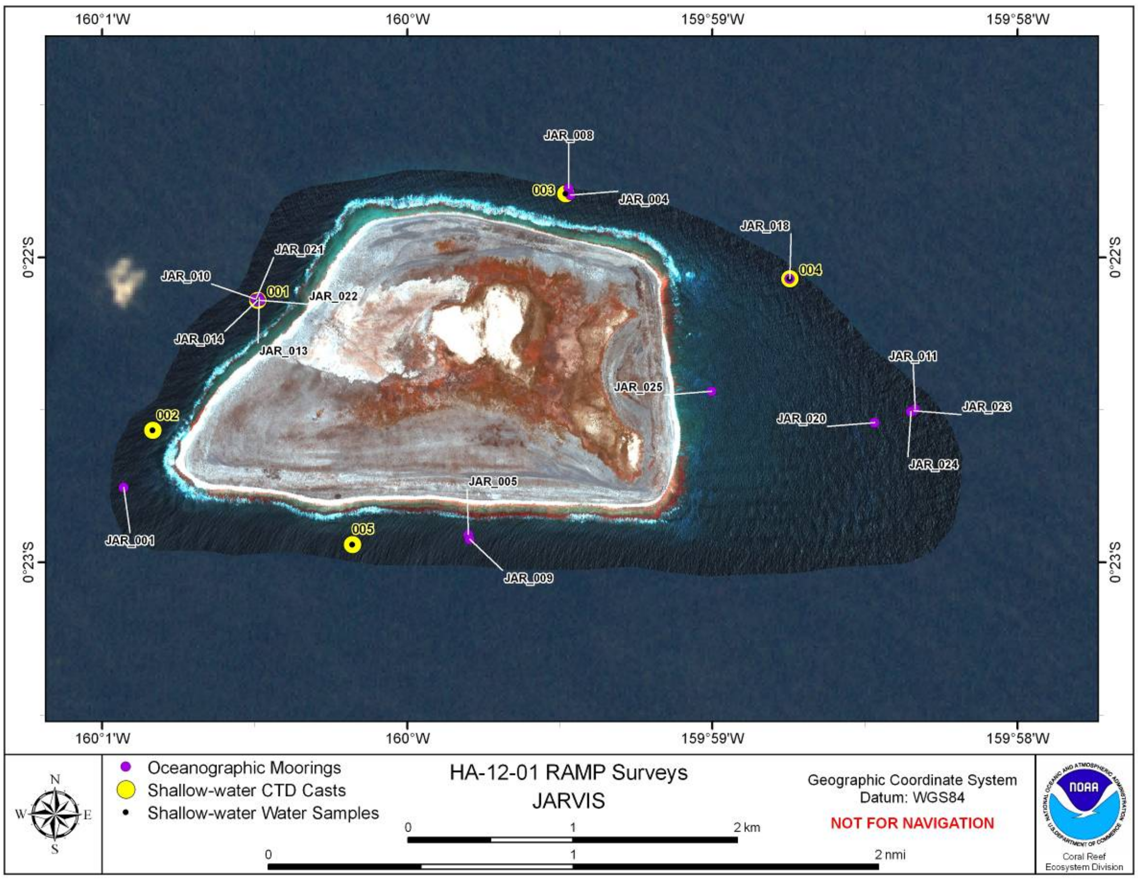

Figure B.1.1.--Mooring sites where oceanographic instruments were retrieved or deployed and REA and CAU sites where nearshore CTD casts and water sampling were performed. Jarvis Island, HA-12-01, Leg IV (IKONOS Carterra Geo Data, 2003).

Table B.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments that were retrieved or deployed at Jarvis Island during cruise HA-12-01, Leg IV.

Mooring Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
JAR_001	3-May	EAR	–0.37924	–160.01549	15.2	1	1
JAR_001	3-May	STR	–0.37924	–160.01549	14.9	1	1
JAR_005	3-May	STR	–0.38180	–159.99667	10.4	2	–
JAR_009	3-May	STR	–0.38207	–159.99660	33.2	1	–
JAR_010	3-May	STR	–0.36893	–160.00832	31.1	1	–
JAR_013	3-May	STR	–0.36888	–160.00809	10.1	1	–
JAR_014	3-May	ADP	–0.36901	–160.00818	15.8	–	1
JAR_014	3-May	CTD	–0.36901	–160.00818	15.8	–	1
JAR_014	3-May	STR	–0.36900	–160.00817	14.3	1	1
JAR_021	3-May	STR	–0.36893	–160.00826	25	–	1
JAR_022	3-May	STR	–0.36901	–160.00802	5.8	1	1
JAR_004	4-May	STR	–0.36326	–159.99110	10.1	2	–
JAR_008	4-May	STR	–0.36287	–159.99119	29.3	1	–
JAR_011	4-May	STR	–0.37494	–159.97226	33.2	1	–
JAR_018	4-May	SBE37	–0.36783	–159.97912	10.1	1	–
JAR_020	4-May	STR	–0.37569	–159.97448	10.1	1	–
JAR_023	4-May	STR	–0.37504	–159.97234	25	–	1
JAR_024	4-May	STR	–0.37508	–159.97248	14.6	–	1
JAR_025	4-May	STR	–0.37398	–159.98338	5.2	–	1
JAR_014	6-May	ADP	–0.36908	–160.00820	15.5	1	–
JAR_014	6-May	CTD	–0.36908	–160.00820	15.5	1	–

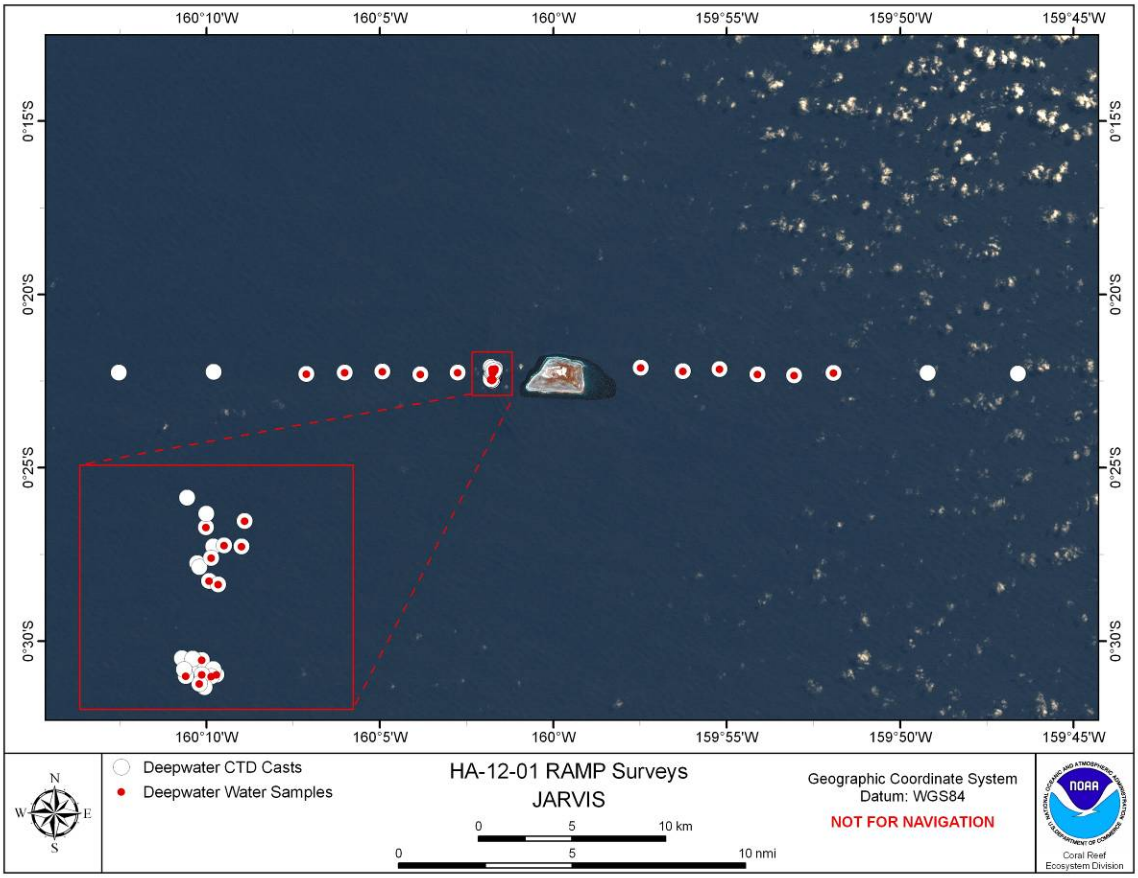

Figure B.1.2.--Locations of deepwater CTD casts and water sampling performed at Jarvis Island during cruise HA-12-01, Leg IV. Island satellite image IKONOS Carterra Geo Data, 2003, and background imagery SIO, NOAA, U.S. Navy, NGA, GEBCO (Becker, 2009; Smith and Sandwell, 1997) © 2008 The Regents of the University of California.

B.2. Benthic Environment

Belt-transect, line-point-intercept (LPI), and roving-diver surveys were conducted and photographs were taken along transect lines at 10 REA sites around Jarvis Island to assess benthic composition, coral and algal community structure, and coral and coralline algal disease (Fig. B.2.1 and Table B.2.1).

Various samples were collected at 8 REA sites (Table B.2.2): 3 algal voucher specimens at one REA site for taxonomic identification, 50 individuals of the algal genus *Halimeda* at five REA sites for calcification analysis and 30 at five sites for isotope analysis, 3 coral cores at two sites from *Porites* coral heads for calcification research, and 21 water samples for microbial analyses at seven REA sites with two water samples of 2 L each at each site, three water samples of 20 L each at JAR-12, and four water samples of 20 L each at JAR-11. Additional microbial work included benthic grabs of coral rubble and unidentified macroalgae at JAR-11. For more information about collections made at REA sites, see Table E.1.1 in Appendix E: "Biological Collections."

Nine autonomous reef monitoring structures (ARMS) were recovered: Three ARMS each from JAR-04, JAR-08, JAR-09 (Table B.2.2). Nine ARMS were deployed with three ARMS each at JAR-04, JAR-08, JAR-11. At five select REA sites, an array of five CAUs were deployed for a total of 25 CAUs installed and 24 were recovered from the previous deployments in 2010 (Table B.2.2). For information about EAR installations, see Section B.2: “Oceanography and Water Quality.”

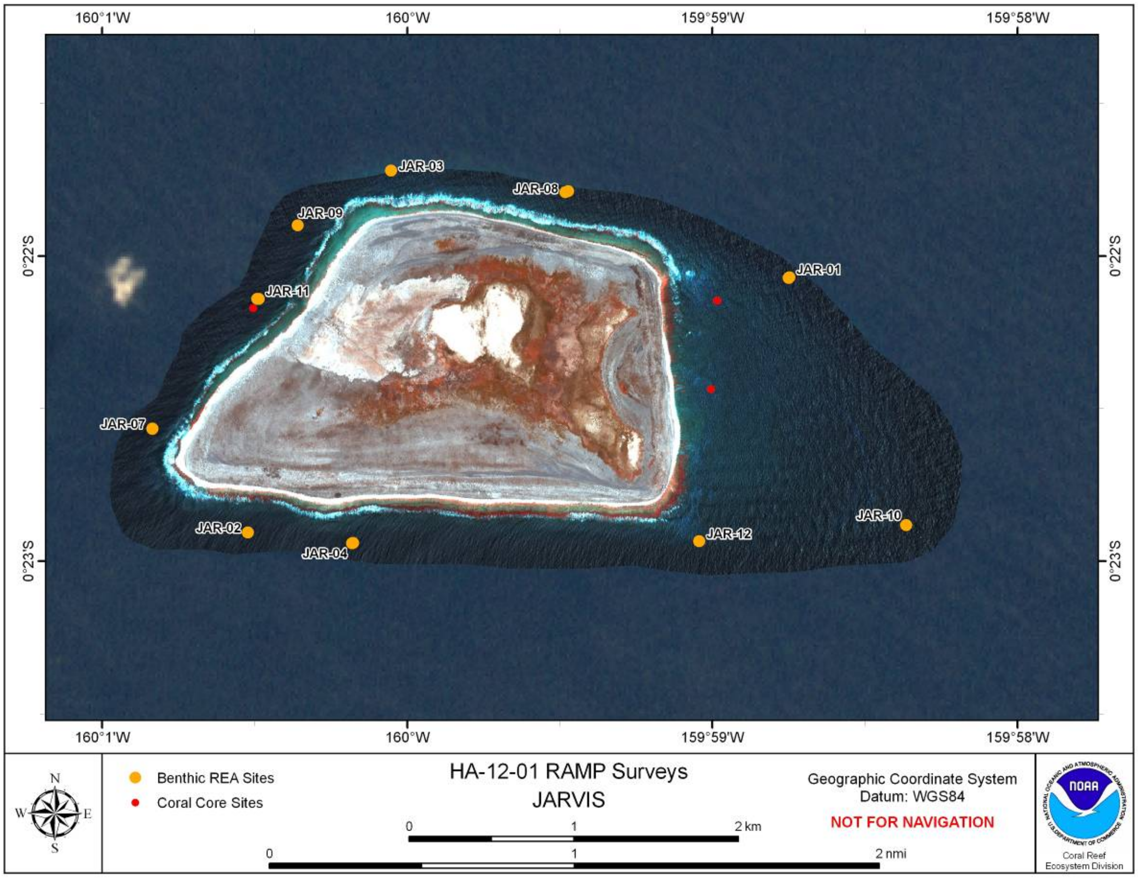

Figure B.2.1.--Locations of REA benthic sites at Jarvis during cruise HA-12-01, Leg IV. Island satellite image IKONOS Carterra Geo Data, 2003.

Table B.2.1.--Summary of REA benthic surveys performed at Jarvis during cruise HA-12-01, Leg IV. Indication that an LPI survey was completed also means that photographs were taken along transect lines.

REA Site	Date	Latitude	Longitude	REA Surveys		
				LPI	Roving Diver	Corals
JAR-02	3-May	–0.38176	–160.00870	×	×	×
JAR-04	3-May	–0.38233	–160.00295	×	×	×
JAR-07	3-May	–0.37609	–160.01392	×	×	×
JAR-01	4-May	–0.36786	–159.97916	×	×	×
JAR-08	4-May	–0.36312	–159.99121	×	×	×
JAR-10	4-May	–0.38137	–159.97275	×	×	×
JAR-03	5-May	–0.36200	–160.00087	×	×	×
JAR-09	5-May	–0.36498	–160.00598	×	×	×
JAR-12	5-May	–0.38224	–159.98404	×	×	×
JAR-11	6-May	–0.36900	–160.00812	×	×	×

Table B.2.2.--Summary of CAU and ARMS retrievals (Ret.) and deployments (Dep.) performed as well as algal specimens, microbial water and benthic samples, and coral cores collected at Jarvis during cruise HA-12-01, Leg IV. Counts of algal samples include both algal voucher specimens and *Halimeda* samples for calcification or isotope analysis.

REA Site	Date	Latitude	Longitude	Installations and Collections						
				CAU Ret	CAU Dep	ARMS Ret	ARMS Dep	Algae	Microbial Samples	Coral Cores
JAR-02	3-May	–0.38176	–160.00870	0	0	0	0	16	2	0
JAR-04	3-May	–0.38233	–160.00295	0	0	3	3	16	0	0
JAR-07	3-May	–0.37610	–160.01391	5	5	0	0	0	0	0
JAR-07	3-May	–0.37609	–160.01392	0	0	0	0	19	2	0
JAR-11	3-May	–0.36901	–160.00818	5	5	0	0	0	0	0
JAR-01	4-May	–0.36786	–159.97916	0	0	0	0	16	2	0
JAR-01	4-May	–0.36783	–159.97912	5	5	0	0	0	0	0
JAR-04	4-May	–0.38235	–160.00301	4	5	0	0	0	0	0
JAR-08	4-May	–0.36318	–159.99135	5	5	0	0	0	0	0
JAR-08	4-May	–0.36312	–159.99121	0	0	3	3	0	0	0
JAR-10	4-May	–0.38137	–159.97275	0	0	0	0	0	2	0
JAR-01	5-May	–0.37393	–159.98340	0	0	0	0	0	0	1
JAR-03	5-May	–0.36200	–160.00087	0	0	0	0	16	2	0
JAR-09	5-May	–0.36498	–160.00598	0	0	3	0	0	0	0
JAR-12	5-May	–0.38224	–159.98404	0	0	0	0	0	5	0
JAR-01	6-May	–0.36908	–159.98306	0	0	0	0	0	0	1
JAR-11	6-May	–0.36950	–160.00842	0	0	0	0	0	0	1
JAR-11	6-May	–0.36900	–160.00812	0	0	0	3	0	16	0

During cruise HA-12-01, Leg IV, CRED completed 11 towed-diver surveys at Jarvis Island, covering a total length of 23.2 km (an area of 23.2 ha) on the ocean floor (Fig. B.2.2). The mean survey length was 2.1 km with a range of 0.9–3.0 km. The mean survey depth was 11.7 m with a range of 6.6–14.8 m. The mean temperature from data recorded during these surveys was 26.9°C with a range of 25.9°C–27.2°C.

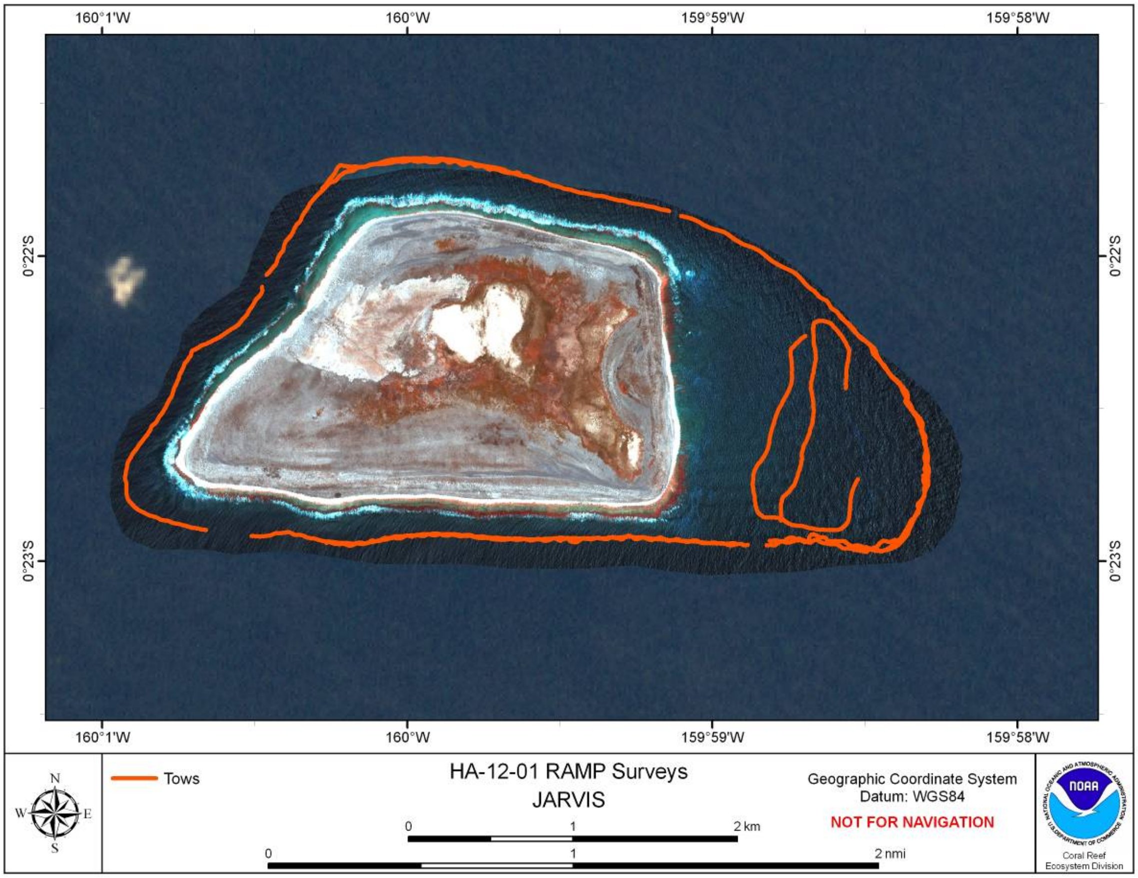

Figure B.2.2.--Track locations of towed-diver surveys conducted at Jarvis during cruise HA-12-01, Leg IV. Island satellite image IKONOS Carterra Geo Data, 2003.

B.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 42 REA sites at Jarvis Island over three different habitat strata: deep forereef, moderate forereef, and shallow forereef (Table B.3.1 and Fig.B.3.1). No fishes were collected during these surveys.

In addition, CRED completed 11 towed-diver surveys at Jarvis Island, as described previously in Section B.2 of this appendix.

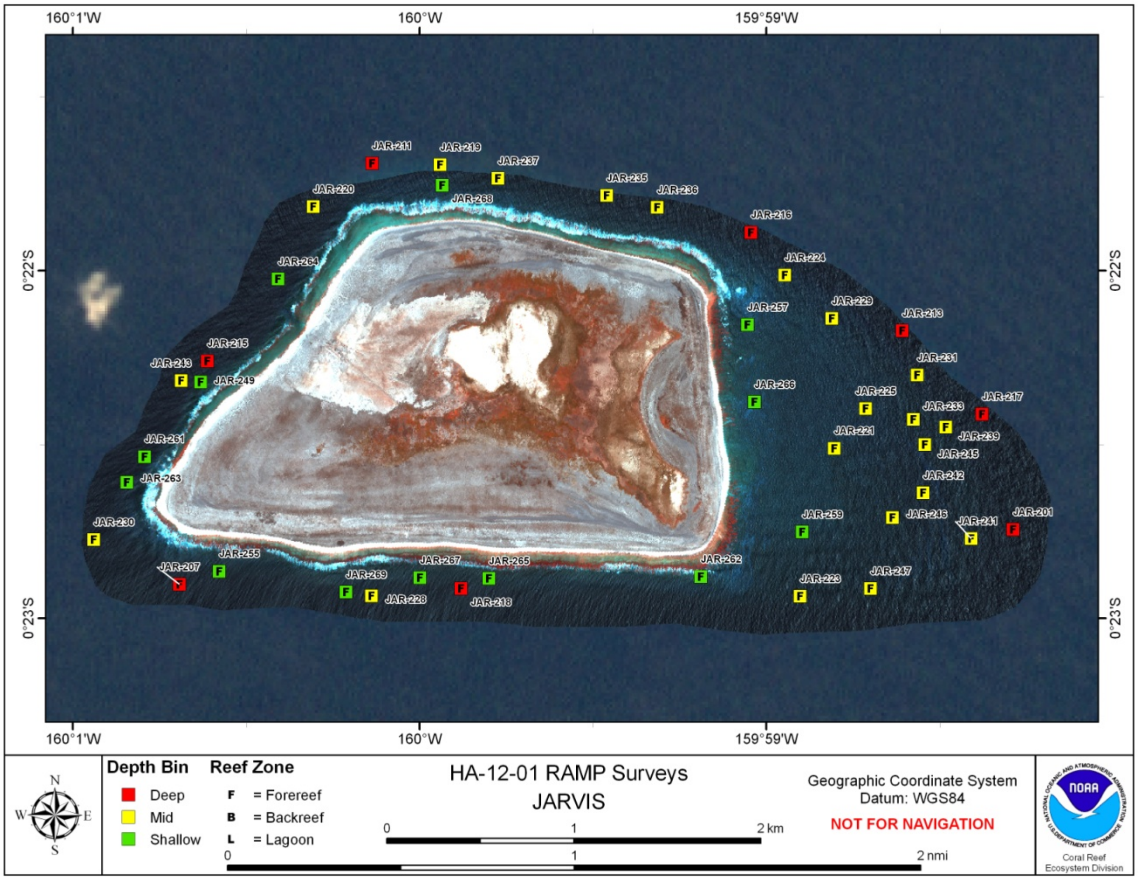

Figure B.3.1.--Locations of REA fish sites surveyed at Jarvis during cruise HA-12-01, Leg IV. All of these REA sites were selected using a stratified random design. Island satellite image IKONOS Carterra Geo Data, 2003.

Table B.3.1.--Summary of sites where REA fish surveys were conducted at Jarvis during cruise HA-12-01, Leg IV.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
JAR-215	3-May	Deep	Forereef	21	–0.37099	–160.01020
JAR-218	3-May	Deep	Forereef	23	–0.38190	–159.99802
JAR-223	3-May	Moderate	Forereef	11	–0.38227	–159.98171
JAR-228	3-May	Moderate	Forereef	15.2	–0.38226	–160.00231
JAR-230	3-May	Moderate	Forereef	16.5	–0.37956	–160.01566
JAR-243	3-May	Moderate	Forereef	11	–0.37193	–160.01146
JAR-255	3-May	Shallow	Forereef	4.5	–0.38107	–160.00964
JAR-259	3-May	Shallow	Forereef	6.8	–0.37920	–159.98160
JAR-262	3-May	Shallow	Forereef	4.9	–0.38134	–159.98648
JAR-263	3-May	Shallow	Forereef	4	–0.37680	–160.01408
JAR-207	4-May	Deep	Forereef	22	–0.38171	–160.01155
JAR-217	4-May	Deep	Forereef	25.6	–0.37354	–159.97296
JAR-229	4-May	Moderate	Forereef	7.5	–0.36895	–159.98019
JAR-231	4-May	Moderate	Forereef	7.9	–0.37166	–159.97608
JAR-241	4-May	Moderate	Forereef	11	–0.37951	–159.97349
JAR-245	4-May	Moderate	Forereef	11.2	–0.37501	–159.97571
JAR-247	4-May	Moderate	Forereef	10.4	–0.38190	–159.97833
JAR-249	4-May	Shallow	Forereef	5	–0.37200	–160.01053
JAR-265	4-May	Shallow	Forereef	5.1	–0.38141	–159.99666
JAR-211	5-May	Deep	Forereef	24	–0.36152	–160.00228
JAR-213	5-May	Deep	Forereef	23	–0.36954	–159.97681
JAR-216	5-May	Deep	Forereef	22.7	–0.36482	–159.98407
JAR-219	5-May	Moderate	Forereef	12.4	–0.36159	–159.99902
JAR-220	5-May	Moderate	Forereef	14.9	–0.36360	–160.00512
JAR-221	5-May	Moderate	Forereef	7.9	–0.37518	–159.98007
JAR-225	5-May	Moderate	Forereef	8.5	–0.37327	–159.97857
JAR-233	5-May	Moderate	Forereef	10.6	–0.37379	–159.97626
JAR-235	5-May	Moderate	Forereef	13	–0.36306	–159.99101
JAR-237	5-May	Moderate	Forereef	10.3	–0.36223	–159.99624
JAR-239	5-May	Moderate	Forereef	8	–0.37415	–159.97471
JAR-264	5-May	Shallow	Forereef	4.1	–0.36706	–160.00680
JAR-268	5-May	Shallow	Forereef	5.8	–0.36257	–159.99892
JAR-201	6-May	Deep	Forereef	25.3	–0.37908	–159.97148
JAR-224	6-May	Moderate	Forereef	7	–0.36687	–159.98245
JAR-236	6-May	Moderate	Forereef	12	–0.36363	–159.98857
JAR-242	6-May	Moderate	Forereef	9	–0.37731	–159.97580
JAR-246	6-May	Moderate	Forereef	7.6	–0.37850	–159.97727
JAR-257	6-May	Shallow	Forereef	4.7	–0.36925	–159.98424
JAR-261	6-May	Shallow	Forereef	5.8	–0.37558	–160.01323
JAR-266	6-May	Shallow	Forereef	4.7	–0.37295	–159.98391
JAR-267	6-May	Shallow	Forereef	7.6	–0.38139	–159.99999
JAR-269	6-May	Shallow	Forereef	6.7	–0.38207	–160.00353

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APPENDIX C: KINGMAN ATOLL

Kingman Atoll is located at 06°25´N, 162°25´W in the equatorial Pacific and is part of the Line Islands and the recently formed Pacific Remote Islands Marine National Monument. 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 the cruise HA-12-01, Leg IV, at Kingman Atoll entailed numerous retrievals and deployments of oceanographic moored instruments, calcification acidification units (CAUs), nearshore water sampling, and Conductivity, Temperature, and Depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, shipboard water sampling and CTD casts offshore to a depth of 500 m, and offshore acoustic Doppler current profiler (ADCP) transect lines.

Numerous oceanographic instruments were retrieved and deployed in the nearshore waters at Kingman Reef. In total, 11 subsurface temperature recorders (STRs) were retrieved and 13 were deployed, 4 of which were deployed in the same location as they were retrieved while 7 additional STRs were deployed in new locations (Fig. C.1.1 and Table C.1.1). The STR deployment strategy at Kingman is part of NOAA's newly developed National Coral Reef Monitoring Program (NCRMP). Please see Appendix A: "Methods" for more information pertaining to NCRMP. In addition, one Aandera current meter was retrieved and not replaced while the sea surface temperature (SST) buoy was not retrieved as it had broken free at some point since the deployment in 2010. The SST buoy was not replaced owing to funding constraints.

Shallow-water CTD casts were performed at 8 select REA sites concurrent with CAUs' retrieval and deployments (Fig. C.1.1). See section C.2: "Benthic Environment" for more information pertaining to CAU deployment and retrievals. In concert with each CTD cast, two water samples were taken (surface and near reef) to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, dissolved nutrients (NO_3^-, NO_2^-,PO_4^{3-}, $Si(OH)_4$), and chlorophyll-*a* (Chl-*a*) concentrations. Accounting for losses and microbiological nutrient samples taken alone, a total of 16 DIC and TA, 16 salinity, 16 nutrient, and 16 Chl-*a* water samples were collected.

Two pneumatic and two hydraulic coral cores were extracted from mounding *Porites* species around Kingman Reef. Please see Appendix A: "Methods" for more information pertaining to coral core operations and Table E.1.1 in Appendix E: "Biological Collections" for more information pertaining to coral core locations.

Deepwater CTD casts were collected during 4 nights of operations around Kingman. Four CTD transects were conducted to the north, east, south and west totaling 27 CTD casts (Fig. C.1.2). Water samples for nutrients and Chl-*a* were collected at 5 depths concurrently with 4 CTD casts; one on each transect (Fig. C.1.2). ADCP data were collected concurrently along CTD transects.

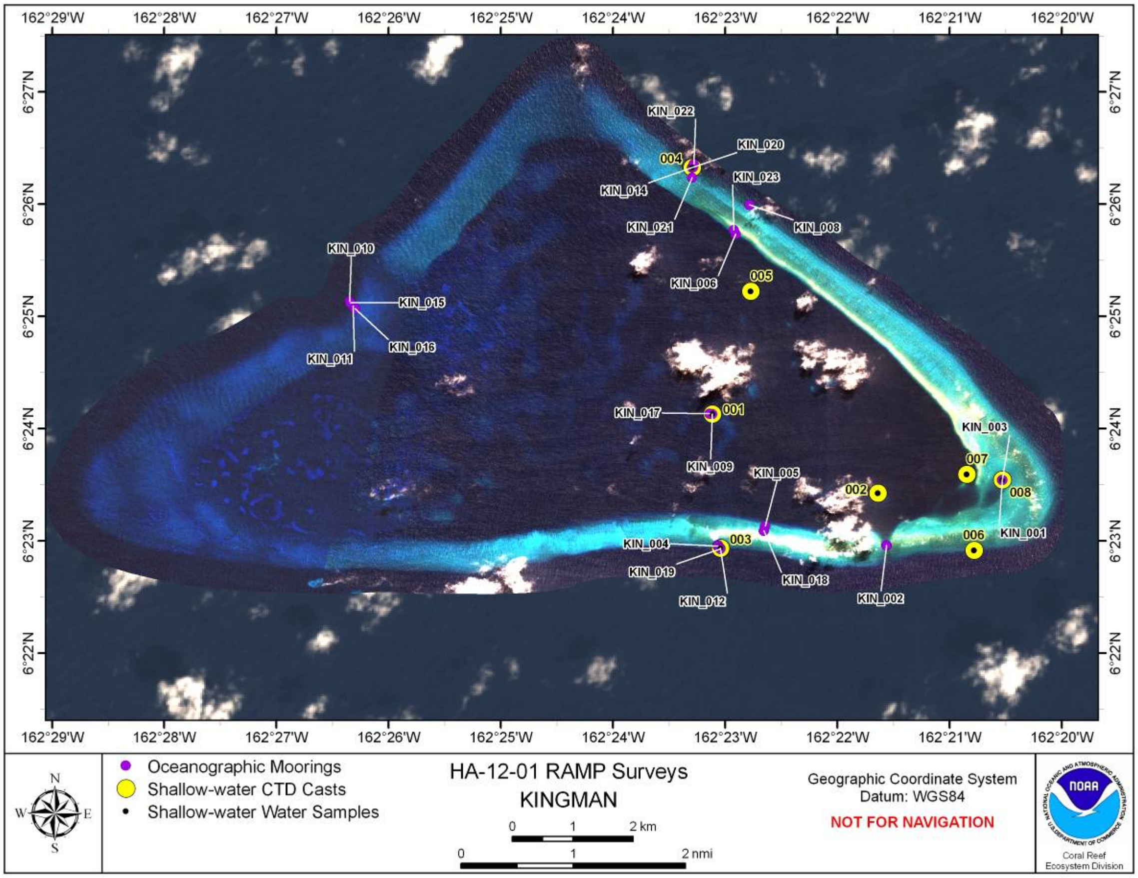

Figure C.1.1.--Mooring sites where oceanographic instruments were retrieved or deployed and REA and CAU sites where nearshore CTD casts and water sampling were performed. Kingman Atoll, HA-12-01, Leg IV (IKONOS Carterra Geo Data, 2003).

Table C.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments that were retrieved or deployed at Kingman Atoll during cruise HA-12-01, Leg IV.

Mooring Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
KIN_004	9-May	EAR	6.38256	– 162.38441	7.3	1	1
KIN_004	9-May	STR	6.38265	– 162.38439	6.25	1	1
KIN_005	9-May	STR	6.38555	– 162.37739	3	1	–
KIN_009	9-May	STR	6.40222	– 162.38524	10.1	1	–
KIN_010	9-May	STR	6.41891	– 162.43918	32.9	1	–
KIN_011	9-May	STR	6.41824	– 162.43865	17.7	1	–
KIN_012	9-May	STR	6.38226	– 162.38408	13.7	1	1
KIN_015	9-May	STR	6.41874	– 162.43901	24.7	–	1
KIN_016	9-May	STR	6.41786	– 162.43831	14.6	–	1
KIN_017	9-May	STR	6.40223	– 162.38566	14.6	–	1
KIN_018	9-May	STR	6.38486	– 162.37758	0.9	–	1
KIN_019	9-May	STR	6.38214	– 162.38407	23.2	–	1
KIN_006	10-May	STR	6.42891	– 162.38179	4.9	1	–
KIN_008	10-May	STR	6.43329	– 162.37972	8.2	1	–
KIN_014	10-May	STR	6.43879	– 162.38827	13.1	1	–
KIN_020	10-May	STR	6.43884	– 162.38811	14.6	–	1
KIN_021	10-May	STR	6.43729	– 162.38826	5.8	–	1
KIN_022	10-May	STR	6.43932	– 162.38797	25	–	1
KIN_023	10-May	STR	6.42956	– 162.38202	1.2	–	1
KIN_001	11-May	SST	6.39239	– 162.34215	0.3	1	–
KIN_002	11-May	RCM	6.38266	– 162.35934	6.4	1	–
KIN_002	11-May	STR	6.38266	– 162.35934	6.7	1	1
KIN_003	11-May	STR	6.39239	– 162.34215	7.3	1	1

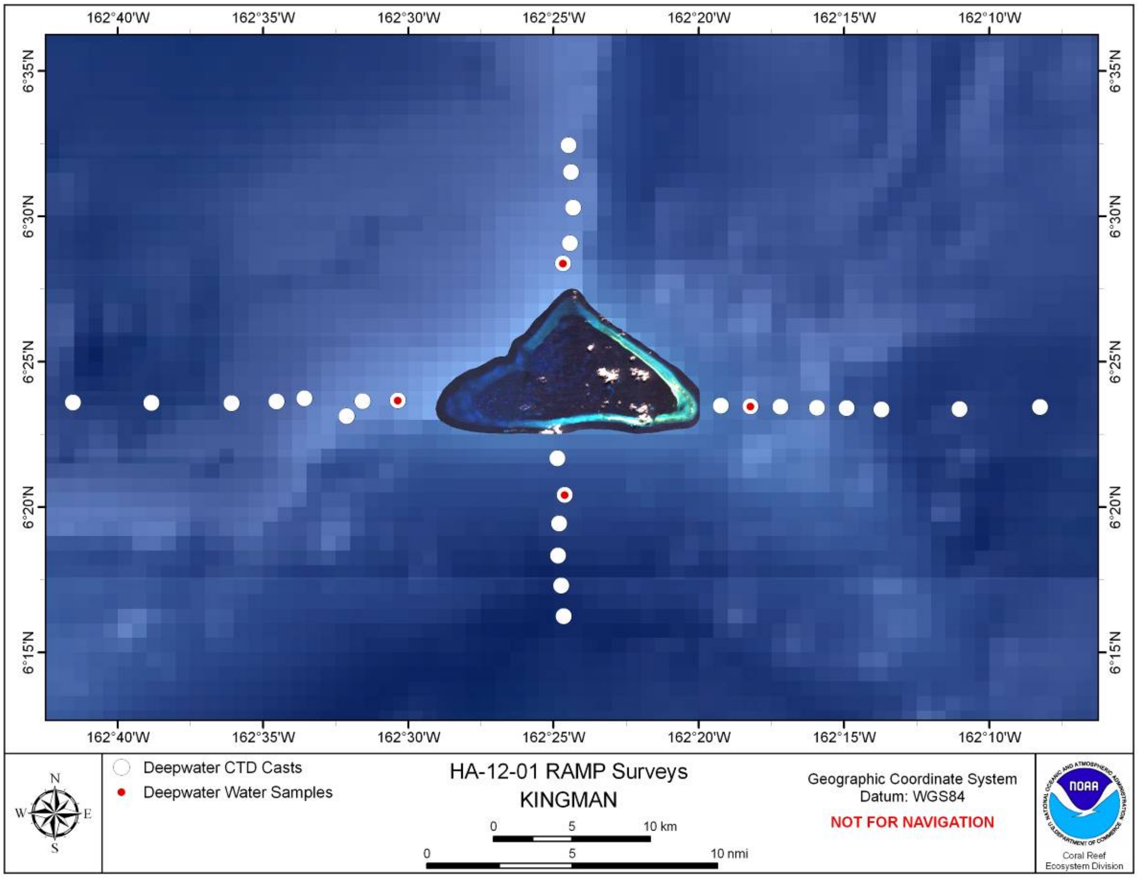

Figure C.1.2.--Locations of deepwater CTD casts and water sampling performed at Kingman Atoll during cruise HA-12-01, Leg IV. Island satellite image IKONOS Carterra Geo Data, 2003, and background imagery SIO, NOAA, U.S. Navy, NGA, GEBCO (Becker, 2009; Smith and Sandwell, 1997) © 2008 The Regents of the University of California.

C.2. Benthic Environment

Belt-transect, line-point-intercept (LPI), and roving-diver surveys were conducted and photographs were taken along transect lines at 15 REA sites around Kingman Reef to assess benthic composition, coral and algal community structure, and coral and coralline algal disease (Fig. C.2.1 and Table C.2.1).

Various samples were collected at 13 REA sites (Table C.2.2): 6 algal voucher specimens at six REA sites for taxonomic identification, 120 individuals of the algal genus *Halimeda* at six REA sites for calcification analysis and 24 at two sites for isotope analysis, 4 coral cores at three sites from *Porites* coral heads for calcification research, and 26 water samples for microbial analyses at nine REA sites with two water samples of 2 L each at each site, four water samples of 20 L each at KIN-05 and KIN-25. Additional microbial work included benthic grabs of coral rubble and unidentified macroalgae at KIN-05 and KIN-25. For more information about collections made at REA sites, see Table E.1.1 in Appendix E: "Biological Collections."

A new site, KIN-25, was created in the vicinity of the shipwreck located at the northeast side of Kingman Reef. The reef in this area was originally surveyed in December 2009 by James Maragos of USFWS, and again in 2010 by CRED Pacific RAMP. In both instances, surveys were qualitative. In 2010, CRED reported that cyanobacteria and *Rhodactis* sp. were not present in substantial numbers along the reef crest but that a cyanobacterial bloom was observed in the lagoon, extending from 5 m down to ~25 m. During the 2012 survey, the benthic team performed a full benthic survey, including the LPI method and community structure and disease methods. Preliminary results from the LPI survey reveal cyanobacteria representing the highest percent cover (54.4%) of the benthic community, while hard coral was only 7.6%. Visual observations indicated high percent cover of *Rhodactis* sp. in the shallower reef crest of this site and cyanobacteria exhibiting increased dominance at ~10 m.

Nine autonomous reef monitoring structures (ARMS) were recovered: three ARMS each from KIN-13, KIN-05, KIN-23 (Table C.2.2). Nine ARMS were deployed with three ARMS each at KIN-13, KIN-05, KIN-11. At each of eight select REA sites, an array of five CAUs was deployed for a total of 40 CAUs installed and 40 were recovered from previous deployments in 2010 (Table C.2.2). For information about EAR installations, see Section C.2: "Oceanography and Water Quality."

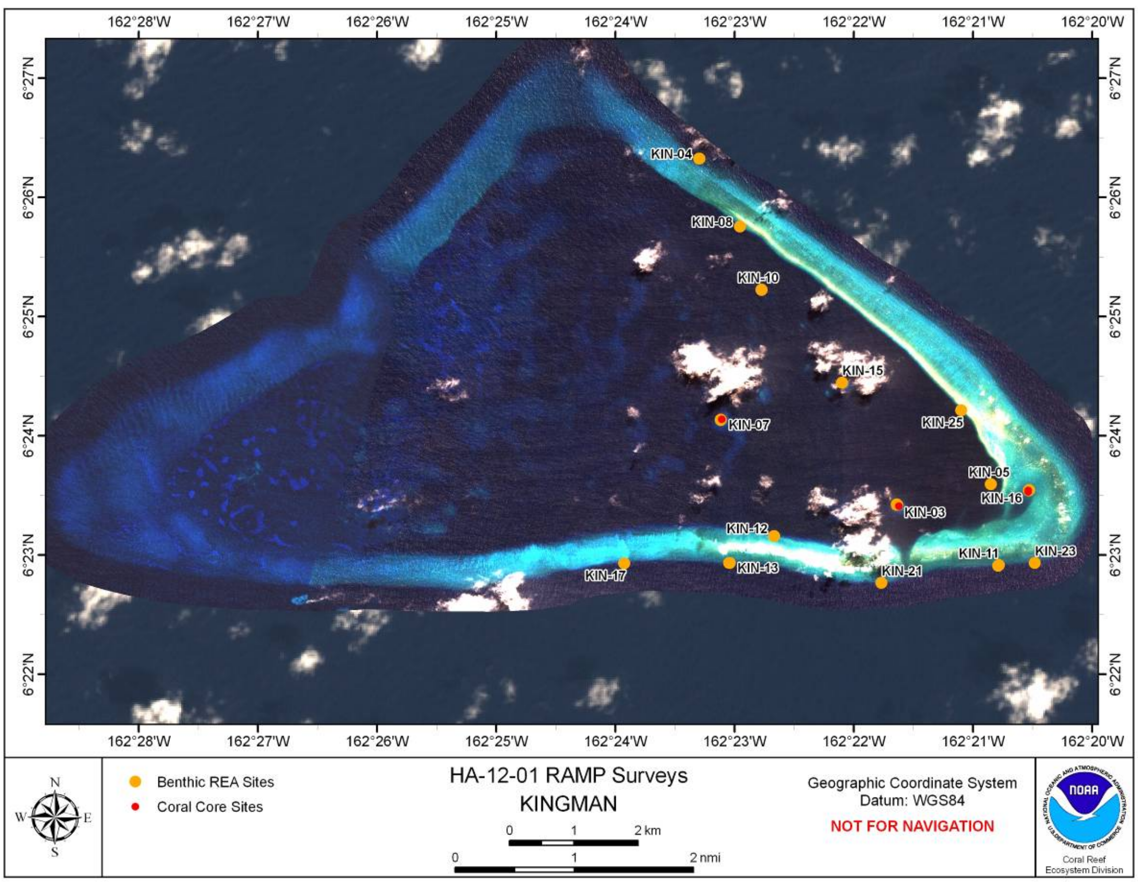

Figure C.2.1.--Locations of REA benthic sites surveyed and coral cores at Kingman during cruise HA-12-01, Leg IV. Island satellite image IKONOS Carterra Geo Data, 2003.

Table C.2.1.--REA benthic surveys performed at Kingman during cruise HA-12-01, Leg IV. Indication that an LPI survey was completed also means that photographs were taken along transect lines.

REA Site	Date	Latitude	Longitude	REA Surveys		
				LPI	Roving Diver	Corals
KIN-03	9-May	6.39038	–162.36059	×	×	×
KIN-13	9-May	6.38224	–162.38401	×	×	×
KIN-17	9-May	6.38220	–162.39878	×	×	×
KIN-08	10-May	6.42929	–162.38257	×	×	×
KIN-10	10-May	6.42044	–162.37955	×	×	×
KIN-23	10-May	6.38225	–162.34137	×	×	×
KIN-07	11-May	6.40226	–162.38525	×	×	×
KIN-11	11-May	6.38185	–162.34645	×	×	×
KIN-12	11-May	6.38599	–162.37779	×	×	×
KIN-04	12-May	6.43878	–162.38825	×	×	×
KIN-05	12-May	6.39323	–162.34747	×	×	×
KIN-15	12-May	6.40746	–162.36832	×	×	×
KIN-16	13-May	6.39241	–162.34214	×	×	×
KIN-21	13-May	6.37947	–162.36280	×	×	×
KIN-25	13-May	6.40360	–162.35164	×	×	×

Table C.2.2.--Summary of CAU and ARMS retrievals (Ret.) and deployments (Dep.) performed as well as algal specimens, microbial water and benthic samples, and coral cores collected at Kingman during cruise HA-12-01, Leg IV. Counts of algal samples include both algal voucher specimens and *Halimeda* samples for calcification or isotope analysis.

REA Site	Date	Latitude	Longitude	Installations and Collections						
				CAU Ret	CAU Dep	ARMS Ret	ARMS Dep	Algae	Microbial Samples	Coral Cores
KIN-03	9-May	6.39038	–162.36059	0	0	0	0	32	2	0
KIN-03	9-May	6.39045	–162.36065	5	5	0	0	0	0	0
KIN-07	9-May	6.40222	–162.38524	5	5	0	0	0	0	0
KIN-13	9-May	6.38224	–162.38401	0	0	3	3	32	0	0
KIN-13	9-May	6.38226	–162.38408	5	5	0	0	0	0	0
KIN-17	9-May	6.38220	–162.39878	0	0	0	0	0	2	0
KIN-04	10-May	6.43879	–162.38827	5	5	0	0	0	0	0
KIN-08	10-May	6.42929	–162.38257	0	0	0	0	1	2	0
KIN-10	10-May	6.42042	–162.37956	5	5	0	0	0	0	0
KIN-10	10-May	6.42044	–162.37955	0	0	0	0	1	2	0
KIN-11	10-May	6.38195	–162.34637	5	5	0	0	0	0	0
KIN-23	10-May	6.38225	–162.34137	0	0	3	0	0	0	0
KIN-05	11-May	6.39324	–162.34746	5	5	0	0	0	0	0
KIN-07	11-May	6.40226	–162.38525	0	0	0	0	30	2	0
KIN-11	11-May	6.38185	–162.34645	0	0	0	3	1	0	0
KIN-12	11-May	6.38599	–162.37779	0	0	0	0	10	2	0
KIN-16	11-May	6.39239	–162.34215	5	5	0	0	0	0	0
KIN-04	12-May	6.43878	–162.38825	0	0	0	0	20	0	0
KIN-05	12-May	6.39323	–162.34747	0	0	3	3	20	16	0
KIN-15	12-May	6.40746	–162.36832	0	0	0	0	1	0	0
KIN-16	12-May	6.39225	–162.34227	0	0	0	0	0	0	1
KIN-16	12-May	6.39243	–162.34229	0	0	0	0	0	0	1
KIN-03	13-May	6.39025	–162.36037	0	0	0	0	0	0	1
KIN-07	13-May	6.40235	–162.38513	0	0	0	0	0	0	1
KIN-16	13-May	6.39241	–162.34214	0	0	0	0	1	2	0
KIN-25	13-May	6.40360	–162.35164	0	0	0	0	1	9	0

During cruise HA-12-01, Leg IV, CRED completed 22 towed-diver surveys at Kingman Reef, covering a total length of 43.9 km (an area of 43.9 ha) on the ocean floor (Fig. C.2.2). The mean survey length was 2.0 km with a range of 1.3–2.5 km. The mean survey depth was 14.2 m with a range of 4.3–17.8 m. The mean temperature from data recorded during these surveys was 27.3°C with a range of 27.2°C–27.5°C.

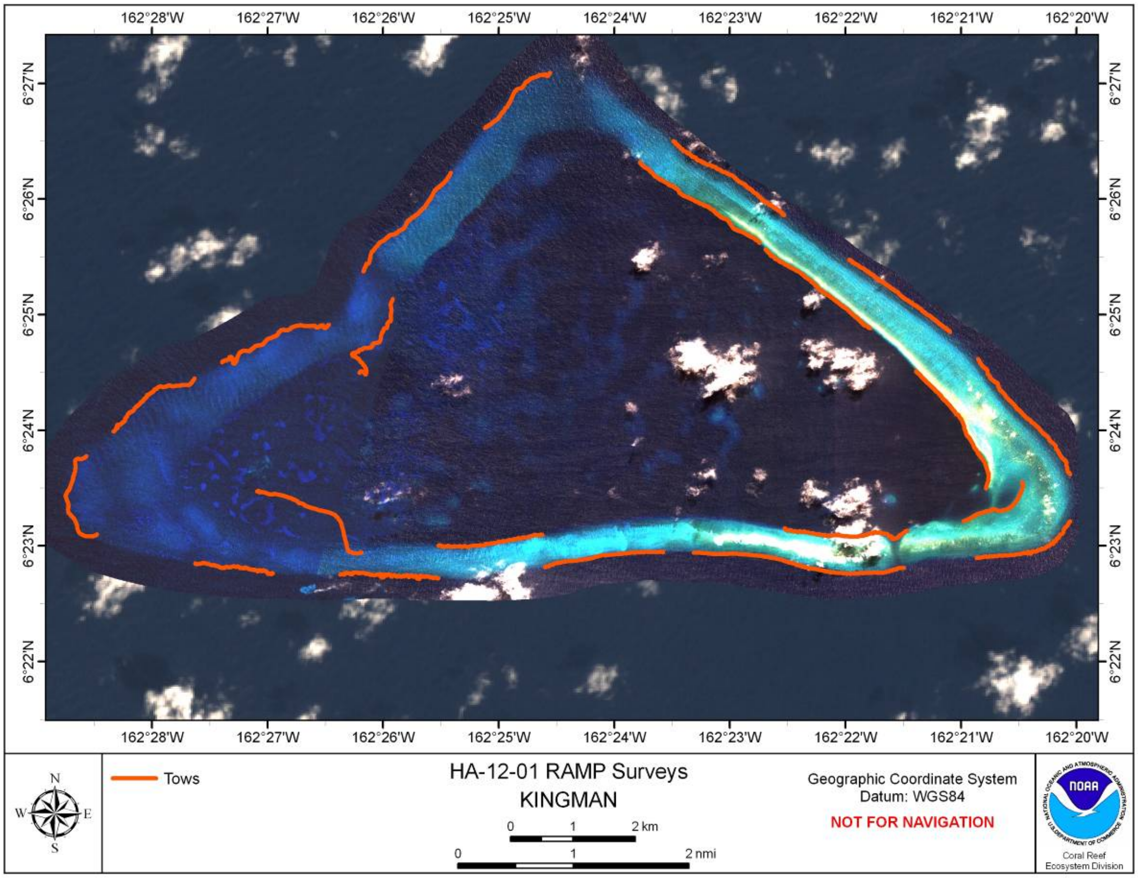

Figure C.2.2.--Track locations of towed-diver surveys conducted at Kingman during cruise HA-12-01, Leg IV. Island satellite image IKONOS Carterra Geo Data, 2003.

C.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 49 REA sites at Kingman Reef over eight different habitat strata: deep forereef, moderate forereef, shallow forereef, deep lagoon, moderate lagoon, deep backreef, moderate backreef, and shallow backreef (Table C.3.1 and Fig.C.3.1). No fishes were collected during these surveys.

In addition, CRED completed 22 towed-diver surveys at Kingman Reef, as described previously in Section C.2 of this appendix.

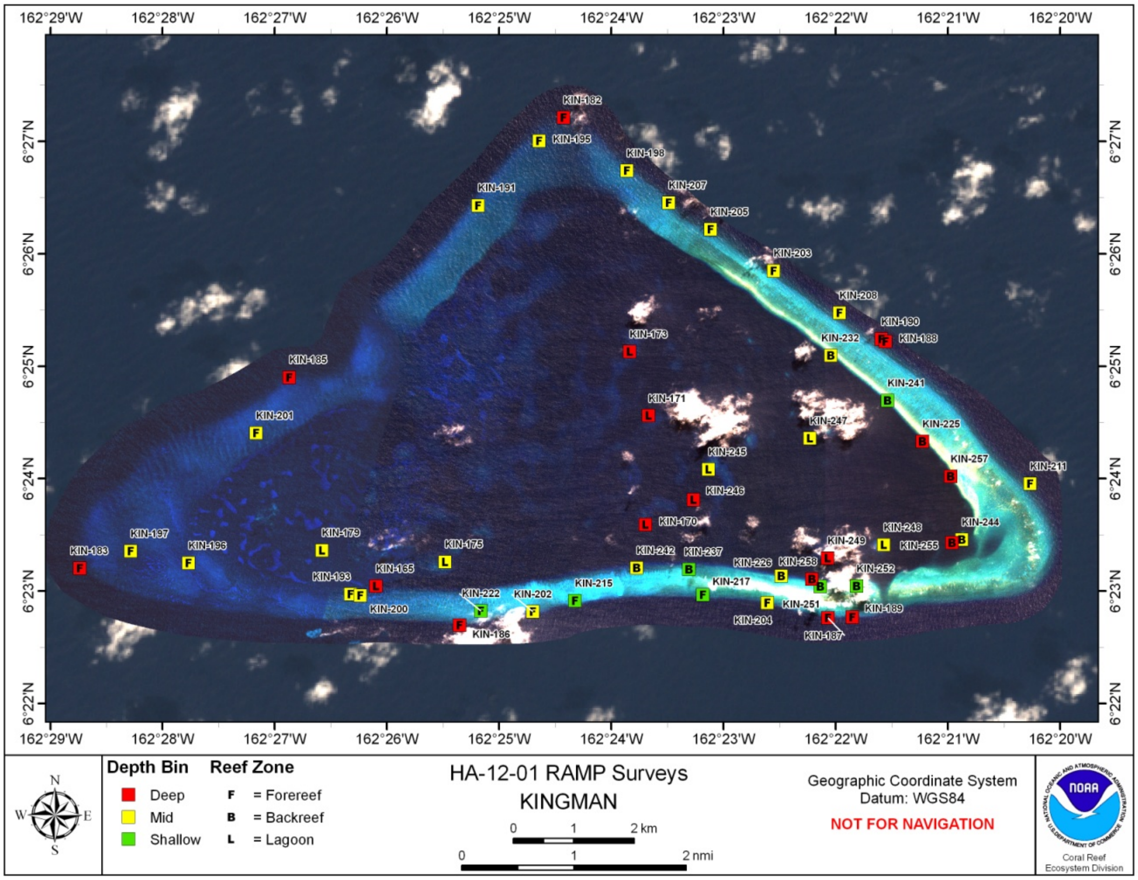

Figure C.3.1.--Locations of REA fish sites surveyed at Kingman during cruise HA-12-01, Leg IV. All of these REA sites were selected using a stratified random design. Island satellite image IKONOS Carterra Geo Data, 2003.

Table C.3.1.--Summary of sites where REA fish surveys were conducted at Kingman during cruise HA-12-01, Leg IV.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
KIN-182	9-May	Deep	Forereef	21.3	6.45353	–162.40713
KIN-187	9-May	Deep	Forereef	25.3	6.37936	–162.36778
KIN-190	9-May	Deep	Forereef	21.2	6.42070	–162.35988
KIN-193	9-May	Moderate	Forereef	17.1	6.38289	–162.43873
KIN-204	9-May	Moderate	Forereef	9.1	6.38162	–162.37681
KIN-205	9-May	Moderate	Forereef	9.5	6.43696	–162.38523
KIN-208	9-May	Moderate	Forereef	15.4	6.42456	–162.36609
KIN-211	9-May	Moderate	Forereef	15.8	6.39927	–162.33775
KIN-215	9-May	Shallow	Forereef	6.3	6.38189	–162.40539
KIN-217	9-May	Shallow	Forereef	5.6	6.38279	–162.38639
KIN-183	10-May	Deep	Forereef	25.3	6.38673	–162.47897
KIN-185	10-May	Deep	Forereef	21.2	6.41503	–162.44787
KIN-186	10-May	Deep	Forereef	21.9	6.37827	–162.42253
KIN-191	10-May	Moderate	Forereef	13.1	6.44050	–162.41979
KIN-195	10-May	Moderate	Forereef	14.5	6.45007	–162.41072
KIN-196	10-May	Moderate	Forereef	18	6.38750	–162.46280

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
KIN-197	10-May	Moderate	Forereef	17.1	6.38925	–162.47141
KIN-201	10-May	Moderate	Forereef	10.1	6.40677	–162.45278
KIN-202	10-May	Moderate	Forereef	10.1	6.38028	–162.41165
KIN-222	10-May	Shallow	Forereef	6.1	6.38042	–162.41940
KIN-171	11-May	Deep	Lagoon	26.1	6.40934	–162.39449
KIN-173	11-May	Deep	Lagoon	21.6	6.41884	–162.39726
KIN-198	11-May	Moderate	Forereef	11.3	6.44567	–162.39767
KIN-225	11-May	Deep	Backreef	21.2	6.40553	–162.35376
KIN-226	11-May	Moderate	Backreef	12.8	6.38558	–162.37474
KIN-232	11-May	Moderate	Backreef	10.7	6.41826	–162.36740
KIN-237	11-May	Shallow	Backreef	5	6.38656	–162.38845
KIN-244	11-May	Moderate	Backreef	11.6	6.39096	–162.34790
KIN-248	11-May	Moderate	Lagoon	10.1	6.39020	–162.35950
KIN-252	11-May	Shallow	Backreef	4.6	6.38407	–162.36355
KIN-257	11-May	Deep	Backreef	25.9	6.40035	–162.34959
KIN-165	12-May	Deep	Lagoon	26.5	6.38410	–162.43497
KIN-175	12-May	Moderate	Lagoon	16.2	6.38768	–162.42472
KIN-241	12-May	Shallow	Backreef	4	6.41158	–162.35893
KIN-242	12-May	Moderate	Backreef	9.8	6.38677	–162.39621
KIN-245	12-May	Moderate	Lagoon	12	6.40137	–162.38556
KIN-246	12-May	Deep	Lagoon	26	6.39687	–162.38777
KIN-247	12-May	Moderate	Lagoon	10	6.40598	–162.37050
KIN-249	12-May	Deep	Lagoon	25.9	6.38822	–162.36785
KIN-251	12-May	Shallow	Backreef	4	6.38403	–162.36892
KIN-255	12-May	Deep	Backreef	20.7	6.39051	–162.34936
KIN-170	13-May	Deep	Lagoon	21.9	6.39321	–162.39493
KIN-179	13-May	Moderate	Lagoon	17.7	6.38939	–162.44299
KIN-188	13-May	Deep	Forereef	22	6.42033	–162.35925
KIN-189	13-May	Deep	Forereef	21.6	6.37947	–162.36420
KIN-200	13-May	Moderate	Forereef	14.8	6.38268	–162.43731
KIN-203	13-May	Moderate	Forereef	11.2	6.43082	–162.37585
KIN-207	13-May	Moderate	Forereef	9.5	6.44088	–162.39148
KIN-258	13-May	Deep	Backreef	21.6	6.38512	–162.37016

APPENDIX D: PALMYRA ATOLL

Palmyra Atoll is located at 05°53´N, 162°05´W in the equatorial Pacific and is part of the Line Islands and the recently formed Pacific Remote Islands Marine National Monument. 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 the cruise HA-12-01, Leg IV, at Palmyra Atoll entailed numerous retrievals and deployments of oceanographic moored instruments, calcification acidification units (CAUs), nearshore water sampling, and Conductivity, Temperature, and Depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, shipboard water sampling and CTD casts offshore to a depth of 500 m, and offshore acoustic Doppler current profiler (ADCP) transect lines.

Numerous oceanographic instruments were retrieved and deployed in the nearshore waters at Palmyra Atoll. In total, 25 subsurface temperature recorders (STRs) were retrieved and 22 were deployed, 4 of which were deployed in the same location as they were retrieved while 18 additional STRs were deployed in new locations (Fig. D.1.1 and Table D.1.1). The STR deployment strategy at Palmyra is part of NOAA’s newly developed National Coral Reef Monitoring Program (NCRMP). Please see Appendix A: “Methods” for more information pertaining to NCRMP. As part of a forereef nearshore hydrodynamic investigation, a number of instruments that collected oceanographic data at a higher sampling frequency were retrieved and not replaced. Instruments included 4 ADPs, 6 SBE 37 temperature/salinity sensors and 12 STRs. An additional two WTRs deployed as part of a lagoon water-level investigation were also retrieved and not replaced. One EAR was retrieved and replaced, while the sea surface temperature (SST) buoy was not retrieved as it had broken free at some point since the deployment in 2010 and could not be located. The SST buoy was not replaced owing to funding constraints.

Shallow-water CTD casts were performed at 8 select REA sites concurrent with CAU retrieval and deployments (Fig. D.1.1). See section D.2: “Benthic Environment” for more information pertaining to CAUs. In concert with each CTD cast, two water samples were taken (surface and near reef) to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, dissolved nutrients (NO_3^-, NO_2^-,$PO_4^{3-,}$ $Si(OH)_4$), and chlorophyll-*a* (Chl-*a*) concentrations. Accounting for losses and microbiological nutrient samples taken alone, a total of 16 DIC and TA, 16 salinity, 16 nutrient, and 16 Chl-*a* water samples were collected.

Deepwater CTD casts were collected during 3 nights of operations at Palmyra Atoll. Weather conditions limited the total number of casts and the number of total transects performed around Palmyra. Three CTD transects were conducted to the west, east, south for a total of 18 CTD casts (Fig. D.1.2). Water samples for nutrients and Chl-*a* were collected at 5 depths concurrently with 16 CTD casts (Fig. D.1.2). ADCP data were collected concurrently along CTD transects.

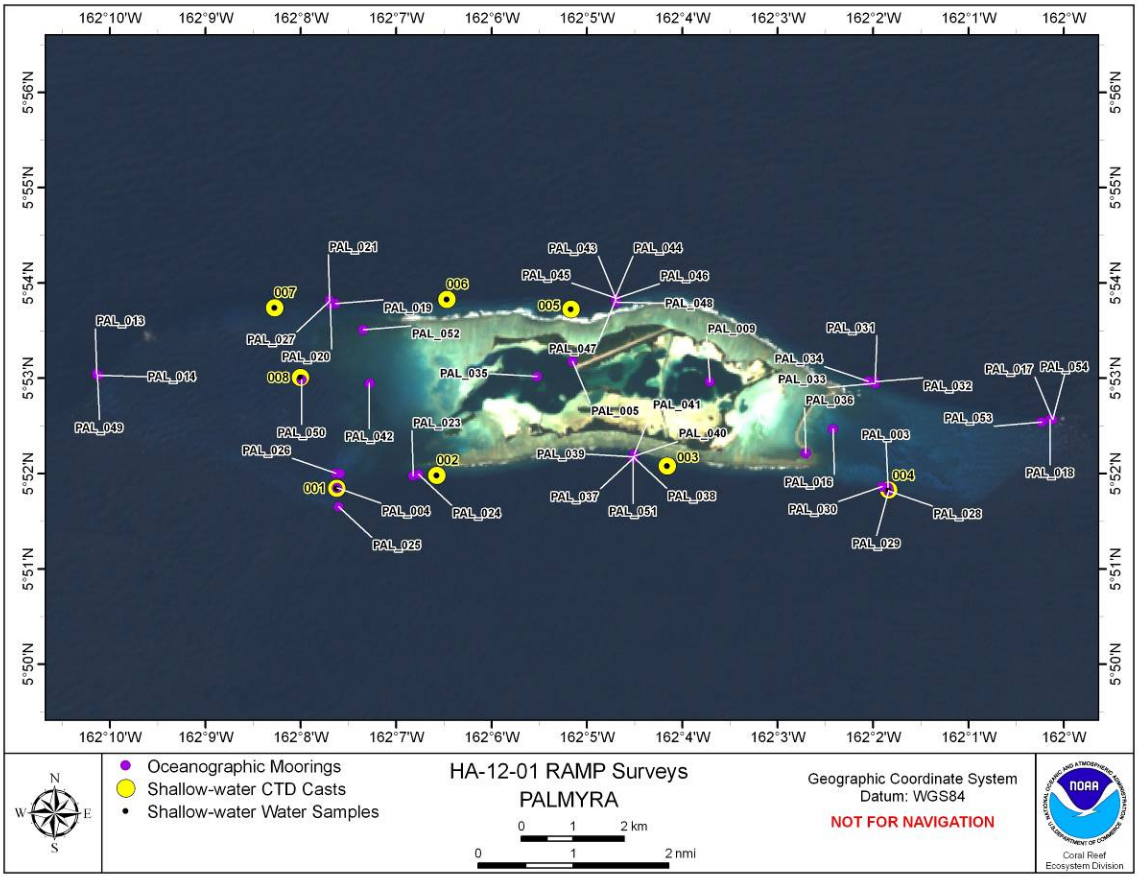

Figure D.1.1.--Mooring sites where oceanographic instruments were retrieved or deployed and REA and CAU sites where nearshore CTD casts and water sampling were performed. Palmyra Atoll, HA-12-01, Leg IV. Landsat satellite imagery data used in this map figure are available from the U.S. Geological Survey.

Table D.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments that were retrieved or deployed at Palmyra Atoll during cruise HA-12-01, Leg IV.

Mooring Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
PAL_003	14-May	STR	5.86426	– 162.03071	10.1	2	–
PAL_004	14-May	EAR	5.86416	– 162.12700	15.5	1	1
PAL_004	14-May	STR	5.86416	– 162.12700	15.5	2	1
PAL_017	14-May	STR	5.87637	– 162.00206	32.3	1	–
PAL_018	14-May	SBE37	5.87611	– 162.00237	21	1	–
PAL_018	14-May	STR	5.87611	– 162.00237	21.9	1	–
PAL_023	14-May	STR	5.86631	– 162.11371	19.8	1	–

Mooring Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
PAL_024	14-May	STR	5.86654	–162.11279	12.2	1	–
PAL_025	14-May	ADP	5.86092	–162.12672	19.8	1	–
PAL_025	14-May	SBE37	5.86092	–162.12672	19.8	1	–
PAL_026	14-May	STR	5.86671	–162.12686	10.4	2	–
PAL_028	14-May	ADP	5.86364	–162.03060	18.9	1	–
PAL_028	14-May	SBE37	5.86364	–162.03060	18.9	1	–
PAL_029	14-May	STR	5.86377	–162.03063	15.2	1	–
PAL_030	14-May	STR	5.86445	–162.03175	10.1	1	–
PAL_016	15-May	STR	5.87447	–162.04034	5.35	1	1
PAL_031	15-May	ADP	5.88296	–162.03294	19.8	1	–
PAL_031	15-May	SBE37	5.88296	–162.03294	19.8	1	–
PAL_032	15-May	STR	5.88279	–162.03297	14.6	1	–
PAL_033	15-May	STR	5.88243	–162.03300	10.4	1	–
PAL_034	15-May	STR	5.88281	–162.03421	10.4	1	–
PAL_037	15-May	STR	5.86942	–162.07522	25	–	1
PAL_038	15-May	STR	5.86953	–162.07517	19.5	–	1
PAL_039	15-May	STR	5.86959	–162.07514	14.6	–	1
PAL_040	15-May	STR	5.86973	–162.07515	10.7	–	1
PAL_041	15-May	STR	5.87011	–162.07509	4.9	–	1
PAL_005	16-May	STR	5.88627	–162.08585	3.4	1	1
PAL_009	16-May	STR	5.88274	–162.06187	4.3	1	–
PAL_009	16-May	WTR	5.88274	–162.06187	4	1	–
PAL_035	16-May	WTR	5.88366	–162.09209	4	1	–
PAL_042	16-May	STR	5.88244	–162.12132	4	1	1
PAL_019	17-May	STR	5.89643	–162.12728	11.3	1	–
PAL_020	17-May	STR	5.89638	–	11.3	1	–

Mooring Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
				162.12817			
PAL_021	17-May	ADP	5.89708	–162.12831	21.6	1	–
PAL_021	17-May	SBE37	5.89708	–162.12831	21.6	1	–
PAL_027	17-May	STR	5.89687	–162.12828	15.5	1	–
PAL_036	17-May	STR	5.87030	–162.04511	1.5	1	1
PAL_043	17-May	STR	5.89746	–162.07834	25.6	–	1
PAL_044	17-May	ADP	5.89752	–162.07834	29.6	–	1
PAL_044	17-May	STR	5.89752	–162.07834	29.6	–	1
PAL_045	17-May	STR	5.89737	–162.07834	19.2	–	1
PAL_046	17-May	STR	5.89729	–162.07834	14.6	–	1
PAL_047	17-May	STR	5.89713	–162.07829	10.1	–	1
PAL_048	17-May	STR	5.89668	–162.07818	5.5	–	1
PAL_013	18-May	STR	5.88414	–162.16900	32.6	1	–
PAL_014	18-May	SBE37	5.88385	–162.16856	19.2	1	–
PAL_014	18-May	STR	5.88385	–162.16856	19.2	1	–
PAL_049	18-May	STR	5.88399	–162.16889	25	–	1
PAL_050	18-May	STR	5.88315	–162.13321	14.6	–	1
PAL_051	18-May	ADP	5.86935	–162.07525	30.5	–	1
PAL_051	18-May	STR	5.86935	–162.07525	30.5	–	1
PAL_052	19-May	STR	5.89187	–162.12240	0.9	–	1
PAL_053	19-May	STR	5.87568	–162.00391	14.6	–	1
PAL_054	19-May	STR	5.87613	–162.00199	26.2	–	1

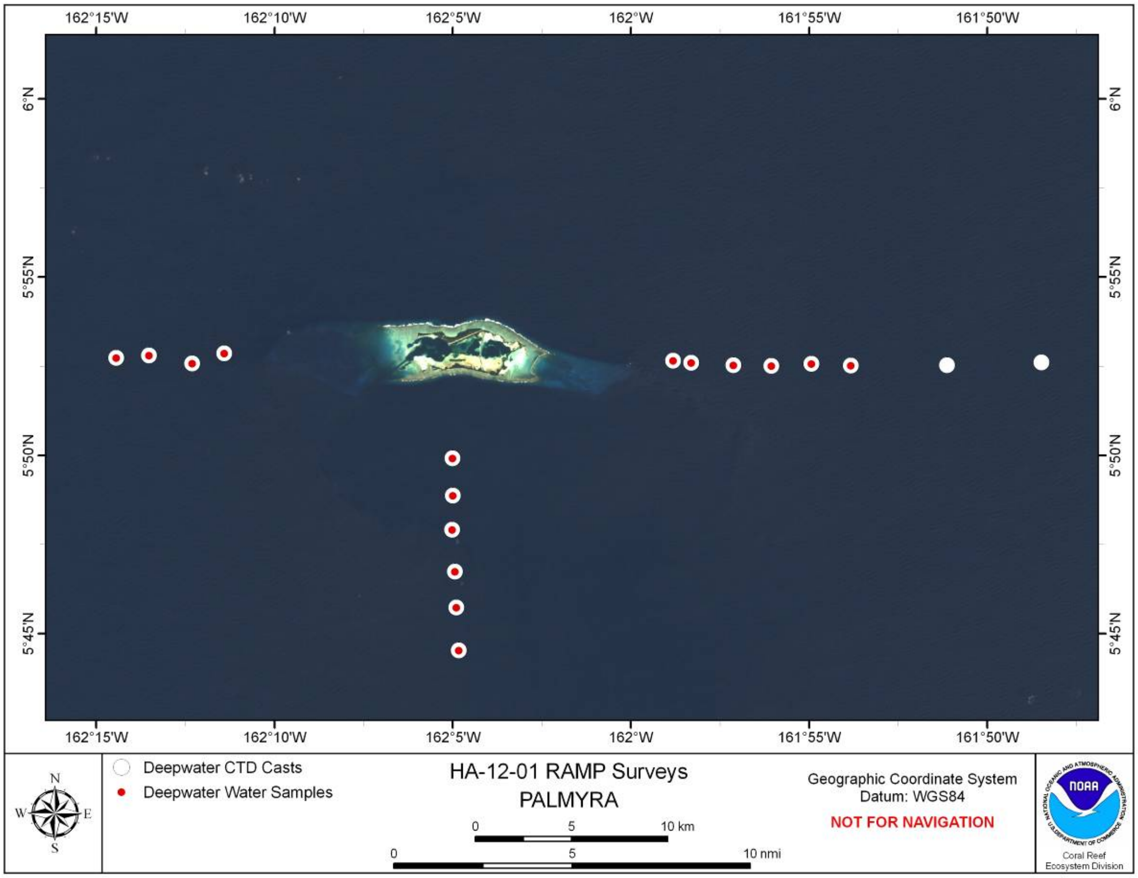

Figure D.1.2.--Locations of deepwater CTD casts and water sampling performed at Palmyra Atoll during cruise HA-12-01, Leg IV. Landsat satellite imagery data used in this map figure are available from the U.S. Geological Survey.

D.2. Benthic Environment

Belt-transect, line-point-intercept (LPI), and roving-diver surveys were conducted and photographs were taken along transect lines at 15 REA sites around Palmyra Atoll to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. D.2.1 and Table D.2.1).

Various samples were collected at 14 REA sites (Table D.2.2): 11 algal voucher specimens at eight REA sites for taxonomic identification, 170 individuals of the algal genus *Halimeda* at eight REA sites for calcification analysis and 36 at six sites for isotope analysis, and 24 water samples for microbial analyses at eight REA sites with two water samples of 2 L each at each site, four water samples of 20 L each at PAL-19 and PAL-06. Additional microbial work included benthic grabs of coral rubble and unidentified macroalgae at PAL-19 and PAL-06. For more information about collections made at REA sites, see Table E.1.1 in Appendix E: “Biological Collections.”

Nine autonomous reef monitoring structures (ARMS) were recovered: three ARMS each from PAL-17, PAL-01, and PAL-19 (Table D.2.2). Nine ARMS were deployed with three ARMS each at PAL-17, PAL-01, and PAL-19. At each of eight select REA sites, an array of five CAUs was deployed for a total of 40 CAUs installed and 40 were recovered (Table D.2.2). For information about EAR installations, see Section D.2: "Oceanography and Water Quality."

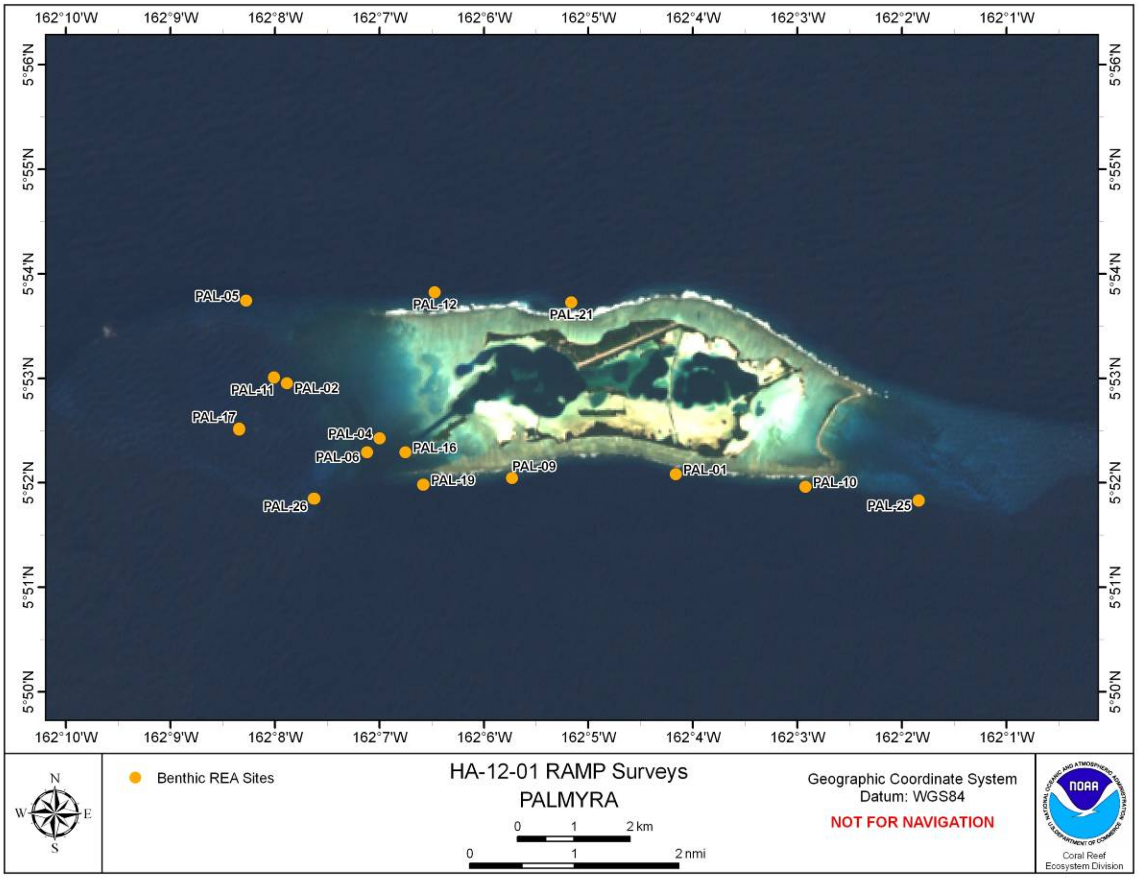

Figure D.2.1.--Locations of REA benthic sites surveyed at Palmyra during cruise HA-12-01, Leg IV. Landsat satellite imagery data used in this map figure are available from the U.S. Geological Survey.

Table D.2.1.--Summary of REA benthic surveys performed at Palmyra during cruise HA-12-01, Leg IV. Indication that an LPI survey was completed also means that photographs were taken along transect lines.

REA Site	Date	Latitude	Longitude	REA Surveys		
				LPI	Roving Diver	Corals
PAL-02	14-May	5.88257	–162.13140	×	×	×
PAL-04	14-May	5.87379	–162.11663	×	×	×
PAL-17	14-May	5.87533	–162.13903	×	×	×
PAL-01	15-May	5.86804	–162.06934	×	×	×
PAL-10	15-May	5.86604	–162.04869	×	×	×
PAL-25	15-May	5.86385	–162.03061	×	×	×
PAL-05	17-May	5.89575	–162.13790	×	×	×
PAL-12	17-May	5.89708	–162.10783	×	×	×
PAL-21	17-May	5.89545	–162.08601	×	×	×
PAL-09	18-May	5.86743	–162.09550	×	×	×
PAL-19	18-May	5.86637	–162.10963	×	×	×
PAL-26	18-May	5.86412	–162.12699	×	×	×
PAL-06	19-May	5.87152	–162.11863	×	×	×
PAL-11	19-May	5.88342	–162.13343	×	×	×
PAL-16	19-May	5.87156	–162.11250	×	×	×

Table D.2.2.--Summary of CAU and ARMS retrievals (Ret.) and deployments (Dep.) performed as well as algal specimens, and microbial water and benthic samples collected at Palmyra during cruise HA-12-01, Leg IV. Counts of algal samples include both algal voucher specimens and *Halimeda* samples for calcification or isotope analysis.

REA Site	Date	Latitude	Longitude	Installations and Collections					
				CAU Ret	CAU Dep	ARMS Ret	ARMS Dep	Algae	Microbial Samples
PAL-02	14-May	5.88257	–162.13140	0	0	0	0	16	2
PAL-04	14-May	5.87379	–162.11663	0	0	0	0	4	2
PAL-17	14-May	5.87533	–162.13903	0	0	3	3	1	0
PAL-19	14-May	5.86637	–162.10960	5	5	0	0	0	0
PAL-26	14-May	5.86413	–162.12710	5	5	0	0	0	0
PAL-01	15-May	5.86804	–162.06934	5	5	3	3	0	0
PAL-10	15-May	5.86604	–162.04869	0	0	0	0	26	2
PAL-25	15-May	5.86381	–162.03063	5	5	0	0	0	0
PAL-25	15-May	5.86385	–162.03061	0	0	0	0	26	2
PAL-05	17-May	5.89575	–162.13790	5	5	0	0	0	2
PAL-11	17-May	5.88352	–162.13345	5	0	0	0	0	0
PAL-12	17-May	5.89708	–162.10783	5	5	0	0	27	2
PAL-21	17-May	5.89545	–162.08601	5	5	0	0	27	0
PAL-09	18-May	5.86743	–162.09550	0	0	0	0	1	0
PAL-17	18-May	5.87518	–162.13899	0	5	0	0	0	0
PAL-19	18-May	5.86637	–162.10963	0	0	3	3	21	16
PAL-26	18-May	5.86412	–162.12699	0	0	0	0	30	0
PAL-06	19-May	5.87152	–162.11863	0	0	0	0	0	16
PAL-11	19-May	5.88342	–162.13343	0	0	0	0	31	0
PAL-16	19-May	5.87156	–162.11250	0	0	0	0	7	0

During cruise HA-12-01, Leg IV, CRED completed 22 towed-diver surveys at Palmyra Atoll, covering a total length of 44.9 km (an area of 44.9 ha) on the ocean floor (Fig. D.2.2). The mean survey length was 2.0 km with a range of 1.5–2.5 km. The mean survey depth was 15.2 m with a range of 11.8–20.0 m. The mean temperature from data recorded during these surveys was 27.3°C with a range of 27.2°C–27.4°C.

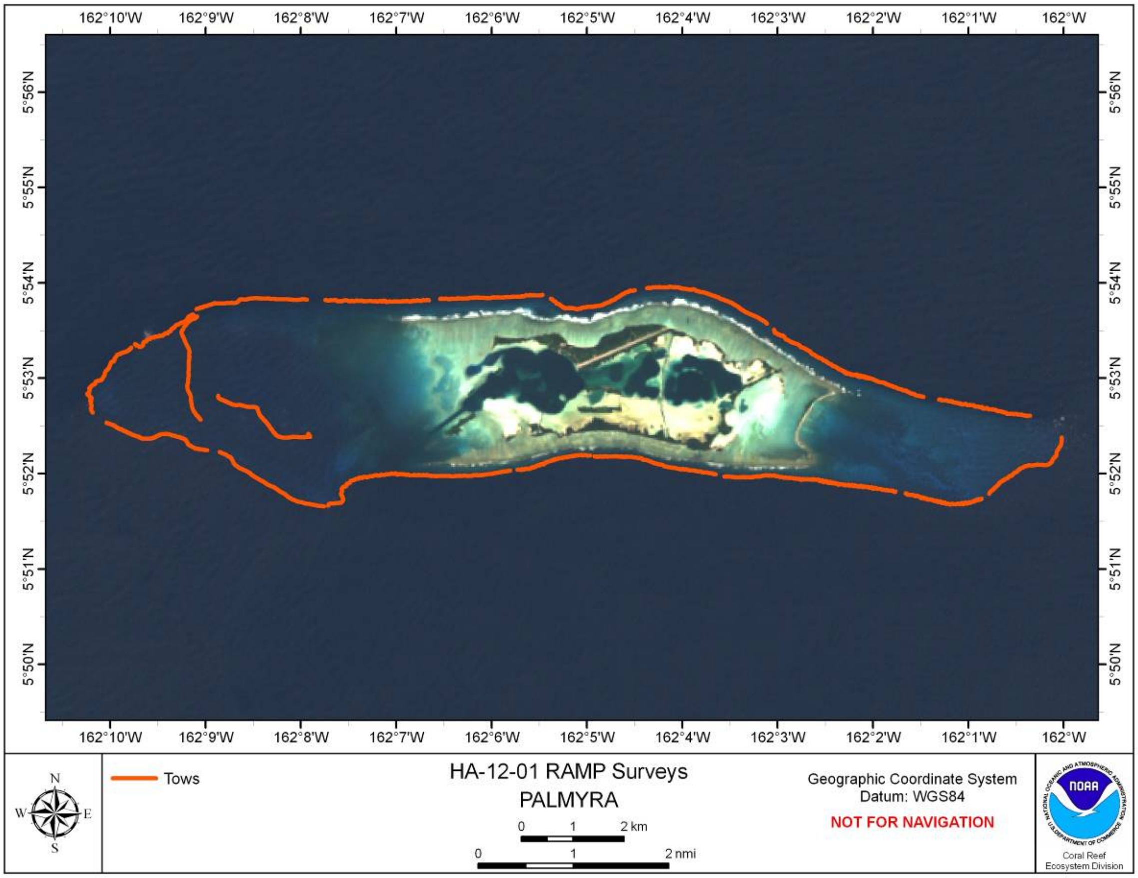

Figure D.2.2.--Track locations of towed-diver surveys conducted at Palmyra during cruise HA-12-01, Leg IV. Landsat satellite imagery data used in this map figure are available from the U.S. Geological Survey.

D.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 42 REA sites at Palmyra Atoll over three different habitat strata: deep forereef, moderate forereef, and shallow forereef (Table D.3.1 and Fig. D.3.1). No fishes were collected during these surveys.

In addition, CRED completed 22 towed-diver surveys at Palmyra Atoll, as described previously in Section D.2 of this appendix.

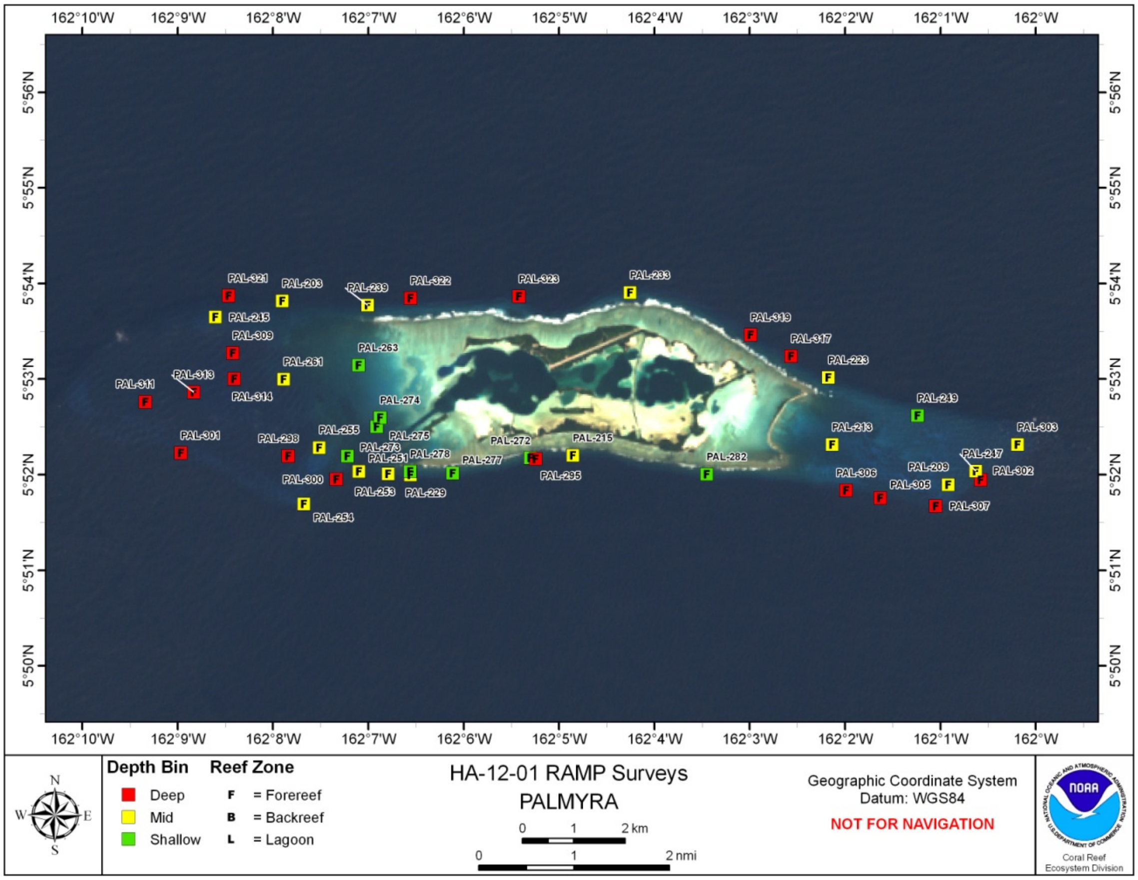

Figure D.3.1.--Locations of REA fish sites surveyed at Palmyra Atoll during cruise HA-12-01, Leg IV. All of these REA sites were selected using a stratified random design. Landsat satellite imagery data used in this map figure are available from the U.S. Geological Survey.

Table D.3.1.--Summary of sites where REA fish surveys were conducted at Palmyra Atoll during cruise HA-12-01, Leg IV.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
PAL-229	14-May	Moderate	Forereef	9.8	5.86660	–162.10932
PAL-251	14-May	Moderate	Forereef	10	5.86722	–162.11833
PAL-255	14-May	Moderate	Forereef	7.8	5.87140	–162.12527
PAL-261	14-May	Moderate	Forereef	12.2	5.88333	–162.13147
PAL-273	14-May	Shallow	Forereef	6.1	5.86990	–162.12034
PAL-277	14-May	Shallow	Forereef	5.3	5.86694	–162.10192
PAL-298	14-May	Deep	Forereef	22.3	5.86993	–162.13066
PAL-300	14-May	Deep	Forereef	20.9	5.86588	–162.12226
PAL-309	14-May	Deep	Forereef	24.2	5.88787	–162.14034
PAL-314	14-May	Deep	Forereef	22.7	5.88339	–162.14011
PAL-209	15-May	Moderate	Forereef	10.7	5.86495	–162.01529
PAL-213	15-May	Moderate	Forereef	7.6	5.87192	–162.03556
PAL-215	15-May	Moderate	Forereef	10.6	5.87001	–162.08093
PAL-254	15-May	Moderate	Forereef	16.9	5.86155	–162.12796
PAL-272	15-May	Shallow	Forereef	5.5	5.86959	–162.08833
PAL-282	15-May	Shallow	Forereef	4.1	5.86672	–162.05752
PAL-295	15-May	Deep	Forereef	24.4	5.86941	–162.08744
PAL-301	15-May	Deep	Forereef	20	5.87048	–162.14945
PAL-305	15-May	Deep	Forereef	21.9	5.86259	–162.02716
PAL-307	15-May	Deep	Forereef	21.9	5.86123	–162.01748
PAL-223	17-May	Moderate	Forereef	13.1	5.88361	–162.03624
PAL-233	17-May	Moderate	Forereef	11.3	5.89843	–162.07094
PAL-245	17-May	Moderate	Forereef	12.4	5.89417	–162.14344
PAL-278	17-May	Shallow	Forereef	6	5.86723	–162.10935
PAL-319	17-May	Deep	Forereef	25.6	5.89106	–162.04981
PAL-321	17-May	Deep	Forereef	26.5	5.89785	–162.14113
PAL-323	17-May	Deep	Forereef	21.9	5.89773	–162.09033
PAL-247	18-May	Moderate	Forereef	10	5.86730	–162.01050
PAL-249	18-May	Shallow	Forereef	6	5.87697	–162.02066
PAL-253	18-May	Moderate	Forereef	7.6	5.86681	–162.11319
PAL-275	18-May	Shallow	Forereef	4.5	5.87502	–162.11522
PAL-302	18-May	Deep	Forereef	23.2	5.86580	–162.00966
PAL-303	18-May	Moderate	Forereef	14	5.87193	–162.00320
PAL-306	18-May	Deep	Forereef	22.3	5.86396	–162.03315
PAL-317	18-May	Deep	Forereef	25.9	5.88733	–162.04281
PAL-203	19-May	Moderate	Forereef	14.6	5.89695	–162.13170
PAL-239	19-May	Moderate	Forereef	9.1	5.89622	–162.11681
PAL-263	19-May	Shallow	Forereef	5	5.88572	–162.11838
PAL-274	19-May	Shallow	Forereef	3.5	5.87662	–162.11462
PAL-311	19-May	Deep	Forereef	20.7	5.87938	–162.15567
PAL-313	19-May	Deep	Forereef	23	5.88106	–162.14718
PAL-322	19-May	Deep	Forereef	24	5.89744	–162.10931

APPENDIX E: BIOLOGICAL COLLECTIONS

Biological and other samples were collected at Jarvis Island, Kingman Reef, and Palmyra Atoll and their surrounding waters for multiple research purposes. These collections are listed here in Table E.1.1.

Table E.1.1.--Samples collected at Jarvis Island (JAR), Kingman Reef (KIN), and Palmyra Atoll (PAL) for taxonomic identification, ocean acidification research, or microbial analyses during cruise HA-12-01, Leg IV.

REA Site	Date	Latitude	Longitude	Specimen Collected	Number of Samples	Depth (m)
Algal Collections: Calcification Analysis						
JAR-02	3-May	–0.38176	–160.00870	*Halimeda* sp.	10	13.7
JAR-04	3-May	–0.38233	–160.00295	*Halimeda* sp.	10	13.7
JAR-07	3-May	–0.37609	–160.01392	*Halimeda* sp.	10	12.8
JAR-01	4-May	–0.36786	–159.97916	*Halimeda* sp.	10	10.7
JAR-03	5-May	–0.36200	–160.00087	*Halimeda* sp.	10	13.7
KIN-03	9-May	6.39038	–162.36059	*Halimeda* sp.	20	13.7
KIN-13	9-May	6.38224	–162.38401	*Halimeda* sp.	20	13.7
KIN-07	11-May	6.40226	–162.38525	*Halimeda* sp.	30	13.7
KIN-12	11-May	6.38599	–162.37779	*Halimeda* sp.	10	13.7
KIN-04	12-May	6.43878	–162.38825	*Halimeda* sp.	20	13.7
KIN-05	12-May	6.39323	–162.34747	*Halimeda* sp.	20	13.7
PAL-02	14-May	5.88257	–162.13140	*Halimeda* sp.	10	13.7
PAL-10	15-May	5.86604	–162.04869	*Halimeda* sp.	20	12.2
PAL-25	15-May	5.86385	–162.03061	*Halimeda* sp.	20	13.7
PAL-12	17-May	5.89708	–162.10783	*Halimeda* sp.	20	13.7
PAL-21	17-May	5.89545	–162.08601	*Halimeda* sp.	20	13.7
PAL-19	18-May	5.86637	–162.10963	*Halimeda* sp.	20	13.7
PAL-26	18-May	5.86412	–162.12699	*Halimeda* sp.	30	13.7
PAL-11	19-May	5.88342	–162.13343	*Halimeda* sp.	30	13.7
Algal Collections: Isotope Analysis						
JAR-02	3-May	–0.38176	–160.00870	*Halimeda* sp.	6	13.7
JAR-04	3-May	–0.38233	–160.00295	*Halimeda* sp.	6	13.7
JAR-07	3-May	–0.37609	–160.01392	*Halimeda* sp.	6	12.8
JAR-01	4-May	–0.36786	–159.97916	*Halimeda* sp.	6	10.7
JAR-03	5-May	–0.36200	–160.00087	*Halimeda* sp.	6	13.7
KIN-03	9-May	6.39038	–162.36059	*Halimeda* sp.	12	13.7
KIN-13	9-May	6.38224	–162.38401	*Halimeda* sp.	12	13.7
PAL-02	14-May	5.88257	–162.13140	*Halimeda* sp.	6	13.7
PAL-10	15-May	5.86604	–162.04869	*Halimeda* sp.	6	12.2
PAL-25	15-May	5.86385	–162.03061	*Halimeda* sp.	6	13.7
PAL-12	17-May	5.89708	–162.10783	*Halimeda* sp.	6	13.7
PAL-21	17-May	5.89545	–162.08601	*Halimeda* sp.	6	13.7
PAL-16	19-May	5.87156	–162.11250	*Halimeda* sp.	6	6.1
Algal Collections: Voucher Specimens						
JAR-07	3-May	–0.37609	–160.01392	Red algae	1	12.8
JAR-07	3-May	–0.37609	–160.01392	Red algae	2	12.8
KIN-08	10-May	6.42929	–162.38257	Red algae	1	13.7

REA Site	Date	Latitude	Longitude	Specimen Collected	Number of Samples	Depth (m)
KIN-10	10-May	6.42044	–162.37955	Red algae	1	13.7
KIN-11	11-May	6.38185	–162.34645	Red algae	1	13.7
KIN-15	12-May	6.40746	–162.36832	Red algae	1	13.7
KIN-16	13-May	6.39241	–162.34214	Red algae	1	13.7
KIN-25	13-May	6.40360	–162.35164	Red algae	1	13.7
PAL-04	14-May	5.87379	–162.11663	Red algae	4	13.7
PAL-17	14-May	5.87533	–162.13903	Red algae	1	13.7
PAL-12	17-May	5.89708	–162.10783	Red algae	1	13.7
PAL-21	17-May	5.89545	–162.08601	Red algae	1	13.7
PAL-09	18-May	5.86743	–162.09550	Red algae	1	13.7
PAL-19	18-May	5.86637	–162.10963	Red algae	1	13.7
PAL-11	19-May	5.88342	–162.13343	Red algae	1	13.7
PAL-16	19-May	5.87156	–162.11250	Red algae	1	6.1
Coral Collections: Cores						
JAR-01	5-May	–0.37393	–159.98340	*Porites* sp.	1	4.6
JAR-01	6-May	–0.36908	–159.98306	*Porites* sp.	1	3.4
JAR-11	6-May	–0.36950	–160.00842	*Porites* sp.	1	11
KIN-16	12-May	6.39225	–162.34227	*Porites* sp.	1	6.4
KIN-16	12-May	6.39243	–162.34229	*Porites* sp.	1	4.9
KIN-03	13-May	6.39025	–162.36037	*Porites* sp.	1	6.7
KIN-07	13-May	6.40235	–162.38513	*Porites* sp.	1	9.1
Microbial Collections: Water Samples, Coral Rubble, and Macroalgae						
JAR-02	3-May	–0.38176	–160.00870	2 L	2	12.8
JAR-07	3-May	–0.37609	–160.01392	2 L	2	14
JAR-01	4-May	–0.36786	–159.97916	2 L	2	9.8
JAR-10	4-May	–0.38137	–159.97275	2 L	2	12.8
JAR-03	5-May	–0.36200	–160.00087	2 L	2	9.8
JAR-12	5-May	–0.38224	–159.98404	2 L	2	12.8
JAR-12	5-May	–0.38224	–159.98404	20 L	3	12.8
JAR-11	6-May	–0.36900	–160.00812	2 L	2	13.7
JAR-11	6-May	–0.36900	–160.00812	20 L	4	13.7
JAR-11	6-May	–0.36900	–160.00812	Unidentified macroalgae	5	14.6
JAR-11	6-May	–0.36900	–160.00812	Coral rubble	5	14.6
KIN-03	9-May	6.39038	–162.36059	2 L	2	12.8
KIN-17	9-May	6.38220	–162.39878	2 L	2	14.3
KIN-08	10-May	6.42929	–162.38257	2 L	2	12.8
KIN-10	10-May	6.42044	–162.37955	2 L	2	12.8
KIN-07	11-May	6.40226	–162.38525	2 L	2	9.8
KIN-12	11-May	6.38599	–162.37779	2 L	2	12.8
KIN-05	12-May	6.39323	–162.34747	2 L	2	12.8
KIN-05	12-May	6.39323	–162.34747	20 L	4	12.8
KIN-05	12-May	6.39323	–162.34747	Unidentified macroalgae	5	13.7
KIN-05	12-May	6.39323	–162.34747	Coral rubble	5	13.7
KIN-16	13-May	6.39241	–162.34214	2 L	2	8.2
KIN-25	13-May	6.40360	–162.35164	2 L	2	12.8
KIN-25	13-May	6.40360	–162.35164	20 L	4	12.8

REA Site	Date	Latitude	Longitude	Specimen Collected	Number of Samples	Depth (m)
KIN-25	13-May	6.40360	–162.35164	Unidentified macroalgae	2	13.7
KIN-25	13-May	6.40360	–162.35164	Coral rubble	1	13.7
PAL-02	14-May	5.88257	–162.13140	2 L	2	12.8
PAL-04	14-May	5.87379	–162.11663	2 L	2	3.7
PAL-10	15-May	5.86604	–162.04869	2 L	2	14.3
PAL-25	15-May	5.86385	–162.03061	2 L	2	12.8
PAL-05	17-May	5.89575	–162.13790	2 L	2	11.3
PAL-12	17-May	5.89708	–162.10783	2 L	2	12.8
PAL-19	18-May	5.86637	–162.10963	2 L	2	12.8
PAL-19	18-May	5.86637	–162.10963	20 L	4	12.8
PAL-19	18-May	5.86637	–162.10963	Unidentified macroalgae	5	13.7
PAL-19	18-May	5.86637	–162.10963	Coral rubble	5	13.7
PAL-06	19-May	5.87152	–162.11863	2 L	2	4.6
PAL-06	19-May	5.87152	–162.11863	20 L	4	4.6
PAL-06	19-May	5.87152	–162.11863	Unidentified macroalgae	5	4.6
PAL-06	19-May	5.87152	–162.11863	Coral rubble	5	4.6