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CRUISE REPORT[1]

VESSEL: NOAA Ship *Hi`ialakai*, Cruise HA-10-01, Leg 3

CRUISE PERIOD: 27 March–24 April 2010

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 Pacific Islands Fisheries Science Center, the U.S. Fish and Wildlife Service (USFWS), and their partner agencies 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 Pacific Reefs National Wildlife Refuge Complex special-use permit number 12521-10001 (effective date: January 15, 2010; expiration date: May 30, 2010).

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.

March 27	Start of cruise HA-10-01, Leg 3. Embarked all scientific crew. Departed Pago Pago Harbor, American Samoa, and began transit to Jarvis Island.
March 28	Transit day.
March 29	Transit day.
March 30	Transit day.
April 1	Arrived at Jarvis Island. USFWS observers disembarked to this island. Conducted field operations, and deployed and retrieved the following types of instruments: subsurface temperature recorder (STR), acoustic Doppler profiler (ADP), ecological acoustic recorder (EAR), calcification acidification unit (CAU), and autonomous reef monitoring structure (ARMS). Water samples were collected

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for chlorophyll-*a* (Chl-*a*), nutrients, dissolved inorganic carbon (DIC), salinity, and microbial community analysis. Coral voucher samples were collected in support of the NOAA status review of several coral species for possible listing under the *Endangered Species Act* (ESA). Nearhsore conductivity, temperature, and depth (CTD) profiles were conducted, and shipboard operations included acoustic Doppler current profiler (ADCP) transects and deepwater CTD casts.

April 2 Continued field operations at Jarvis Island. Deployed and retrieved the following types of instruments: STR, remote access sampler (RAS), pH sensor, and ARMS. Water samples were collected for Chl-*a*, nutrients, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Shipboard operations included ADCP transects and deepwater CTD casts.

April 3 Continued field operations at Jarvis Island. Deployed and retrieved the following types of instruments: sea-surface temperature (SST) buoy, temperature and salinity sensor (SBE 37 MicroCAT, Sea-Bird Electronics Inc., Bellevue, Wash.), STR, pH sensor, CAU, and ARMS. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Nearhsore CTD profiles were conducted, and shipboard operations included ADCP transects and deepwater CTD casts.

April 4 Continued field operations at Jarvis Island. Deployed and retrieved the following types of instruments: STR and CAU. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral cores were obtained, and coral voucher samples were collected for the ESA status review, and algal voucher specimens and non-coral invertebrate specimens were collected. Nearhsore CTD profiles were conducted. No towed-diver surveys were performed on this day, since these surveys for this island were completed the previous day.

April 5 Continued field operations at Jarvis Island. USFWS observers embarked from this island. Deployed and retrieved the following types of instruments: RAS and ocean data platform (ODP) anchor. Water samples were collected for microbial community analysis. Coral voucher samples were collected for the ESA status review, and non-coral invertebrate specimens were collected. Plankton tows were conducted. No towed-diver surveys were performed. Departed Jarvis Island en route to Palmyra Atoll.

April 6 Transit day.

April 7 — Arrived at Palmyra Atoll and conducted field operations. USFWS observers disembarked to this island and embarked Amanda Meyer, a USFWS employee serving on the REA fish team. Deployed and retrieved the following types of instruments: STR, ADP, temperature and salinity sensor (SBE 37), EAR, pH sensor, and CAU. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Nearhsore CTD profiles were conducted, and shipboard operations included ADCP transects and deepwater CTD casts.

April 8 — Continued field operations at Palmyra Atoll. Deployed and retrieved the following types of instruments: STR, ADP, temperature and salinity sensor (SBE 37), pH sensor, CAU, and ARMS. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Nearhsore CTD profiles were conducted, and shipboard operations included ADCP transects and deepwater CTD casts.

April 9 — Continued field operations at Palmyra Atoll. Deployed and retrieved the following types of instruments: STR, RAS, ADP, temperature and salinity sensor (SBE 37), SST, and CAU. Water samples were collected for microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected.

April 10 — Continued field operations at Palmyra Atoll. Deployed and retrieved the following types of instruments: Coral Reef Early Warning System (CREWS) buoy, wave-and-tide recorder (WTR), STR, CAU, and ARMS. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Nearhsore CTD profiles were conducted, and shipboard operations included ADCP transects and deepwater CTD casts.

April 11 — Continued field operations at Palmyra Atoll. Deployed and retrieved the following types of instruments: RAS, temperature and salinity sensor (SBE 37), STR, CAU, and ARMS. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Nearhsore CTD profiles were conducted.

April 12 — Continued field operations at Palmyra Atoll. Deployed and retrieved the following types of instruments: STR, CAU, and ARMS. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Nearhsore CTD profiles were conducted, and shipboard operations included ADCP transects and deepwater CTD casts.

April 13 Continued field operations at Palmyra Atoll. Deployed and retrieved the following types of instruments: temperature and salinity sensor (SBE 37) and STR. Coral cores were obtained, and coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Plankton tows were conducted. No towed-diver surveys were conducted, since these surveys for this island were completed the previous day. Departed Palmyra Atoll en route to Kingman Reef. (Note: USFWS personnel who disembarked to Palmyra to conduct terrestrial surveys did not return to the ship; they had arranged other transport back to Honolulu.)

April 14 Arrived at Kingman Reef and conducted field operations. Deployed and retrieved the following types of instruments: SST, single-point current sensor (RCM 9, Aanderaa Data Instruments, Bergen, Norway), STR, CAU, and ARMS. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Nearhsore CTD profiles were conducted.

April 15 Continued field operations at Kingman Reef. Deployed and retrieved the following types of instruments: RAS, EAR, STR, pH sensor, CAU, and ARMS. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Nearhsore CTD profiles were conducted, and shipboard operations included ADCP transects and deepwater CTD casts.

April 16 Continued field operations at Kingman Reef. Deployed and retrieved the following types of instruments: STR, pH sensor, and CAU. Water samples were collected for Chl-*a*, nutrients, DIC, salinity, and microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. Nearhsore CTD profiles were conducted.

April 17 Continued field operations at Kingman Reef. Deployed and retrieved ARMS. Water samples were collected for microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens and non-coral invertebrate specimens were collected.

April 18 Continued field operations at Kingman Reef. Deployed and retrieved RAS. Water samples were collected for microbial community analysis. Coral voucher samples were collected for the ESA status review, and algal voucher specimens were collected. A REA benthic survey was performed at the site of a shipwreck located on the northeast side of this atoll. Plankton tows were conducted. No towed-diver surveys were conducted, since these surveys for this island were completed the previous day.

April 19 Continued field operations at Kingman Reef. Water samples were collected for microbial community analysis. Coral cores were obtained, and coral voucher samples were collected for the ESA status review. No towed-diver surveys were performed. Departed Kingman Reef en route to Honolulu.

April 20 Transit day.

April 21 Transit day.

April 22 Transit day.

April 23 Transit day.

April 24 Arrived at Honolulu. Disembarked all scientific crew. End of cruise HA-10-01.

MISSIONS:

A. Conducted ecosystem monitoring of the species composition, abundance, percentage of cover, size distribution, and general health of the fishes, corals, other invertebrates, and algae of the shallow-water (≤ 30 m) coral reef ecosystems of Jarvis Island, Palmyra Atoll, and Kingman Reef.

B. Deployed and retrieved an array of instruments—including ADPs, a CREWS buoy, an ODP, pH sensor, RAS, single-point current sensors (RCM 9), SST buoys, STRs, temperature and salinity sensors (SBE 37), WTRs, ARMS, CAUs, and EARs—to allow for remote, long-term monitoring of oceanographic, environmental, and ecological conditions affecting the coral reef ecosystems of Jarvis Island, Palmyra Atoll, and Kingman Reef.

C. Conducted shallow-water CTD casts and collected water samples for Chl-*a*, nutrients, dissolved inorganic carbon (DIC), salinity, and microbial community analysis to depths of ~ 30 m to examine physical and biological linkages supporting and maintaining these island and atoll ecosystems.

D. Conducted shipboard oceanographic and meteorological observations, using CTD casts deployed to a depth of 500 m, collecting water samples to a depth of 150 m, collecting ADCP data around reef ecosystems, measuring SST and salinity, and collecting fundamental meteorological data, such as air temperature, wind speed and direction, barometric pressure, and relative humidity to examine physical and biological linkages supporting and maintaining these island and atoll ecosystems.

E. Collected a small number of cores from shallow-water corals 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).

RESULTS:

This section provides tallies of research activities (Table 1), a list of data collected during cruise HI-10-01, Leg 3, and a summary of important observations. See also Appendices B–E for additional information on activities and results for each island or atoll.

Table 1. Statistics for the Pacific RAMP 2010 cruise to Jarvis Island, Palmyra Atoll and Kingman Reef (cruise HA-10-01, Leg 3). The CAUs deployed during this cruise and the other legs of HA-10-01 were the first such units deployed by CRED. Other instrument types included ARMS, ADP, EAR, ODP, RAS, SST buoy, STRs, and WTR. REA and towed-diver surveys were conducted on most days. Oceanographic surveys included CTD casts and ADCP transects. Water sampling collected data on nutrient, chlorophyll-*a* (Chl-*a*), and dissolved inorganic carbon (DIC) concentrations. The totals for scuba dives include all dives carried out for all activities at each island. Coral voucher samples were collected in support of the NOAA status review of several coral species for possible listing under the ESA. For information about biological sample collections by REA site, see Table E.1 in Appendix E: "Biological Collections."

Research Activity	Total	Jarvis Island	Palmyra Atoll	Kingman Reef
Scuba Dives	849	252	308	289
BIOLOGICAL SURVEYS				
Towed-diver Surveys: Benthic and Fish	63	14	28	21
Combined Length (km) of Towed-diver Surveys	122.8	25.3	54.6	42.9
REA: Benthic	45	12	17	16
REA: Fish	103	30	40	33
BIOLOGICAL SAMPLE COLLECTIONS				
Algal Voucher Specimens	360	40	150	170
Coral Voucher Samples for ESA Status Review	290	76	106	108
Coral Core Samples	12	6	3	3
Non-coral Invertebrate Specimens	25	12	0	13
Plankton Tows	6	2	2	2
BIOLOGICAL MOORED INSTALLATIONS				
ARMS Retrieved	30	9	12	9
ARMS Deployed	27	9	9	9
CAUs Deployed	154	40	64	50
EARs Retrieved	3	1	1	1
EARs Deployed	3	1	1	1

Research Activity	Total	Jarvis Island	Palmyra Atoll	Kingman Reef
OCEANOGRAPHIC MOORED INSTRUMENTS				
CREWS Buoys Retrieved	1	0	1	0
ODP Retrieved	1	1	0	0
SST Buoys Retrieved	2	0	1	0
SST Buoys Deployed	3	1	1	1
STRs Retrieved	38	9	20	9
STRs Deployed	53	15	27	11
WTRs Deployed	2	0	2	0
Temperature and Salinity Sensors (SBE 37) Deployed	2	2	0	0
pH Sensors Recovered	2	0	2	0
pH Sensors Deployed	7	2	3	2
ADPs Deployed	6	2	4	0
Single-point Current Sensor (RCM 9) Recovered	1	0	0	1
Single-point Current Sensor (RCM 9) Deployed	1	0	0	1
HYDROGRAPHIC SURVEYS				
Deepwater CTD Casts (from *Hi`ialakai*)	79	26	39	4
Shallow-water CTD Casts (from small boats)	40	19	13	8
Total Length (km) of ADCP Transects	300	100	100	100
WATER-QUALITY SAMPLING				
Shallow-water Nutrient Water Samples Collected	52	12	22	16
Shallow-water Chl-*a* Water Samples Collected	52	12	22	16
Shallow-water salinity Water Samples Collected	52	12	22	16
Shallow-water DIC Water Samples Collected	52	12	22	16
Deepwater nutrient Water Samples Collected	155	65	100	10
Deepwater Chl-*a* Water Samples Collected	155	65	100	10
Microbial Water Samples Collected	39	7	8	24
RAS Deployed and Retrieved	3	1	1	1

The coral reef ecosystems of the Pacific Remote Islands Marine National Monument are surveyed biennially through the CRED's Pacific RAMP. HA-10-01, Leg 3, marked this program's seventh survey around Jarvis Island (0°22′ S, 160°03′ W), Palmyra Atoll (5°52′ N, 162°6′ W), and Kingman Reef (6°24′N, 162°24′ W). Here, we present highlights from our observations during this latest expedition. For more information pertaining to the data collected, methodology employed, and preliminary findings at the island and atolls visited, see Appendices A–E.

In general, preliminary survey observations from this research cruise appear to be consistent with previously conducted Pacific RAMP surveys at Jarvis, Palmyra and Kingman. This outcome was a departure from what researchers aboard had anticipated, given the relatively strong El Niño-Southern Oscillation conditions in 2009, which among other environmental impacts, causes anomalous warming of ocean temperatures in the central equatorial Pacific. Periods of prolonged warming can result in deleterious impacts to coral reef ecosystem, including widespread coral mortality; however, large-scale impacts to these reef ecosystems were not observed during this research cruise.

At the onset of 2009, a general warming pattern was observed in ocean temperatures recorded by STRs at Jarvis Island, Palmyra Atoll, and Kingman Reef. Beginning in the winter, water temperatures slowly increased throughout the year, rising ~ 2.5°C–6°C at the island and atolls visited. Temperatures eventually peaked in January 2010, when ocean temperatures are typically cool because of seasonal forcing. This warming trend can be attributed to the relatively strong El Niño in 2009. Despite the anomalously warm temperatures in 2009 and 2010, widespread coral bleaching was not observed at any of the 3 locations visited, although low levels of bleaching were observed during towed-diver surveys at Palmyra Atoll.

Researchers continued to record the invasive expansion of the corallimorph *Rhodactis howesii* at Palmrya Atoll stemming from a shipwrecked longline vessel in 1991. Colonies of *R. howesii* have formed dense, carpet-like stretches, with large quantities observed at REA sites near the main boat channel as well as across the channel and into this atoll.

At Kingman Reef, REA benthic surveys were performed in the vicinity of the shipwreck located at the northeast side of this atoll, which was most recently surveyed in December 2009 by James Maragos of the USFWS. In comparison to that survey, observations from this latest Pacific RAMP cruise suggest that this wreck has been farther pushed on top of this atoll's crest and is deteriorating as it moves westward into Kingman Reef's lagoon. As a result of this westward movement, a large metal well from the vessel is now in this lagoon, in addition to timbers, fiberglass sections, and miscellaneous pipework scattered along the forereef, reef crest, and backreef of Kingman Reef. At the time of this Pacific RAMP survey, cyanobacteria and *Rhodactis* sp. were not present in significant numbers along this reef crest; however, a cyanobacterial bloom was observed in this lagoon extending from 5 m down to visible depths (~ 25 m). It is unknown if this bloom was a direct result of this shipwreck.

Fish surveys recorded a high abundance of top predators, dominating the fish assemblages at each of the 3 locations visited. Large quantities of grey reef sharks (*Carcharhinus amblyrhynchos*), manta rays (*Manta birostris*), black jacks (*Caranx lugubris*), and great barracuda (*Sphyraena barracuda*) were observed at each location, with grey reef sharks particularly abundant to the southeast of Jarvis Island and Kingman Reef. Humpback red snapper (*Lutjanus gibbus*) were highly abundant along the western portion of Palmyra. Although more analysis is needed, preliminary findings indicate that abundance of gray reef sharks was greater during Pacific RAMP surveys in 2010 than in 2008.

The following data and samples were collected during this expedition:

REA Benthic Surveys:

- Digital still photos of overall site character and typical benthos
- Digital images of benthic organisms from photoquadrat surveys
- Quantitative assessments of benthic composition from line-point-intercept surveys
- Algal voucher specimens necessary for algal species identification
- Field notes of algal species diversity and relative abundance
- Number of coral colonies by genus, within belt transects of known area, and overall coral colony density
- Size-class metrics of corals within belt transects of known area
- Digital photographs of diseased corals and algae
- Field notes on signs of coral bleaching or disease
- Specimens of non-coral invertebrates collected at REA sites
- Coral voucher specimens for ESA status review
- Assessment of calcification rates from collected cores of massive reef building corals

REA Fish Surveys:

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

Towed-diver Surveys:

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

Shipboard Oceanography:

- Deepwater CTD profiles to a depth of 500 m
- Chl-*a* and nutrient concentrations from water samples collected at variable depths
- Transects of profiles of ocean current velocity and direction collected using a shipboard ADCP unit
- Solar radiation, air temperature, barometric pressure, wind speed and direction

Nearshore Oceanography from Small Boats:

- Shallow-water CTD profiles to depths of ~ 30 m
- Chl-*a* and nutrient concentrations from water samples collected in concert with shallow-water CTD casts
- DIC and salinity concentrations from water samples collected in concert with shallow-water CTD casts

Moored Biological Installations:

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

Moored Oceanographic Instruments:

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

SCIENTIFIC PERSONNEL:

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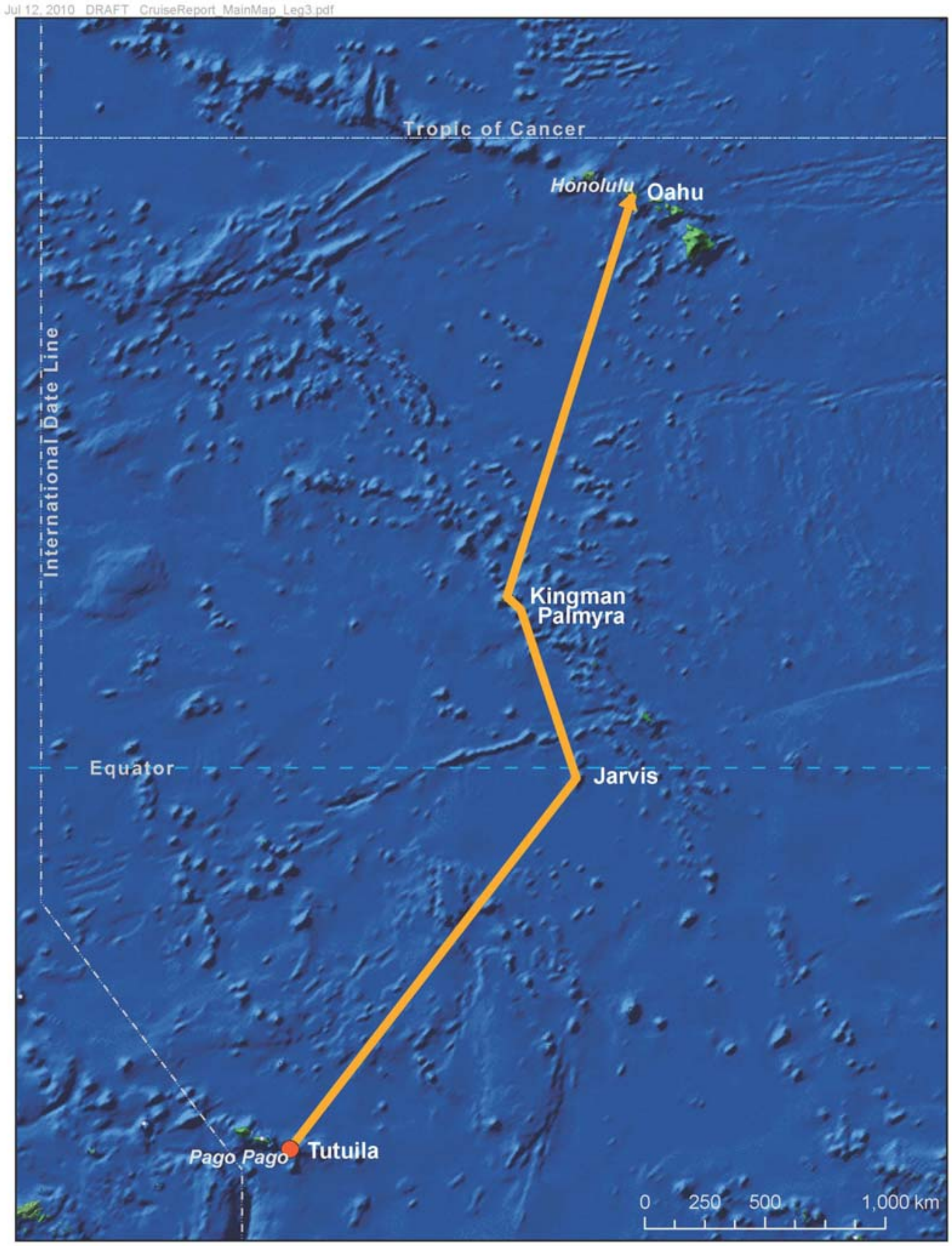

Figure 1.--Track of the NOAA Ship *Hi`ialakai* for the cruise HA-10-01, Leg 3, March 27–April 24, 2010, with Jarvis Island, Palmyra Atoll, and Kingman Reef surveyed en route from American Samoa to Honolulu. Satellite image © 2002 Environmental Systems Research Institute Inc. (ESRI) and © 1998 WorldSat International Inc. All rights reserved.

APPENDIX A: METHODS

This appendix describes the methods and procedures used by the Coral Reef Ecosystem Division (CRED) of the NOAA Pacific Islands Fisheries Science Center during its Pacific Reef Assessment and Monitoring Program (Pacific RAMP) cruise HA-10-01, leg 3, on the NOAA Ship *Hi`ialakai* during the period of March 27–April 24, 2010. The first PIFSC reef assessments at Jarvis Island, Palmyra Atoll, and Kingman Reef were conducted in 2000.

A.1. Oceanography and Water Quality

(Jamison Gove, Mark Hatay, Ronald Hoeke, Frank Mancini, Daniel Merritt, and Charles Young)

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

A.1.1. Moored Instruments for Time-series Observations

CRED accomplishes long-term oceanographic and bioacoustic assessment and monitoring through the deployment and retrieval of a variety of instrument platforms that internally record in situ observations and telemeter subsets of those data in near real time. The following types of instruments were retrieved or deployed during this cruise.

Coral Reef Early Warning System (CREWS) Buoy: provides near real-time, high-resolution sea-surface temperature (SST) and conductivity (SBE 37 MicroCAT temperature and salinity sensor, Sea-Bird Electronics Inc., Bellevue, Wash., accuracy of 0.002°C in temperature and 0.0003 S m^{-1} in conductivity), air temperature (WS425 sensor, R.M. Young Company, Traverse City, Mich.; accuracy of 0.3°C), barometric pressure (Heise DXD transducer, Ashcroft Inc., Stratford, Conn., accuracy of 0.02% FS), wind speed and wind direction (Vaisala sensor, Helsinki, Finland, accuracy of 0.135 m s^{-1} in speed and 2° in direction). Photosynthetically active radiation (PAR) and 3 bands of ultraviolet radiation (305 nm, 330 nm, 380 nm) are measured nominally at 2 m above the surface of the water and nominally 1 m below the surface. Data are sampled at 30-min intervals and internally recorded. Subsets of these data are transmitted daily via satellite telemetry.

Sea-surface Temperature (SST) Buoys: provide high-resolution SST (SBE 39 sensor, 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 high-resolution temperature data (SBE 39 sensor, accuracy of 0.002°C). Data are internally recorded at 30-min intervals. This type of subsurface instrument is deployed at depths of 0.5–40 m.

Ocean Data Platform (ODP): provides directional current profiles and wave spectra using a 3-beam-configured 1-MHz acoustic Doppler profiler (SonTek/YSI, San Diego, Calif., accuracy of 0.005 m s^{-1} in current and 0.1% in pressure) and high-resolution temperature and conductivity (SBE 37 MicroCAT temperature and salinity sensor). Sample intervals for current and wave data vary depending on duration of deployment. Temperature and salinity are sampled at 30-min intervals. This type of subsurface instrument is deployed at depths of 15–40 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 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.

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.

pH Sensor: provides pH (mV) and temperature (°C) data within the reef boundary layer (≤ 0.5 m of benthos). These Durafet sensors (Honeywell Process Solutions, Phoenix, Ariz.) were calibrated with discrete water samples at the beginning and termination of deployment. Values of pH estimated from total dissolved inorganic carbon and total alkalinity were compared to those values measured by the sensor to determine the offset. Sample intervals were set for an average of 60 measurements taken over 1 min every 30 min. This type of subtidal moored sensor typically is deployed at depths of 10–15 m.

Remote Access Sampler (RAS): the McLane Remote Access Sampler (East Falmouth, Mass.) is an autonomous water sampling instrument that can collect up to 48 water samples, each 500 mL, over a programmer-dictated time series. This instrument has the capability for high-frequency, hourly sampling. CRED uses this RAS in depths up to 30 m, but this sampler has a maximum sampling depth of 5500 m. The RAS deployed at Jarvis Island, Palmyra Atoll, and Kingman Reef during this cruise, along with the one installed previously at Rose Atoll, were the first RAS deployed by CRED.

Temperature and Salinity Sensor: provides high-resolution temperature and conductivity data (SBE 37 MicroCAT). Conductivity data is used to calculate salinity.

Single-point Current Sensor: provides single-point ocean current speed and direction. Sample interval is typically 30 min, and this sensor (RCM 9, Aanderaa Data Instruments, Bergen, Norway) is deployed at depths of 5–15 m.

A.1.2. Hydrographic Surveys

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

Shallow-water (Nearshore) Conductivity, Temperature, and Depth (CTD) Casts: a CTD profiler deployed from a small boat provided data on temperature; conductivity, which is related to salinity; and pressure, which is related to depth (SBE 19*plus* Seacat Profiler, accuracy of 0.005 S m^{-1} in conductivity, 0.0002°C in temperature, and 0.1% in pressure). A transmissometer (C-Star, WET Labs, Philomath, Ore.) provided profiles of beam transmittance, which is related to turbidity. A dissolved oxygen sensor (SBE 43, accuracy of 2% of saturation) was also attached and measurements were made in concert with CTD measurements. A CTD cast was performed at each of the Rapid Ecological Assessment (REA) sites where calcification acidification units (CAUs) were deployed. In addition, a series of casts were completed around Jarvis Island at depths of ~ 30 m at regular horizontal intervals around each island. Data were collected by hand lowering this profiler off a small boat at descent rates of ~ 0.5–0.75 m s^{-1} to the depths of REA sites or to depths of ~ 30 m at other nearshore locations.

Deepwater (Shipboard) CTD Casts: a ship-based CTD profiler provided high-resolution conductivity, temperature, and pressure data (Sea-Bird Electronics, SBE 911*plus* CTD, accuracy of 0.003 S m^{-1} in conductivity, 0.001°C in temperature, and 0.015% in pressure). Measurements of dissolved oxygen (SBE43) and fluorescence and turbidity (*ECO* FLNTU, WET Labs, accuracy of 0.01 µg l^{-1} in fluorescence and 0.01 NTU in turbidity) were performed in concert with CTD measurements. Data were collected at depths up to 500 m.

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

Water Chemistry: water samples for analyses of concentrations of chlorophyll-*a* (Chl-*a),* dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, and the nutrients phosphate, PO_4^{3-}; silicate, $Si(OH)_4$; nitrate, NO_3^-; and nitrite, NO_2^-, were collected at select locales concurrently with shallow-water CTD casts. At each select CTD cast location, 4 water samples were taken at each of 2 depths (at the surface and near the reef), with 1 sample from each set of 4 analyzed for both DIC and TA. In concert with shipboard CTD casts, water samples were collected for analyses of Chl-*a* and nutrient concentrations.

A.2. Benthic Surveys and Biological Monitoring Installations and Sampling

(Jacob Asher, Edmund Coccagna, Kerry Grimshaw, Jason Helyer, James Maragos, Nichole Price, Russell Reardon, and Molly Timmers)

CRED collected integrated information on the species composition (diversity), condition, abundance, and distribution of communities of corals, algae, and non-coral invertebrates and on benthic habitat complexity and substrates using 2 primary methodologies: Rapid Ecological Assessment (REA) surveys and towed-diver surveys. Performed at selected hard-bottom locations, REA benthic surveys include multiple methodologies that use two 25-m transect lines deployed at each REA site. Towed-diver surveys, which follow a depth contour of ~ 15 m and encompass various substrates, cover an area that is much broader than the area surveyed using fine-scale REA techniques. In addition, moored installations, autonomous reef monitoring structure (ARMS) and calcification acidification unit (CAU), serve as mechanisms to quantify marine invertebrates that are not easily identifiable during REA surveys and help to determine accretion rates of coralline algae and scleractinian (hard) corals. Note that the REA sites selected for benthic surveys are different from the sites where REA fish surveys were conducted.

A.2.1. Benthic Composition

Using a line-point-intercept (LPI) method, hard corals, octocorals, macroalgae, crustose coralline red algae, and non-coral invertebrates, were identified to the highest possible taxonomic resolution and recorded, along with substrate types, at 20-cm intervals along two 25-m transect lines set in a single file row (separated by 5 m). These surveys generated data, 125 points per transect line (250 points per site), that can be used to estimate percentage of cover of benthic organisms at each REA site. Additionally, using the photoquadrat method, the benthos was recorded at predetermined points along the same 2 transect lines with a high-resolution digital camera mounted on a 1-m photoquadrat pole. These surveys generated 30 photographs per site that will be later analyzed by CRED staff and partners at Scripps Institution of Oceanography, University of California San Diego, using the computer program Coral Point Count with Excel extensions (CPCe), to determine the benthic composition at higher taxonomic levels for each REA site (photographs from similar surveys at REA sites surveyed by the fish team will also be analyzed at Scripps).

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 or atoll and to quantify the abundance of key conspicuous macroinvertebrates (crown-of-thorns [COTS] seastars, 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 recorder programmed to record at 5-s intervals. At the end of each day, data were downloaded, processed, and presented in ArcGIS and can be displayed in conjunction with IKONOS satellite imagery, NOAA chart data, or other spatial data layers.

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

A.2.2. Benthic Community Structure and Disease

At each REA site, the belt-transect method, with two 25-m transect lines as the focal point for surveys of coral communities, 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 of either side of each transect line were identified to the highest possible taxonomic resolution and measured using 2 planar size metrics: maximum diameter and diameter perpendicular to the maximum diameter.

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

In separate REA surveys using the belt-transect method but only performed at Palmyra Atoll during this cruise, targeted macroinvertebrates that fell within 1 m on either side of two 25-m transect lines were enumerated. Targeted taxa included species from the following groups: anemones, zoanthids, and other cnidarians; sea urchins, sea cucumbers, and other echinoderms; seastars of the family Asteroidea; spondylid oysters, pearl oysters, tridacnid (giant) clams; Triton's Trumpet (*Charonia* sp.), spider conches (*Lambis* sp.), and other gastropods; octopus; and hermit crabs, lobsters, large crabs, and other crustaceans.

Densities of the targeted macroinvertebrates were generated for each site at Palmyra from the tallied transect counts. In addition, the test diameters of sea urchins were measured up to 25 individuals per species and the maximum shell lengths of giant clams were measured up to 25 individuals per site. Average test diameters and shell lengths were then generated from collected data at each REA site. Fortuitous non-invasive collections of targeted organisms to support research investigating gene flow and connectivity in the Pacific took place.

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

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

A.2.3. Moored 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 installations that were retrieved or deployed during this cruise.

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

ARMS previously deployed during the 2008 RAMP cruise were retrieved. First, on the seafloor, the ARMS were covered in a mesh-lined lid to trap the contents, and then they were removed and transported to the ship. There, each unit was systematically disassembled and photo-documented, and all organisms contained in these structures were sorted by size and preserved in ethanol for later genetic and other molecular analysis.

Calcification Acidification Unit (CAU): Deployed at several sites at each island and atoll, CAUs provide a mechanism to quantify accretion rates by crustose coralline red algae and hard corals. Each CAU consists of 2 gray polyvinylchoride (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 the plate assembly to those rods. It has been demonstrated that PVC encourages growth of crustose coralline red algae and coral recruitment, and the net weight gain of calcium carbonate on the surfaces of the CAUs can be an indicator of net calcification. CAUs deployed during this cruise will remain on the benthos for 2 years, enabling the recruitment and colonization of crustose coralline red algae and hard corals, at which time they will be collected and analyzed. The data obtained via CAUs will enable a comparison of net calcification rates between islands 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.

Ecological Acoustic Recorder (EAR): an 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. An EAR is a digital, low-power system that records ambient sounds up to 30 kHz on a programmable schedule and can also respond to transient acoustic events that meet specific criteria, such as motorized vessels passing nearby or cetaceans. This type of subsurface instrument typically was deployed at depths of 5–25 m.

A.2.4. Coral Core Collections

The coring of massive coral colonies is aimed at studying coral growth and accretion rates to provide calcification and extension rate chronologies to hindcast the carbonate chemistry climate of coral reefs from hundreds of years past. To quantify the size and density of annual growth bands in coral skeletons, core samples are collected and preserved for analysis by nondestructive computerized axial tomography (CAT)-scan and image-analysis techniques to visualize growth bands that cannot otherwise be observed.

Dependant on ocean conditions, a maximum of 2 REA sites at each island was selected for coring. Collection of coral core samples targeted colonies of *Porites* spp., since their massive growth forms give them the greatest potential to provide long growth histories. At each REA site, a minimum of 3 and a maximum of 5 sample cores were collected in close proximity (3–5 m) to each other, using a small, hand-held pneumatic drill operated from a scuba tank. The coring bit used was 35 cm long with an outer diameter of 3.8 cm and an inner diameter of 2.5 cm. Each core was collected from a single colony of sufficient size and health such that extracting a core 2.5 cm in diameter and 10–35 cm in length was judged not to be destructive or detrimental to the longevity of a colony. Through analyses of data from past CRED monitoring efforts, the abundance of coral colonies meeting coring criteria was established for each island, and cores were collected from areas where impact to coral populations was determined to be minimal. Upon completion of a coring, a cement plug was affixed to seal the hole, preventing invasion of bioeroding organisms. A cement plug provides a suitable surface over which surrounding coral tissue can grow. Coral core samples will be shipped to Woods Hole Oceanographic Institution in Woods Hole, Mass., for analyses using CAT-scan technology.

A.2.5. Analysis of Microbial Communities

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

Microbial and viral communities on coral reefs have been found to change along with coral reef health. Degraded coral reefs support microbial communities that are primarily heterotrophic and include a high abundance of potential pathogens, whereas near-pristine reefs support microbial communities that are balanced between heterotrophs and autotrophs and contain very few potential pathogens. A primarily heterotrophic and pathogenic microbial community in the water column could potentially lead to coral disease and death.

Microbial and viral communities on coral reefs have been found to change along with coral reef health. Degraded coral reefs support microbial communities that include a high abundance of potential pathogens and are primarily heterotrophic (a heterotrophic organism obtains food only from organic material, such as carbon and nitrogen, and is unable to use inorganic matter to form proteins and carbohydrates). In contrast, near-pristine reefs support microbial communities that are balanced between heterotrophs and autotrophs and contain very few potential pathogens (an autotrophic organism can synthesize food from inorganic material). A primarily heterotrophic and pathogenic microbial community in the water column could potentially lead to coral disease and death.

Collection of Microbial Water Samples: At select REA sites, 20 L of water were collected daily from < 1 m above the benthos using 4–5 L diver-deployable Niskin bottles. These water samples were returned to the ship, where samples were collected first for analysis of dissolved organic carbon (DOC) and particulate organic carbon (POC) and then for determining microbial size and abundance, including bacteria and archaea (single-celled microorganisms). These samples are used for the analyses described below. Also, at one REA site at each island or atoll, ~ 70 L of water were collected at reef crevices and surfaces for more in-depth analysis on the microbial community.

Microscopy: It is well known that bacteriophages (bacterial viruses) are the most abundant form of life in the ocean, ranging from 1×10^6 virus-like particles (VLPs) per mL of seawater in the open ocean to 1×10^8 VLPs per mL in more productive coastal waters. The number of microbial and protistan cells in seawater is typically 1×10^6 and 1×10^3 cells per mL, respectively. Microbial and viral loading and the dominance of heterotrophic bacteria in reef water are linked to coral disease. Trophic-level interactions among bacteria, phages, and protists also affect global nutrient and carbon cycling. The

most direct method for assessing and monitoring changes in the abundance of these microbiological components is by fluorescent microscopy using nucleic acid staining.
Enumeration of microbes and viruses. Two replicate 5-mL samples were collected and fixed using paraformaldehyde and filtered through 0.2-µm filters. These filters were stained using SYBR Gold (Molecular Probes Inc., Eugene, Ore.), a general nucleic acid stain, and mounted onto a microscope slide.

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

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

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

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

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

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

Flow Cytometry: Flow cytometry will be used primarily to characterize the size structure of microbial communities (e.g., autotroph vs. heterotroph abundance and viral abundance). This technique will also provide complementary data for abundance counts, metagenomic analysis, and Chl-*a* analysis.

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

Large Water Samples at Reef Crevices: At one REA site per island, ~ 70 L of water were collected using a manual bilge pump, which fills four 20-L collapsible carboys with water from reef crevices. This sample was then pre-filtered through 100-µm mesh upon return to the ship and then concentrated using tangential flow filtration, which concentrates the bacteria and viruses in the water. The initial ~ 70 L of water were brought to a final volume of ~ 500 mL. This concentrate was then filtered through 0.45-µm filters to capture microbes (bacteria and archaea). These filters were then frozen. The DNA of the entire community will be extracted and sequenced at San Diego State University, and the diversity and function of the microbial communities on the sampled reefs will be analyzed. The filtrate from this sample was also kept and contains concentrated viruses. Chloroform was added to this filtrate to kill any small microbes, and then this sample was stored at 4°C. Once shipped to San Diego State University, viruses will be isolated from the viral concentrate, and community DNA will be extracted and sequenced. This extracted and sequenced DNA will then be analyzed for viral community diversity and function.

Benthic Grabs: At the same REA site where the large water sample of ~70 L was collected, benthic samples were collected: 10 pieces of coral rubble and 10 pieces of macroalgae if present, and they were stored at –20°C. These samples are used to determine the microbial communities associated with the benthos.

Plankton Collection: At each island, 2 plankton tows were conducted from the surface water: one nearshore tow over the reef and one offshore tow ~ 0.8 km from shore. A bongo net with a 200-µm filter was pulled through the water for 15 min at a speed of ~ 1 kn. Upon return to the ship, samples were stored in ethanol at 4°C. These samples will be used to determine the abundance and diversity of planktonic communities.

A.2.6. Coral Diversity Surveys: Target Species Warranting Protection

The Pacific Ocean supports the largest and among the oldest habitat for coral reefs. During the past century, coral reefs have been increasingly threatened by anthropogenic activities, including human population growth, unmanaged fishing, and climate change. Stony (mostly scleractinian) corals are among the main organisms responsible for the biogenic growth and maintenance of reefs worldwide, yet we are only now beginning to focus attention regarding the status of threats to individual reef-building coral species and their habitats. The International Union for the Conservation of Nature has added more than 250 coral species to its Red List of Threatened Species, although the status of most of these species is still uncertain. During the past decade, the Center of Biological Diversity (CBD), based in Tuscon, Ariz., proposed protecting a few stony corals as endangered species. In October 2009, the CBD petitioned NOAA to list an additional 83 coral species under the *Endangered Species Act*, and all but 8 of these species occur in the Indo-Pacific region. Sixty of these species have been observed in the central Pacific (J Maragos, pers. comm.).

Stony corals consist of several thin layers of cell tissues over a much larger, stony skeleton. Over the past 250 years, skeletal characters and morphology served as the basis for distinguishing coral species. However, most reef-building corals are colonial and dependent upon single-celled plants (zooxanthellae) that live in their tissues for growth and nutrition. These factors lead to many different growth forms for each species, complicating efforts to assign proper species names and determine which species are under threat and warrant special protection. Moreover, the large size of the Pacific Ocean isolates many archipelagoes and islands from one another, and this isolation likely leads to genetic drift and evolution of new species without obvious morphological changes. As a result, there are likely many remaining undescribed species of corals. In addition, many of the species that have been recorded are likely to have been misidentified.

Thus, it is important to use supplemental approaches to define coral species more accurately, beyond just skeletal characters before considering them for endangered species status. Over the past several decades, taxonomic guidebooks with colored photographs of living corals taken during scuba dives have helped many scientists discern living coral species in their underwater habitats and in the process add “live tissue” characteristics to supplement skeletal characteristics. Also over the past several decades, coral taxonomists have grappled with additional approaches to differentiate individual species, including numerical taxonomy of morphological features and immunoassay techniques. However, these approaches have met with limited success and are difficult to apply and standardize for widespread use. More recently, molecular approaches that compare the DNA of different corals are showing great promise in determining which morphologically similar species have differing genomes and which corals with differing growth forms have the same genomes. As more useful “markers” are discovered on genes, there should be greater success in defining coral species and their phylogenetic relationships with other cnidarians.

Nevertheless, to resolve coral species assignments, there always will need to be a strong relationship between consistent observed morphological-anatomical characteristics and molecular characteristics determined via laboratory analyses. In turn, this dual approach would better define which species are in greater need of protection.

During this Pacific RAMP cruise, James Maragos collected coral samples focusing on species (1) included in the CBD petition, (2) other species closely related to the species in the petition, (3) undescribed species likely to be new to science, and (4) a selected number of common species of several genera to determine levels of genetic drift and connectivity. Maragos searched for these species during each dive, first taking an underwater photo and then collecting a small (1–3 cm^2) sample of each species, and then placed and sealed each in a separate prenumbered Ziploc bag. Then, each species was recorded on an underwater sheet, listing its in situ identification, Ziploc bag number, and REA site number. Later, each of the underwater photos taken was labeled with the corresponding bag number, based on the sequence of digital photos taken during each dive.

Upon return to the ship after each dive day, samples were immediately taken to the wet lab for processing. Using a hammer and cold chisel, or a surgical bone cutter, small (< 1 cm) fragments of each sample were placed in a vial labeled with the bag number of their sample. A separate waterproof paper tag with the same bag number was also placed inside the vial and the contents filled with 98% ethanol and tightly sealed. To avoid contamination, after the processing of each sample, the chisel, hammer, and bone cutter were washed and each used bag was discarded. At the end of each field day and after sample processing, the day's samples were added to a master spreadsheet of information about samples, including date, depth, site number, species, bag label number, island, etc.

A.3. Surveys of Reef Fishes

(Paula Ayotte, Kaylyn McCoy, Amanda Meyer, Brian Zgliczynski, Kevin Lino, and Marie Ferguson)

Four divers conducted REA fish surveys using the stationary-point-count (SPC) method at preselected REA sites. Two separate teams performed these surveys. Each team consisted of 2 divers and conducted either 1 or 2 SPC surveys per site. All fish REA sites visited were selected using a stratified random sampling design in shallow (0–6 m), moderate (6–18 m), or deep (18–30 m) depth strata. Three habitat strata were surveyed, if available: forereef, backreef, and lagoon. Note that the REA sites selected for fish surveys are different from the sites where REA benthic surveys were conducted.

SPC surveys were performed using a 30-m transect line set along a single depth contour. Once a transect line was deployed, a team of 2 divers moved to positions at 7.5 and 22.5 m. Those marks served as the centers of visually estimated cylindrical survey areas with a radius of 7.5 m. During the first 5 min, divers only recorded the presence of species within their respective cylinders. On completion of that 5 min enumeration period, divers began the count period, in which they systematically go down the species lists created during the enumeration period, sizing and counting all individuals within their cylinder, one species at a time. Cryptic species missed during the initial 5 min of a survey were still counted, sized, and added to the original species list when divers believed that they had most likely been missed during the enumeration period. The presence of notable species (e.g., sharks, bumphead parrotfish, turtles, and cetaceans) observed at any time during a dive but not recorded during SPC surveys was noted as "presence" data.

After a survey was completed, divers estimated benthic habitat cover and structural complexity of their respective survey areas: habitat complexity on a 6-point scale and benthic habitat by percentage of cover for categories that included hard corals, soft corals, macroalgae, crustose coralline algae, sand, and other invertebrates. In addition, a photoquadrat survey was made along the 30-m reference line, with photographs taken every 2 m. These photographs will be later analyzed by CRED staff and partners at Scripps Institution of Oceanography.

If bottom time and air permitted, the 30-m transect line was moved to a location that was nearby (but not overlapping) and at the same depth level, and the SPC procedure was repeated.

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

Towed-diver fish surveys record, to the lowest possible taxon, all fishes > 50 cm in total length (TL) along a 10-m swath in front of and centered on the diver. Species (or lowest possible taxon) and total length in centimeters were recorded for each fish counted. Sightings of species of particular concern (e.g., turtles, cetaceans, bumphead parrotfish, and Napoleon wrasse) observed outside the survey swath were noted and classified as presence/absence data.

At the end of each day, all fish survey data were transcribed from field data sheets into a centralized Microsoft Access database. The fish towboard was equipped with a forward-looking digital video camera that created a visual archive of the survey track.

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APPENDIX B: JARVIS ISLAND

Jarvis Island is a small island that measures 4 × 2 km and is located in the central, equatorial Pacific at 0°22′ S 160°03′ W. Presently, Jarvis Island is a U.S. National Wildlife Refuge and part of the Pacific Remote Islands National Marine 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 HA-10-01, Leg 3, at Jarvis Island entailed numerous retrievals and deployments of oceanographic moored instruments, installation of calcification acidification units (CAUs), nearshore water sampling and conductivity, temperature, and depth (CTD) casts around this island to depths of ~ 30 m or the depths of Rapid Ecological Assessment (REA) sites, shipboard water sampling and CTD casts offshore to a depth of 500 m, and acoustic Doppler current profiler (ADCP) transect lines.

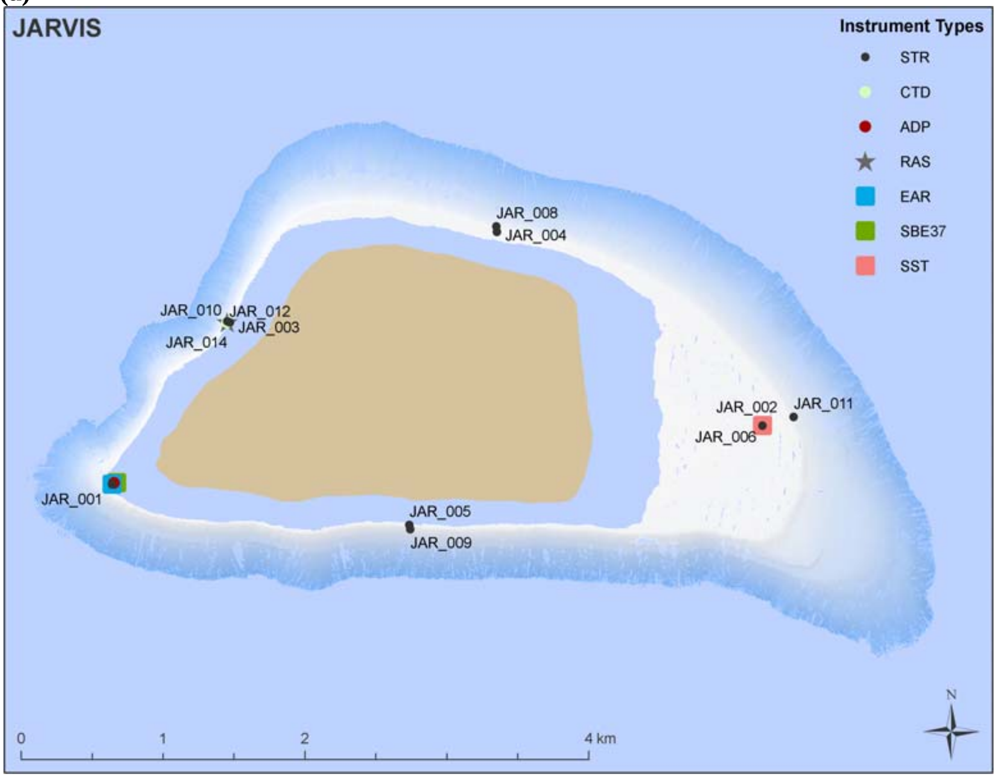
Nine subsurface temperature recorders (STRs) were retrieved and 15 STRs were deployed at Jarvis Island. One ocean data platform (ODP), which contains an acoustic Doppler profiler (ADP) and a temperature and salinity sensor (SBE 37), was recovered from Jarvis Island but not replaced. Additionally, 1 sea-surface temperature (SST) buoy was deployed and 1 ecological acoustic recorder (EAR) was recovered and replaced (Fig. B.1.1). For information about CAU deployments completed at Jarvis Island, see Figure B.1.2 and Section B.2: "Benthic Environment."

Oceanographic moorings were deployed around Jarvis as part of a short-term (8 month), site-specific study looking at biophysical interactions on coral reefs. This study is a collaborative project between CRED, the University of Hawaii, and the Scripps Institution of Oceanography (SIO) of the University of California San Diego with the purpose of researching the impacts of physical oceanographic forcing on benthic coral reef community structure, variability in ambient pH, and community calcification rates. These moorings are principally concentrated on the western side of Jarvis Island (at the site identified as JAR-003 in Figure B.1.1b). These instruments included 6 STRs, 2 ADPs, 2 pH sensors, and 2 temperature and salinity (SBE 37) sensors. SIO plans to return to Jarvis Island in November 2010 to retrieve these temporary moorings for CRED.

At nearshore locations around Jarvis Island, 19 shallow-water CTD casts were performed (Fig. B.1.2), including 13 casts at depths of ~ 30 m at regular horizontal intervals and 1 cast at each of the 6 select REA sites where CAUs were installed. In concert with the CTD cast at each of those same REA sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), salinity, and nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. A total of 12 DIC, 12 salinity, 12 nutrient, and 12 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each site. In addition to the standard discrete water sampling, a remote auto sampler (RAS) was deployed at 1 REA site to collect hourly water samples over a 48-h period for DIC and total alkalinity measurements (Fig. B.1.1). A Sea-Bird Electronics Inc. (Bellevue, Wash.) CTD (SBE 19*plus* Seacat Profiler) attached to that RAS collected salinity and temperature measurements every 15 min during the same 48-h period.

Four 20-km ADCP transect lines were run from the NOAA Ship *Hi`ialakai* in the 4 cardinal directions away from this island. A total of 36 deepwater CTD casts were performed, with 9 CTD casts done per line on the reciprocal course every 2 km to a depth of 500 m (Fig. B.1.3). Shipboard water samples were collected on every other CTD cast at 5 depths between the surface and 200 m, depending on the depth of mixed layer as determined by the CTD downcast. A total of 90 shipboard water samples, 45 Chl-*a* and 45 nutrient, were collected at Jarvis (Fig. B.1.3).

(a)



(b)

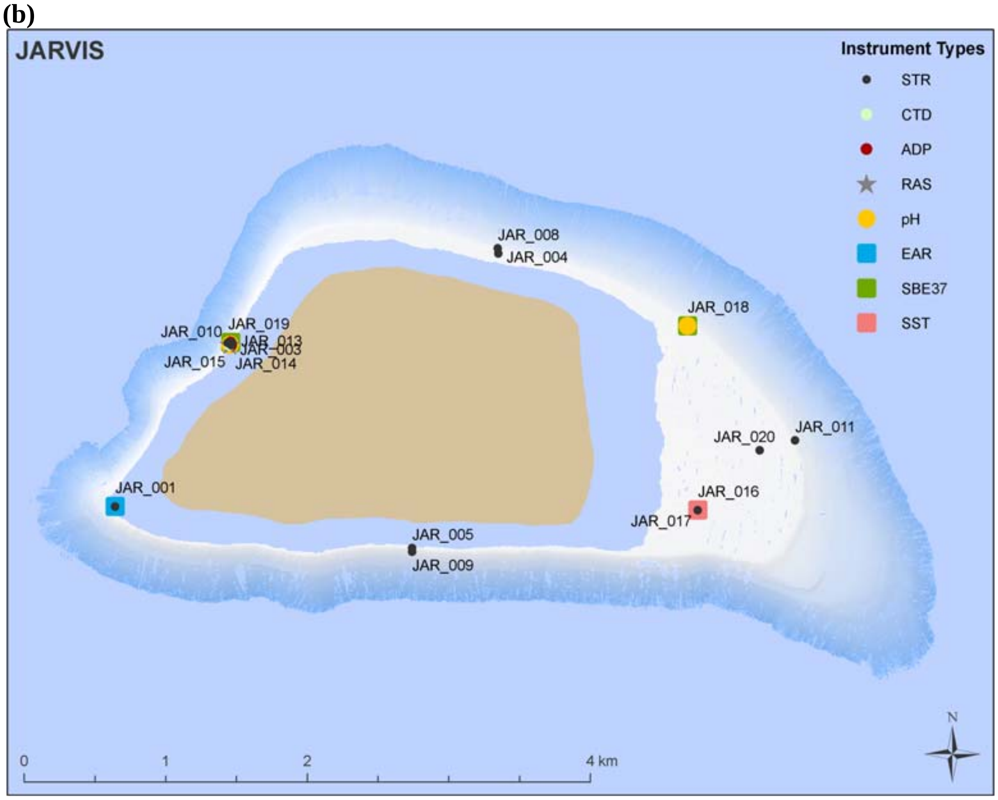


Figure B.1.1. Moored instruments (*a*) retrieved and (*b*) deployed at Jarvis Island during cruise HA-10-01, Leg 3.

Table B.1.1. Geographic coordinates and sensor depths of the moored instruments that were retrieved or deployed at Jarvis Island during cruise HA-10-01, Leg 3.

Mooring Site	Instrument Type	Latitude	Longitude	Sensor Depth (m)
Retrievals				
JAR-001	EAR	–0.37926	–160.01552	15.24
JAR-001	STR	–0.37926	–160.01552	15.24
JAR-001	ADP	–0.37916	–160.01540	14.63
JAR-001	SBE 37	–0.37916	–160.01540	14.63
JAR-003	STR	–0.36902	–160.00804	6.4
JAR-004	STR	–0.36329	–159.99110	9.75
JAR-005	STR	–0.38183	–159.99665	10.06
JAR-006	STR	–0.37555	–159.97426	12.8
JAR-008	STR	–0.36294	–159.99114	28.96
JAR-009	STR	–0.38210	–159.99661	32.61
JAR-010	STR	–0.36895	–160.00822	32
JAR-011	STR	–0.37500	–159.97228	33.22
JAR-014	CTD	–0.36902	–160.00822	15.2
JAR-014	RAS	–0.36902	–160.00822	15.2
Deployments				
JAR-001	EAR	–0.37924	–160.01551	15.2
JAR-001	STR	–0.37924	–160.01551	15.2
JAR-003	STR	–0.36902	–160.00807	6.4
JAR-004	STR	–0.36324	–159.99114	9.8
JAR-004	STR	–0.36324	–159.99114	9.8
JAR-005	STR	–0.38187	–159.99663	10.1
JAR-005	STR	–0.38187	–159.99663	10.1
JAR-008	STR	–0.36291	–159.99118	29.3
JAR-009	STR	–0.38209	–159.99663	32.3
JAR-010	STR	–0.36889	–160.00835	32.3
JAR-011	STR	–0.37505	–159.97227	33.2
JAR-013	ADP	–0.36903	–160.00813	11
JAR-013	STR	–0.36903	–160.00813	11
JAR-013	STR	–0.36889	–160.00808	10.1
JAR-014	STR	–0.36899	–160.00814	14.6
JAR-014	CTD	–0.36902	–160.00822	15.2
JAR-014	RAS	–0.36902	–160.00822	15.2
JAR-015	pH sensor	–0.36902	–160.00819	12.2
JAR-016	SST	–0.37947	–159.97845	0.2
JAR-017	STR	–0.37947	–159.97845	9.1
JAR-018	SBE 37	–0.36782	–159.97911	11.3
JAR-018	pH sensor	–0.36782	–159.97911	11.3
JAR-019	ADP	–0.36887	–160.00816	18.6
JAR-019	SBE 37	–0.36887	–160.00816	18.6
JAR-020	STR	–0.37568	–159.97453	10.1

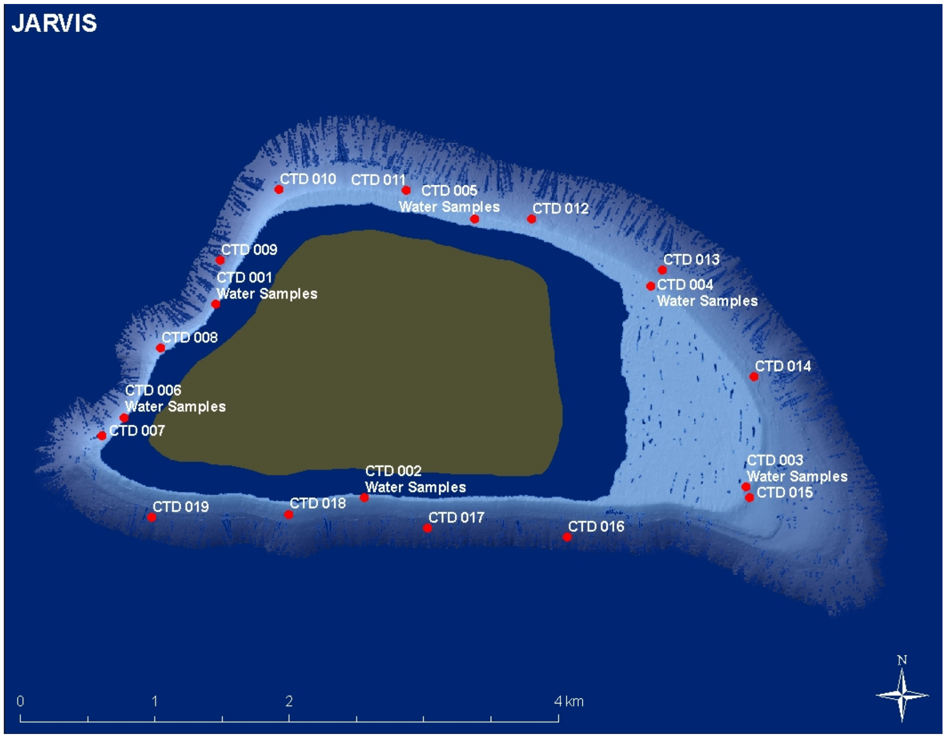


Figure B.1.2. Locations of shallow-water CTD casts performed at Jarvis Island during cruise HA-10-01, Leg 3. At 6 select nearshore cast locations, water samples for analyses of dissolved inorganic carbon, total alkalinity, nutrient, and Chl-*a* concentrations were collected.

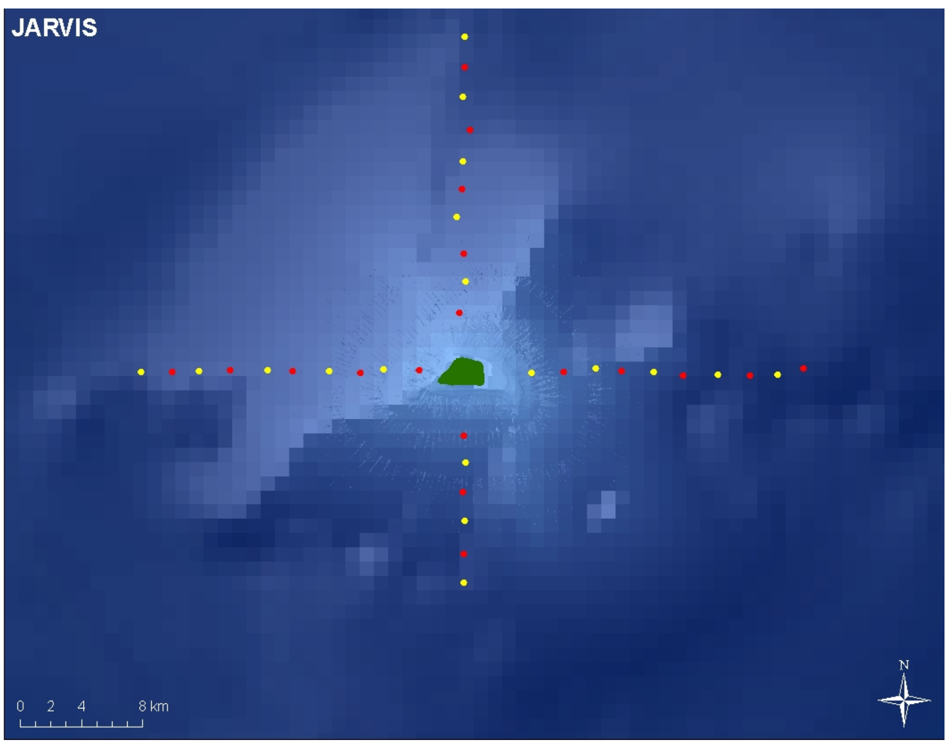


Figure B.1.3. Locations of deepwater CTD casts conducted at Jarvis Island from the NOAA Ship *Hi`ialakai* to a depth of 500 m. Shipboard water samples for analyses of nutrient and Chl-*a* concentrations were collected in concert with the casts conducted at the 18 locations displayed in red. Satellite data: SIO, NOAA, U.S. Navy, NGA, GEBCO (Becker, 2009; Smith and Sandwell, 1997). © 2008 The Regents of the University of California. All Rights Reserved.

Preliminary Results: Temperatures

Temperature data from 8 locations around Jarvis Island show an atypical pattern for subsurface temperature fluctuations in this region (Figure B.1.4). The lowest water temperatures recorded during the 2-year deployment of STRs occurred in April 2009 and December 2009, with ~ 24°C recorded to the north, south, and east of Jarvis Island. To the west, water temperatures dropped below 24°C multiple times between April 2008 and March 2009, particularly at the deeper sensor. Such reduced water temperatures, caused by strong upwelling of subsurface waters, have been observed previously on the western side of Jarvis. At the onset of 2009, a general warming pattern was observed in the temperature data from Jarvis, with values rising ~ 5°C from January 2009 to January 2010 and peaking at ~ 30°C at all depths and all locations around this island. Warming of equatorial ocean temperatures is typical of forcing from the El Niño-Southern Oscillation, and, as such, it is presumed this observed anomalous warming pattern is a result of 2009–2010 El Niño conditions.

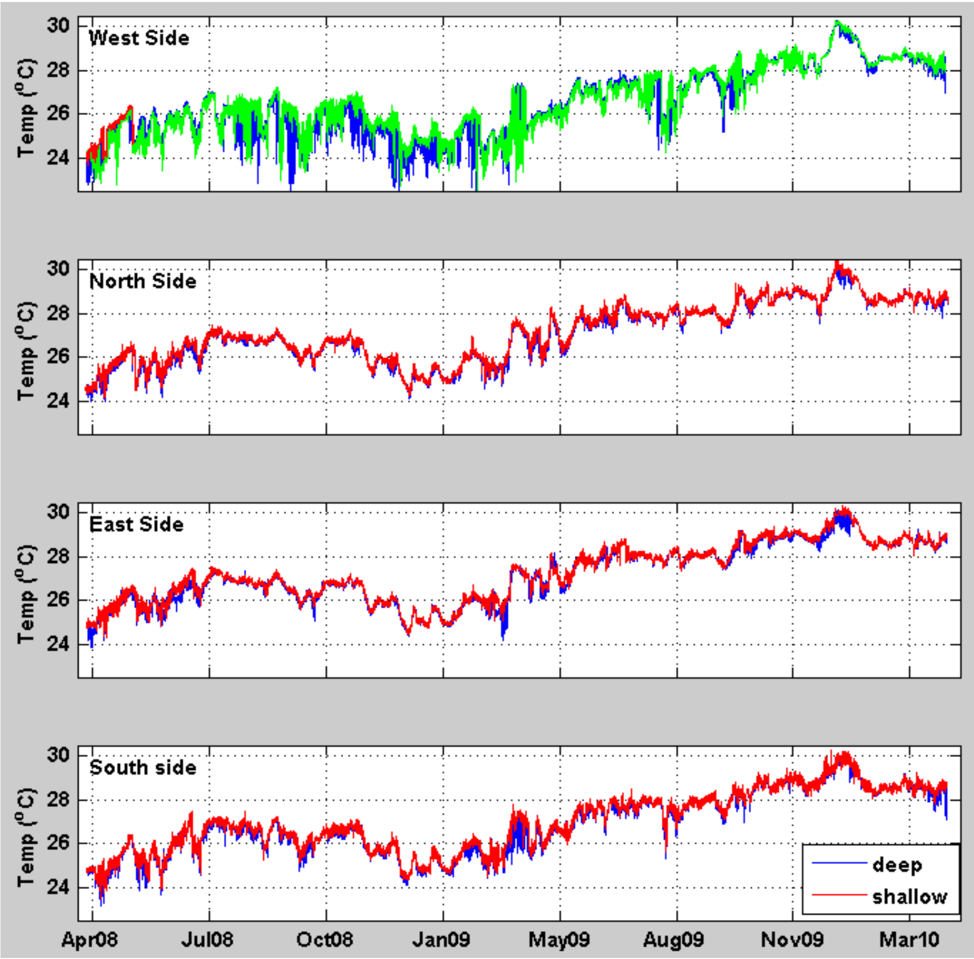


Figure B.1.4. Time-series observations of temperatures during the period of April 2008 to April 2010 collected from STRs deployed at 8 locations and deep and shallow depths at Jarvis Island.

B.2. Benthic Environment

During HA-10-01, Leg 3, CRED conducted Rapid Ecological Assessment (REA) benthic surveys, using the line-point-intercept and belt-transect methods, at 10 sites at Jarvis Island to assess benthic composition and coral and algal community structure and disease (Fig. B.2.1 and Table B.2.1). Two REA sites were surveyed twice.

A total of 14 towed-diver surveys were completed at Jarvis Island, covering 25.3 km of ocean floor (Fig. B.2.2). The mean survey length was 1.8 km with a range of 1.2–2.4 km. The mean survey depth was 14.2 m with a range of 9.2–18.1 m. The mean temperature from data recorded during these surveys was 28.6°C with a range of 28.1°C–28.9°C.

Various samples were collected at several REA sites (Table B.2.1), including 40 algal voucher specimens at 7 sites and 7 microbial water samples at 5 sites. Additional microbial collections included plankton tows at 2 locations. Non-coral invertebrate samples included 12 arms from seastars (*Linkia multifora*). A total of 5 coral cores (30–35 cm in length) were recovered from *Porites lobata* at 2 REA sites. A sixth coral core sample was taken from a brain coral. These core samples will be sent to Woods Hole Oceanographic Institute to measure calcification rates. For a full list of collections made at REA sites, see Table E.1 in Appendix E: "Biological Collections."

A total of 76 samples of 29 coral species were collected at 9 REA sites in support of the NOAA status review of 82 coral species in response to a petition by the Center of Biological Diversity to list them under the *Endangered Species Act* (ESA). For an ESA collections list, see Table E.2 in Appendix E.

At 6 select REA sites at Jarvis Island, a total of 40 CAUs were deployed, with 1 array of 5 CAUs deployed at each of 4 sites and 2 arrays of 5 units deployed at each of 2 sites (Fig. B.1.1 and Table B.2.1). These CAU deployments are the first undertaken by CRED, along with those installations made at other islands in the Pacific Remote Islands Marine National Monument and American Samoa during the cruises HA-10-01, Legs 1, 2, and 3.

A total of 9 autonomous reef monitoring structures (ARMS) were recovered and installed near 3 REA sites (Table B.2.1).

Figure B.2.1. Locations of REA benthic sites surveyed at Jarvis Island during cruise HA-10-01, Leg 3 (IKONOS Carterra Geo Data, 2003).

Table B.2.1. Summary of REA benthic surveys, deployments and retrievals of moored biological installations, and sample collections performed at REA sites at Jarvis Island during cruise HA-10-01, Leg 3. The line-point-intercept (LPI) method was used to estimate percentage of cover of algae, corals, and other invertebrates. Photoquadrat surveys (Photo) recorded digital images of benthos for later analysis of benthic cover. Surveys of coral community structure and condition (Corals) were performed using the belt-transect method. Belt-transect surveys of other invertebrates and roving-diver surveys of algae were not conducted. This table does not include the coral specimens for taxonomic verification that were collected by U.S. Fish and Wildlife Service biologist James Maragos.

REA Site	Date	Latitude	Longitude	REA Surveys			Deployments and Retrievals		Sample Collections	
				LPI	Photo	Corals	CAUs	ARMS	Algae	Microbial Samples
JAR-04	1-Apr	–0.3818	–159.9984	×	×	×	×	×	—	×
JAR-07	1-Apr	–0.3764	–160.0144	×	×	×	×	—	—	—
JAR-11	1-Apr	–0.3695	–160.0086	×	×	×	×	—	—	—
JAR-02	2-Apr	–0.3813	–160.0082	×	×	×	—	—	×	—
JAR-03	2-Apr	–0.3620	–160.0086	×	×	×	—	—	×	—
JAR-09	2-Apr	–0.3654	–159.0064	×	×	×	—	×	×	×
JAR-01	3-Apr	–0.3678	–159.9795	×	×	×	×	—	×	—
JAR-08	3-Apr	–0.3633	–159.9909	×	×	×	×	×	×	×
JAR-10	3-Apr	–0.3806	–159.9731	×	×	×	×	—	—	—
JAR-04	4-Apr	–0.3818	–159.9984	×	×	×	—	—	×	×
JAR-12	4-Apr	–0.3825	–159.9839	×	×	×	—	—	×	×
JAR-11	5-Apr	–0.3695	–160.0086	×	×	×	—	—	—	×

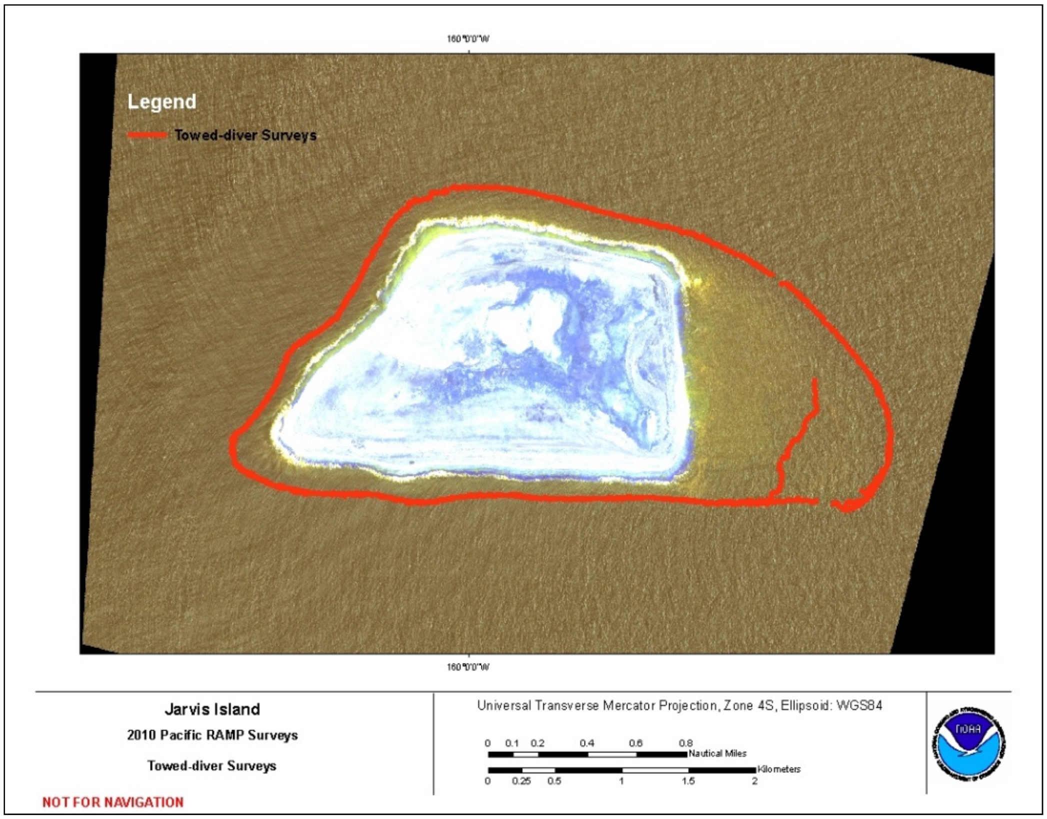


Figure B.2.2. Tracks of towed-diver surveys (fish and benthic) conducted at Jarvis Island during cruise HA-10-01, Leg 3 (IKONOS Carterra Geo Data, 2003).

B.3. Reef Fish Community

During HA-10-01, Leg 3, CRED conducted REA fish surveys, using a stratified random design and stationary-point-count method, at 30 REA sites at Jarvis Island in 3 different habitat strata: deep, moderate, and shallow forereefs (Fig. B.3.1 and Table B.3.1). The fish team made no collection efforts at Jarvis Island.

In addition, CRED completed 14 towed-diver surveys at Jarvis Island as described in Section B.2 of this report (Figure B.2.2.).

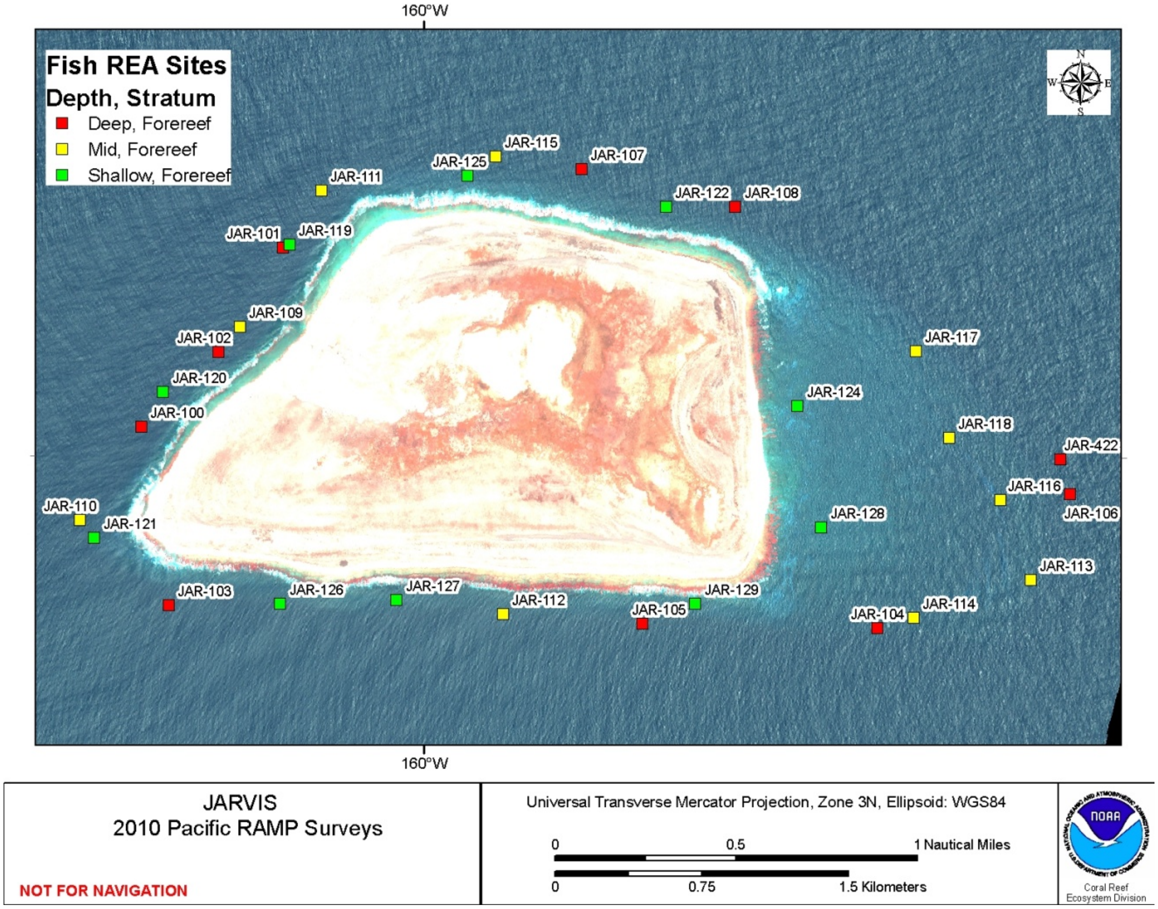


Figure B.3.1. Locations of REA fish sites surveyed around Jarvis Island during cruise HA-10-01, Leg 3. All of these REA sites were selected using a stratified random design (IKONOS Carterra Geo Data, 2003).

Table B.3.1. Summary of sites where REA fish surveys were conducted around Jarvis Island during cruise HA-10-01, Leg 3.

REA Site	Date	Depth, Stratum Description	Depth (m)	Latitude	Longitude
JAR-110	28-Mar	Moderate, Forereef	14	–0.37783667	–160.01541803
JAR-100	1-Apr	Deep, Forereef	21	–0.37371193	–160.01272459
JAR-103	1-Apr	Deep, Forereef	24	–0.38160810	–160.01150150
JAR-120	1-Apr	Shallow, Forereef	5	–0.37215902	–160.01175983
JAR-121	1-Apr	Shallow, Forereef	7	–0.37864049	–160.01477782
JAR-101	2-Apr	Deep, Forereef	21	–0.36575273	–160.00651494
JAR-102	2-Apr	Deep, Forereef	20	–0.37040653	–160.00931516
JAR-109	2-Apr	Moderate, Forereef	15	–0.36926256	–160.00839475
JAR-111	2-Apr	Moderate, Forereef	12	–0.36323849	–160.00480511
JAR-119	2-Apr	Shallow, Forereef	5	–0.36564100	–160.00620975
JAR-104	3-Apr	Deep, Forereef	23	–0.38255610	–159.98034311
JAR-105	3-Apr	Deep, Forereef	23	–0.38238360	–159.99066635
JAR-106	3-Apr	Deep, Forereef	19	–0.37660687	–159.97189139
JAR-112	3-Apr	Moderate, Forereef	13	–0.38199317	–159.99679738
JAR-113	3-Apr	Moderate, Forereef	9	–0.38040513	–159.97360080
JAR-116	3-Apr	Moderate, Forereef	11	–0.37687568	–159.97495598
JAR-126	3-Apr	Shallow, Forereef	6	–0.38155312	–160.00660404
JAR-127	3-Apr	Shallow, Forereef	6	–0.38137525	–160.00149049
JAR-107	4-Apr	Deep, Forereef	23	–0.36226502	–159.99339248
JAR-108	4-Apr	Deep, Forereef	21	–0.36391810	–159.98663407
JAR-114	4-Apr	Moderate, Forereef	10	–0.38211102	–159.97875307
JAR-117	4-Apr	Moderate, Forereef	8	–0.37030477	–159.97867755
JAR-118	4-Apr	Moderate, Forereef	10	–0.37412859	–159.97720728
JAR-124	4-Apr	Shallow, Forereef	5	–0.37275120	–159.98387374
JAR-128	4-Apr	Shallow, Forereef	6	–0.37810178	–159.98281687
JAR-129	4-Apr	Shallow, Forereef	5	–0.38149050	–159.98835546
JAR-115	5-Apr	Moderate, Forereef	13	–0.36170829	–159.99717020
JAR-122	5-Apr	Shallow, Forereef	5	–0.36392262	–159.98967351
JAR-125	5-Apr	Shallow, Forereef	6	–0.36258009	–159.99838893
JAR-422	5-Apr	Deep, Forereef	19	–0.37505890	–159.97232708

In addition to the previously described activities, a U.S. Fish and Wildlife Service field party went ashore to Jarvis Island during HA-10-01, Leg 3, to conduct surveys of terrestrial flora and fauna.

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APPENDIX C: PALMYRA ATOLL

Located at 5°52′ N, 162°6′ W in the central, equatorial Pacific at the northern end of the Line Islands, Palmyra Atoll is elliptical in shape and measures 18.5 × 3.5 km. Palmyra, a U.S. National Wildlife Refuge and part of the Pacific Remote Islands National Marine Monument, is presently operated by The Nature Conservancy, serving as a destination for research and limited ecotourism. 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 HA-10-01, Leg 3, at Palmyra Atoll entailed numerous retrievals and deployments of oceanographic moored instruments, installation of calcification acidification units (CAUs), nearshore water sampling and conductivity, temperature, and depth (CTD) casts around this atoll to a depth of ~ 30 m or the depths of Rapid Ecological Assessment (REA) sites, shipboard water sampling and CTD casts offshore to a depth of 500 m, acoustic Doppler current profiler (ADCP) transect lines, and meteorological measurements.

Twenty subsurface temperature recorders (STRs) were retrieved and 27 deployed around Palmyra Atoll (Fig. C.1.1). One sea-surface temperature (SST) buoy and 1 ecological acoustic recorder (EAR) were both retrieved and replaced, and 1 Coral Reef Early Warning System (CREWS) buoy and 1 CREWS buoy anchor were recovered. For information about CAU deployments completed at Palmyra Atoll, see Figure C.1.2 and Section C.2: "Benthic Environment."

Oceanographic moorings were deployed around Palmyra as part of a site-specific study looking at biophysical interactions on coral reefs. This study is a collaborative project between CRED, the University of Hawaii, and the Scripps Institution of Oceanography of the University of California San Diego with the purpose of understanding the impacts of physical oceanographic forcing on benthic coral reef community structure, variability in ambient pH, and community calcification rates. These moorings consisted of 4 cross-shelf transects on the northwest, northeast, southwest, and southeast sides of Palmyra. At each transect, the following instruments were deployed: 1 acoustic Doppler profiler (ADP) with directional wave capabilities and a Sea-Bird Electronics Inc. (Bellevue, Wash.) SBE 37 temperature and salinity sensor at 20 m, STRs at 15 and 10 m, and 1 STR parallel to the 10 m isobathic contour, ~ 100 m away from each cross-shelf transect. At a depth of 20 m on the western and eastern sides of this atoll, 2 SBE 37 temperature and salinity sensors were deployed. Also, 2 wave-and-tide recorders (WTRs) with STRs attached were deployed inside Palmyra's lagoons, 1 in East Lagoon and 1 in West Lagoon. These WTRs are set to measure changes in sea level inside and across these lagoons based on tidal forcing and wave and current setup. These moored instruments will remain in place for one year so that a full seasonal cycle of oceanographic conditions can be recorded.

At nearshore locations around Palmyra Atoll, 13 shallow-water CTD casts were performed (Fig. C.1.2), including 1 cast at 10 select REA sites. In concert with the CTD cast at each of those same REA sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), salinity, and nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. At 2 additional locations, water samples were collected with no concurrent CTD cast performed; these samples were collected by visiting scientist Nichole Price for Scripps Institution of Oceanography. In total, 24 DIC, 24 salinity, 24 nutrient, and 24 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each site. (Figure C.1.2). In addition to the standard discrete water sampling, a remote auto sampler (RAS) was deployed at REA site PAL-25, where it collected hourly samples over a 48-h period (Fig. C.1.1). Water samples from this RAS will be used for additional carbonate chemistry analysis. A SBE 19*plus* Seacat Profiler attached to that RAS collected conductivity and temperature measurements every 15 min during the same 48-h deployment.

Four 20-km ADCP transect lines were run from the NOAA Ship *Hi`ialakai* in the cardinal directions away from this atoll. A total of 39 shipboard CTD casts were performed, with 9-10 casts done per line on the reciprocal course every 2 km to a depth of 500 m (Fig. C.1.3). Shipboard water samples were collected on every other cast at 5 depths between the surface and 200 m, depending on the depth of the mixed layers as determined by the CTD downcast. A total of 200 shipboard water samples, 100 nutrient and 100 Chl-*a*, were collected at Palmyra Atoll (Fig. C.1.3).

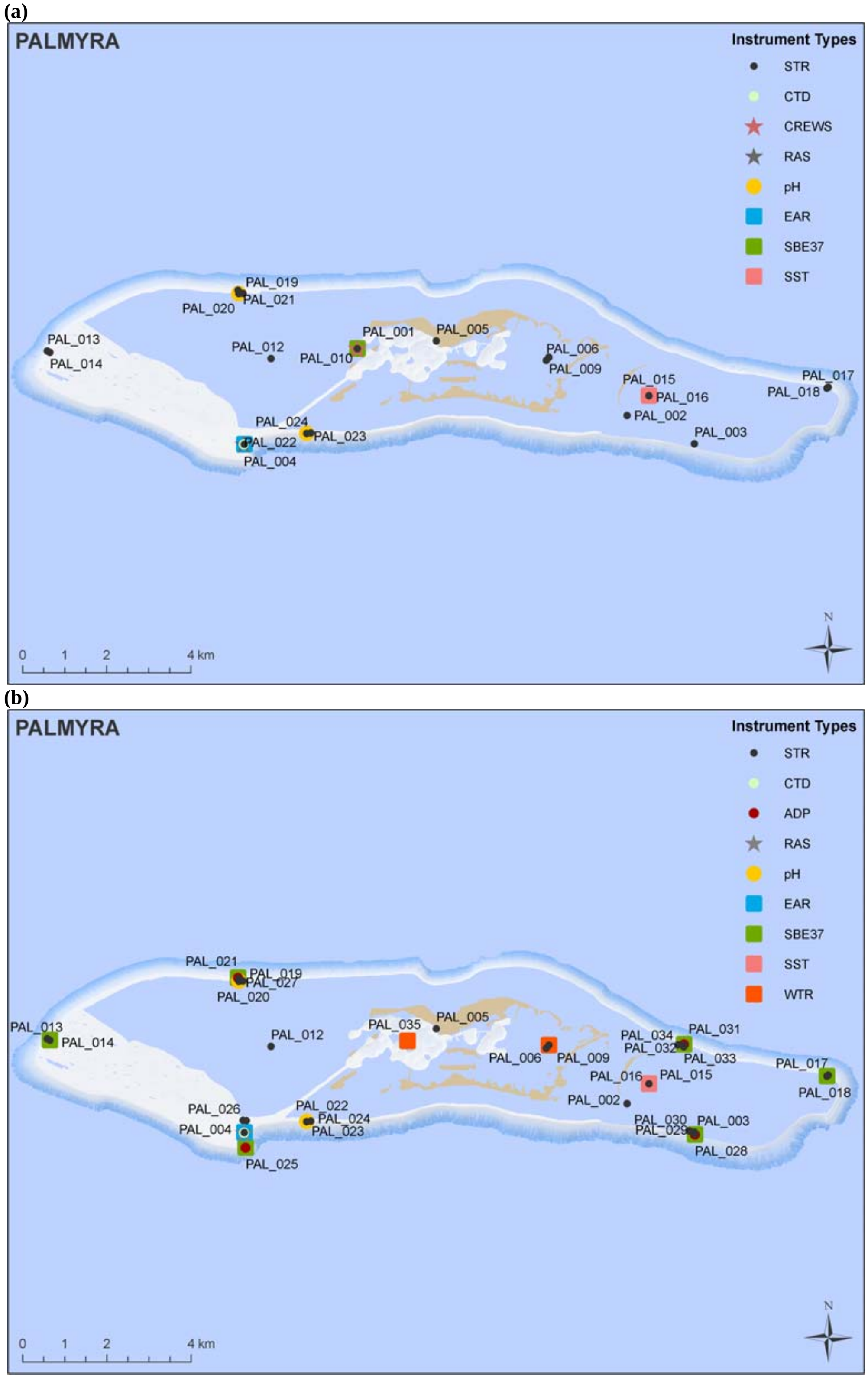

Figure C.1.1. Moored instruments (*a*) retrieved and (*b*) deployed at Palmyra Atoll during cruise HA-10-01, Leg 3.

Table C.1.1. Geographic coordinates and sensor depths of the moored instruments that were retrieved or deployed at Palmyra Atoll during cruise HA-10-01, Leg 3.

Mooring Site	Instrument Type	Latitude	Longitude	Sensor Depth (m)
Retrievals				
PAL-001	CREWS	5.88458	–162.10277	0
PAL-001	SBE37	5.88458	–162.10277	1
PAL-001	STR	5.88458	–162.10277	1
PAL-002	STR	5.87030	–162.04511	1.5
PAL-003	STR	5.86426	–162.03070	10.1
PAL-004	CTD	5.86412	–162.12706	15.2
PAL-004	EAR	5.86414	–162.12698	15.5
PAL-004	RAS	5.86412	–162.12706	15.2
PAL-004	STR	5.86414	–162.12698	15.5
PAL-005	STR	5.88622	–162.08591	3.4
PAL-006	STR	5.88207	–162.06235	25.6
PAL-009	STR	5.88276	–162.06183	4.6
PAL-010	STR	5.88458	–162.10277	9.1
PAL-012	STR	5.88244	–162.12125	3.7
PAL-013	STR	5.88407	–162.16909	32.9
PAL-014	STR	5.88382	–162.16857	19.2
PAL-015	SST	5.87453	–162.04045	0.2
PAL-016	STR	5.87453	–162.04045	5.8
PAL-017	STR	5.87637	–162.00206	32.6
PAL-018	STR	5.87611	–162.00237	19.5
PAL-019	STR	5.89642	–162.12724	10.4
PAL-020	pH sensor	5.89639	–162.12811	11.3
PAL-020	STR	5.89639	–162.12811	11.3
PAL-021	STR	5.89711	–162.12831	21
PAL-022	pH sensor	5.86648	–162.11362	13.1
PAL-022	STR	5.86648	–162.11362	14
PAL-023	STR	5.86645	–162.11363	19.5
PAL-024	STR	5.86655	–162.11275	12.2
Deployments				
PAL-002	STR	5.87030	–162.04511	1.5
PAL-003	STR	5.86426	–162.03070	10.1
PAL-003	STR	5.86426	–162.03070	10.1
PAL-004	CTD	5.86406	–162.12700	15.2
PAL-004	EAR	5.86414	–162.12698	15.5
PAL-004	RAS	5.86406	–162.12700	15.2
PAL-004	STR	5.86414	–162.12698	15.5
PAL-004	STR	5.86414	–162.12698	15.5
PAL-005	STR	5.88622	–162.08591	3.4
PAL-006	STR	5.88207	–162.06235	25.6
PAL-009	STR	5.88276	–162.06183	4.6

PAL-009	WTR	5.88276	–162.06183	4.6
PAL-012	STR	5.88244	–162.12125	3.7
PAL-013	STR	5.88407	–162.16909	32.9
PAL-014	SBE 37	5.88382	–162.16857	19.2
PAL-014	STR	5.88382	–162.16857	19.2
PAL-015	SST	5.87453	–162.04045	0.2
PAL-016	STR	5.87453	–162.04045	5.8
PAL-017	STR	5.87637	–162.00206	32.6
PAL-018	SBE 37	5.87611	–162.00237	20.4
PAL-018	STR	5.87611	–162.00237	20.7
PAL-019	STR	5.89642	–162.12724	10.4
PAL-020	pH sensor	5.89639	–162.12811	11.3
PAL-020	STR	5.89639	–162.12811	11.3
PAL-021	ADP	5.89711	–162.12831	21
PAL-021	SBE 37	5.89711	–162.12831	21
PAL-022	pH Sensor	5.86648	–162.11362	14
PAL-022	STR	5.86648	–162.11362	14
PAL-023	STR	5.86645	–162.11363	19.5
PAL-024	STR	5.86655	–162.11275	12.2
PAL-025	ADP	5.86087	–162.12671	20.7
PAL-025	SBE 37	5.86087	–162.12671	20.7
PAL-026	STR	5.86666	–162.12653	10.4
PAL-026	STR	5.86671	–162.12723	10.7
PAL-027	STR	5.89693	–162.12821	14.6
PAL-028	ADP	5.86366	–162.03059	18.9
PAL-028	SBE 37	5.86366	–162.03059	18.9
PAL-029	STR	5.86379	–162.03064	15.8
PAL-030	STR	5.86445	–162.03178	10.1
PAL-031	ADP	5.88292	–162.03292	19.5
PAL-031	SBE 37	5.88292	–162.03292	19.5
PAL-032	STR	5.88277	–162.03299	14.6
PAL-033	STR	5.88243	–162.03300	10.4
PAL-034	STR	5.88281	–162.03420	10.1
PAL-035	WTR	5.88365	–162.09205	3.7

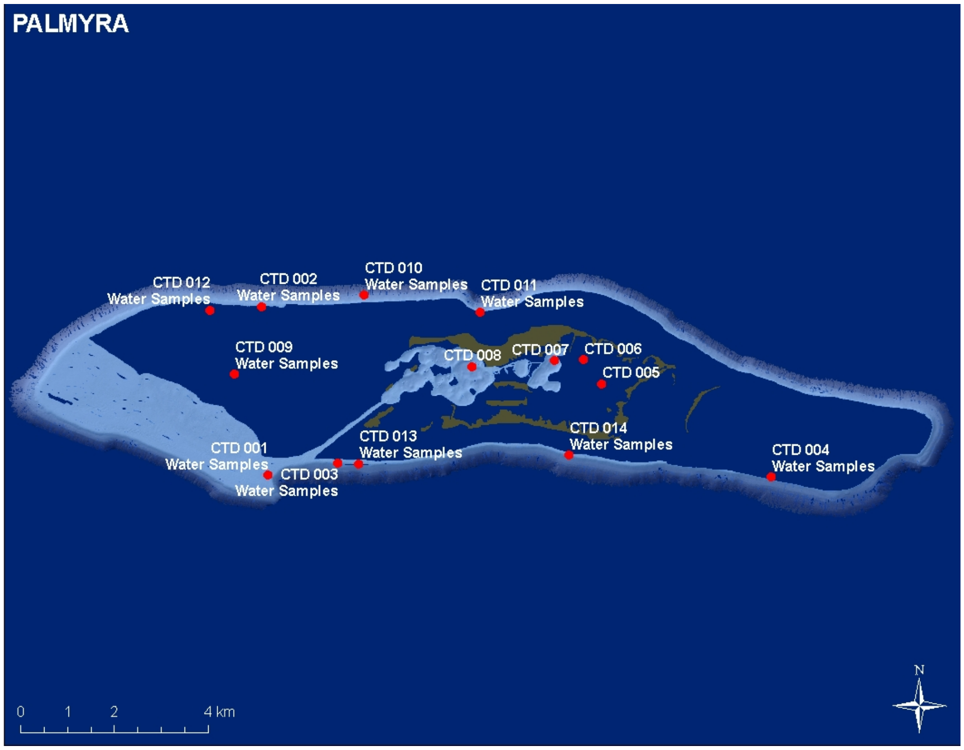

Figure C.1.2. Locations of shallow-water CTD casts performed at Palmyra Atoll during cruise HA-10-01, Leg 3. At 10 of these nearshore cast locations, water samples for analyses of nutrient and Chl-*a* concentrations were collected.

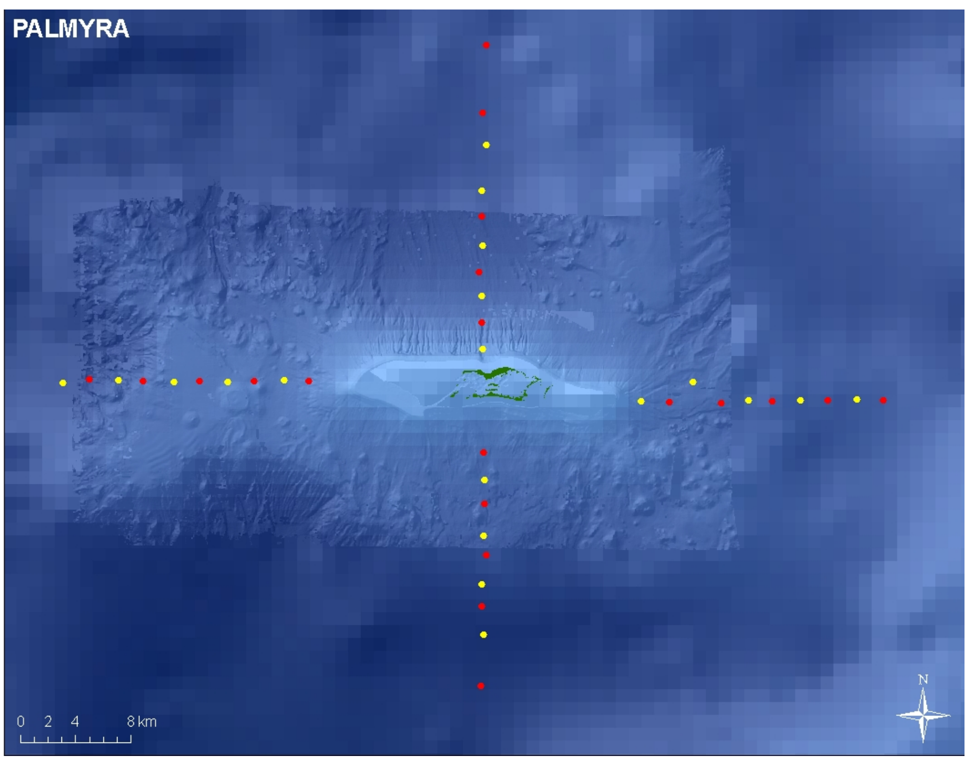

Figure C.1.3. Locations of deepwater CTD casts conducted at Palmyra Atoll from the NOAA Ship *Hi`ialakai* to a depth of 500 m. Shipboard water samples for analyses of nutrient and Chl-*a* concentrations were collected in concert with the casts conducted at the 20 locations displayed in red. Satellite data: SIO, NOAA, U.S. Navy, NGA, GEBCO (Becker, 2009; Smith and Sandwell, 1997). © 2008 The Regents of the University of California. All Rights Reserved.

Preliminary Results: Subsurface Temperatures

Temperature data recorded at various depths from 13 locations in 3 regions (western terrace, eastern terrace, and lagoon) at Palmyra Atoll are shown in Figure C.1.4. At all locations, a seasonal warming of temperatures was recorded in summer or fall 2008 before a seasonal cooling in January 2009. Beginning in winter 2009 and extending into November 2009, a general warming pattern was observed in the temperature record, rising 3°C–4°C at all depths and all locations around this atoll. Warming of equatorial ocean temperature is typical of forcing from the El Niño-Southern Oscillation, and, as such, it is presumed the anomalous warming pattern observed was a result of the El Niño conditions observed in 2009 and 2010. An anomalous cooling event was recorded at Palmyra in September 2008. For ~ 3 weeks, temperatures dropped ~ 2°C at all depths in all locations around this atoll. The physical forcing mechanism behind this cooling event is presently unknown without additional data analysis.

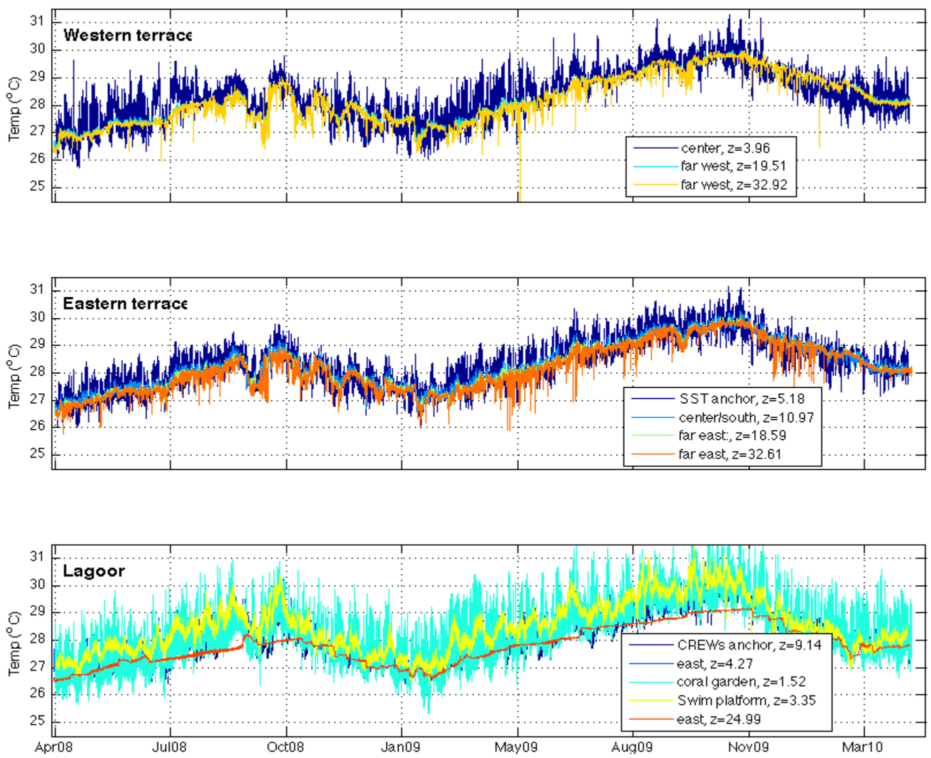

Figure C.1.4. Time-series observations of temperatures during the period from April 2008 to April 2010collected from oceanographic instruments moored at 13 locations at Palmyra Atoll

C.2. Benthic Environment

During HA-10-01, Leg 3, CRED conducted Rapid Ecological Assessment (REA) benthic surveys, using the line-point-intercept and belt-transect methods, at 17 sites at Palmyra Atoll to assess coral and algal community structure and disease and benthic composition (Fig. C.2.1 and Table C.2.1).

A total of 28 towed-diver surveys were completed at Palmyra Atoll, covering 54.6 km of ocean floor (Fig. C.2.2). The mean survey length was 1.9 km with a range of 1.3–3.2 km. The mean survey depth was 15.8 m with a range of 12.2–23.1 m. The mean temperature from data recorded during these surveys was 28.1°C with a range of 27.9°C–28.3°C.

Various samples were collected at 13 REA sites (Table.E.1), including 150 algal specimens at 11 sites and 8 microbial water samples at 7 sites. Additional microbial collections included plankton tows at 2 locations. A total of 3 coral cores (30–35 cm in length) were recovered from *Porites lobata* at REA site PAL-19. These core samples will be sent to Woods Hole Oceanographic Institute to measure calcification rates. For a full list of collections made at these REA sites, see Table E.1 in Appendix E: "Biological Collections."

A total of 106 samples of 35 coral species were collected at the same 13 REA sites in support of the NOAA status review of 82 coral species in response to a petition by the Center of Biological Diversity (CBD) to list them under the *Endangered Species Act* (ESA). For an ESA collections list, see Table E.2 in Appendix E.

At 12 locations at Palmyra Atoll, a total of 64 CAUs were deployed (Fig. C.1.1), with 1 array of 5 CAUs installed at each of 8 select REA sites for long-term monitoring and 24 units installed at 4 locations for Scripps Institution of Oceanography for short-term monitoring. These CAU deployments are the first undertaken by CRED, along with those installations made at other islands in the Pacific Remote Islands Marine National Monument and American Samoa during the cruises HA-10-01, Legs 1, 2, and 3.

A total of 12 autonomous reef monitoring structures (ARMS) were retrieved near 4 REA sites, and, near 3 of those sites, a total of 9 ARMS were deployed.

Figure C.2.1. Locations of REA benthic sites surveyed at Palmyra Atoll during cruise HA-10-01, Leg 3 (IKONOS Carterra Geo Data, 2001).

Table C.2.1. Summary of REA benthic surveys, deployments and retrievals of moored biological installations, and sample collections performed at REA sites at Palmyra Atoll during cruise HA-10-01, Leg 3. The line-point-intercept (LPI) method was used to estimate percentage of cover of algae, corals, and other invertebrates. Photoquadrat surveys (Photo) recorded digital images of benthos for later analysis of benthic cover. Surveys of coral community structure and condition (Corals) were performed using the belt-transect method, as were separate surveys of other invertebrates (Inverts). Roving-diver surveys of algae were not conducted. This table does not include the coral specimens for taxonomic verification that were collected by U.S. Fish and Wildlife Service biologist James Maragos.

				REA Surveys				Deployments and Retrievals		Sample Collections	
REA Site	Date	Latitude	Longitude	LPI	Photo	Corals	Inverts	CAUs	ARMS	Algae	Microbial Samples
PAL-05	7-Apr	5.8956	–162.1379	×	×	×	×	×	—	×	—
PAL-12	7-Apr	5.8974	–162.1080	×	×	×	×	×	—	×	×
PAL-21	7-Apr	5.8957	–162.0861	×	×	×	×	×	—	×	—
PAL-11	8-Apr	5.8834	–162.1335	×	×	×	—	×	—	×	—
PAL-17	8-Apr	5.8755	–162.1392	×	×	×	—	—	×	×	×
PAL-26	8-Apr	5.8640	–162.1269	×	×	×	—	×	—	×	—
PAL-10	9-Apr	5.8659	–162.0486	×	×	×	—	—	—	×	—
PAL-25	9-Apr	5.8641	–162.0318	×	×	×	—	×	—	×	×
PAL-04	10-Apr	5.8737	–162.1165	×	×	×	—	—	—	—	—
PAL-06	10-Apr	5.8715	–162.1185	×	×	×	—	—	—	—	—
PAL-19	10-Apr	5.8664	–162.1100	×	×	×	—	×	×	×	×
PAL-09	11-Apr	5.8676	–162.0954	×	×	×	—	—	—	×	×
PAL-16	11-Apr	5.8716	–162.1123	×	×	×	—	—	—	—	×
PAL-27	11-Apr	5.8777	–162.10436	—	—	—	—	—	×	—	—
PAL-01	12-Apr	5.8678	–162.0689	×	×	×	—	×	×	×	×
PAL-03	12-Apr	5.8697	–162.0687	×	×	×	—	—	—	—	—
PAL-15	12-Apr	5.8704	–162.045	×	×	×	—	—	—	—	—
PAL-02	13-Apr	5.8825	–162.1313	×	×	×	—	—	—	×	—

Figure C.2.2 Tracks of towed-diver surveys (fish and benthic) conducted at Palmyra Atoll during cruise HA-10-01, Leg 3 (IKONOS Carterra Geo Data, 2001).

C.3. Reef Fishes

During cruise HA-10-01, Leg 3, CRED conducted REA fish surveys, using a stratified random design and stationary-point-count method, at 40 REA sites at Palmyra Atoll over 3 different habitat strata: deep, moderate, and shallow forereef (Figure C.3.1. and Table C.3.1.). The fish team made no collection efforts at Palmyra Atoll.

In addition, CRED completed 28 towed-diver surveys at Palmyra Atoll as described in Section D.2 of this report (Figure C.2.2.).

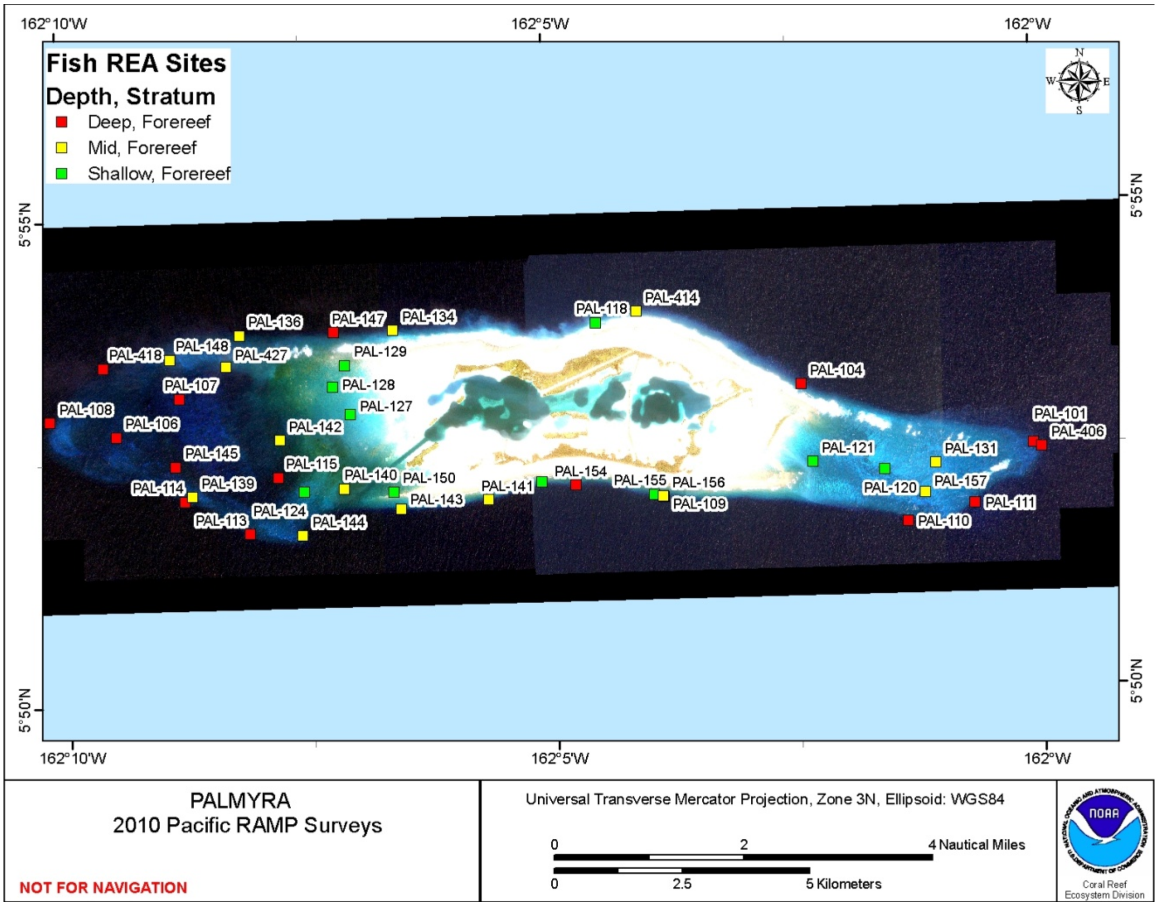

Figure C.3.1. Locations of REA fish sites surveyed around Palmyra Atoll during cruise HA-10-01, Leg 3. All of these REA sites were selected using a stratified random design (IKONOS Carterra Geo Data, 2001).

Table C. 3.1. Summary of sites where REA fish surveys were conducted around Palmyra Atoll during cruise HA-10-01, Leg 3.

REA Site	Date	Depth, Stratum Description	Depth (m)	Latitude	Longitude
PAL-106	07-Apr	Deep, Forereef	20	5.87966619	–162.15816951
PAL-108	07-Apr	Deep, Forereef	20	5.88249114	–162.16948014
PAL-140	07-Apr	Moderate, Forereef	6	5.86989222	–162.11933029
PAL-144	07-Apr	Moderate, Forereef	17	5.86198063	–162.12662808
PAL-101	08-Apr	Deep, Forereef	20	5.87492321	–162.00120100
PAL-110	08-Apr	Deep, Forereef	21	5.86189957	–162.02294108
PAL-111	08-Apr	Deep, Forereef	21	5.86472075	–162.01141010
PAL-120	08-Apr	Shallow, Forereef	10	5.87089118	–162.02676223
PAL-121	08-Apr	Shallow, Forereef	6	5.87246966	–162.03903110
PAL-131	08-Apr	Moderate, Forereef	9	5.87173373	–162.01799970
PAL-157	08-Apr	Moderate, Forereef	10	5.86669855	–162.01993391
PAL-406	08-Apr	Deep, Forereef	26	5.87413799	–161.99979440
PAL-109	09-Apr	Deep, Forereef	22	5.86709937	–162.06470450

REA Site	Date	Depth, Stratum Description	Depth (m)	Latitude	Longitude
PAL-154	09-Apr	Deep, Forereef	24	5.86951068	–162.07961930
PAL-155	09-Apr	Shallow, Forereef	12	5.86756985	–162.06628950
PAL-156	09-Apr	Moderate, Forereef	14	5.86721169	–162.06476837
PAL-113	10-Apr	Deep, Forereef	21	5.86247885	–162.13562781
PAL-114	10-Apr	Deep, Forereef	21	5.86831106	–162.14669440
PAL-115	10-Apr	Deep, Forereef	21	5.87205878	–162.13053606
PAL-124	10-Apr	Shallow, Forereef	9	5.86947162	–162.12625215
PAL-139	10-Apr	Moderate, Forereef	15	5.86911480	–162.14542890
PAL-142	10-Apr	Moderate, Forereef	12	5.87848074	–162.13017790
PAL-145	10-Apr	Deep, Forereef	20	5.87431510	–162.14812750
PAL-150	10-Apr	Shallow, Forereef	3	5.86915436	–162.11088010
PAL-107	11-Apr	Deep, Forereef	26	5.88603090	–162.14725376
PAL-127	11-Apr	Shallow, Forereef	4	5.88261897	–162.11798005
PAL-128	11-Apr	Shallow, Forereef	5	5.88741207	–162.12089620
PAL-129	11-Apr	Shallow, Forereef	3	5.89103666	–162.11872512
PAL-134	11-Apr	Moderate, Forereef	14	5.89687625	–162.11033466
PAL-136	11-Apr	Moderate, Forereef	15	5.89661691	–162.13668695
PAL-147	11-Apr	Deep, Forereef	23	5.89675262	–162.12049060
PAL-148	11-Apr	Moderate, Forereef	15	5.89279803	–162.14860149
PAL-104	12-Apr	Deep, Forereef	23	5.88582412	–162.04071940
PAL-118	12-Apr	Shallow, Forereef	5	5.89727724	–162.07565450
PAL-125	12-Apr	Shallow, Forereef	6	5.87016178	–162.08548852
PAL-141	12-Apr	Moderate, Forereef	15	5.86734027	–162.09467744
PAL-143	12-Apr	Moderate, Forereef	14	5.86618583	–162.10971222
PAL-414	12-Apr	Moderate, Forereef	12	5.89902973	–162.06865670
PAL-418	13-Apr	Deep, Forereef	25	5.89154620	–162.16012518
PAL-427	13-Apr	Moderate, Forereef	16	5.89134771	–162.13911518

In addition to the previously described activities, a U.S. Fish and Wildlife Service field party went ashore to Palmyra Atoll during HA-10-01, Leg 3, to conduct surveys of terrestrial flora and fauna.

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APPENDIX D: KINGMAN REEF

Located in the central, equatorial Pacific at the northern end of the Line Islands at 6°24′ N, 162°24′ W, Kingman Reef is triangular in shape, largely submerged, and measures 18 × 9 km. Kingman Reef is a U.S. National Wildlife Refuge and part of the Pacific Remote Islands National Marine 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 HA-10-01, Leg 3, at Kingman Reef entailed numerous retrievals and deployments of oceanographic moored instruments, installation of calcification acidification units (CAUs), nearshore water sampling and conductivity, temperature, and depth (CTD) casts around this atoll to the depths of Rapid Ecological Assessment (REA) sites, shipboard water sampling and CTD casts offshore to a depth of 500 m, acoustic Doppler current profiler (ADCP) transect lines, and meteorological measurements.

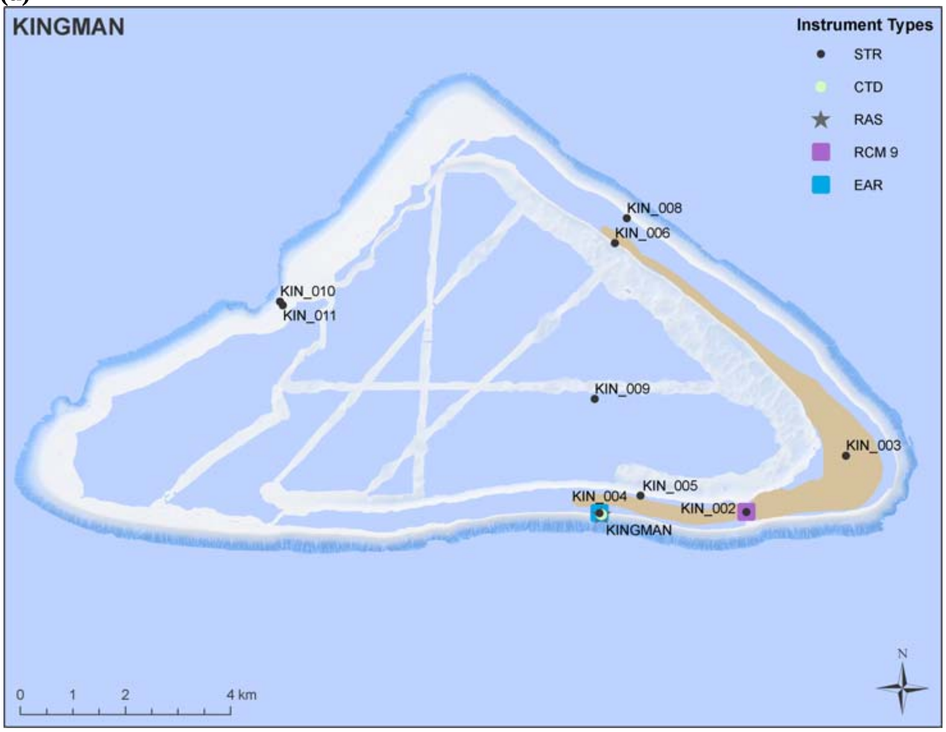
For long-term monitoring, 9 subsurface temperature recorders (STRs), 1 ecological acoustic recorder (EAR), 1 single-point current meter (RCM 9) were recovered and replaced, and 1 sea-surface temperature (SST) buoy was deployed (Figure D.1.1). In addition to these CRED long-term moorings, 4 VR2 listening stations (VEMCO Division, AMIRIX Systems Inc., Halifax, Nova Scotia, Canada) were recovered for Alan Friedlander, PhD, of the U.S. Geological Survey, and 2 pH sensors and 2 STRs were deployed for Nichole Price of the Scripps Institution of Oceanography, University of California San Diego. For information about CAU deployments completed at Kingman Reef, see Figure D.1.2 and Section D.2: "Benthic Environment."

At nearshore locations around Kingman Reef, 8 shallow-water CTD casts were performed (Fig. D.1.2), with 1 cast at each of the 8 select REA sites where CAUs were deployed. In concert with the CTD cast at each of those same REA sites, 2 water samples were taken to measure the following parameters: dissolved inorganic carbon (DIC), salinity, and nutrient, and chlorophyll-*a* (Chl-*a*) concentrations. A total of 16 DIC, 16 salinity, 16 nutrient, and 16 Chl-*a* water samples were collected, 1 from the surface and 1 near the reef at each site. One triplicate sample was also taken at Kingman Reef (Figure D.1.2). In addition to the standard discrete water sampling, a remote auto sampler (RAS) was deployed at REA site KIN-13, where it collected hourly samples over a 48-h period (Fig. D.1.1). Water samples from this RAS will be used for additional carbonate chemistry analysis. A Sea-Bird Electronics Inc. (Bellevue, Wash.) SBE 19*plus* Seacat Profiler attached to that RAS collected conductivity and temperature measurements every 15 min during the same 48-h deployment.

Four deepwater CTD casts were conducted from the NOAA Ship *Hi`ialakai* to a depth of 500 m at Kingman Reef (Fig. D.1.3). Technical problems with the CTD prevented more casts from being performed. A total of 20 shipboard water samples, 10 nutrient and 10

Chl-*a*, were collected at Kingman Reef (a total of 40 CTD casts and 200 discreet water samples had been planned for Kingman Reef.) ADCP data were collected along transect lines for a total length of 20 km.

(a)



(b)

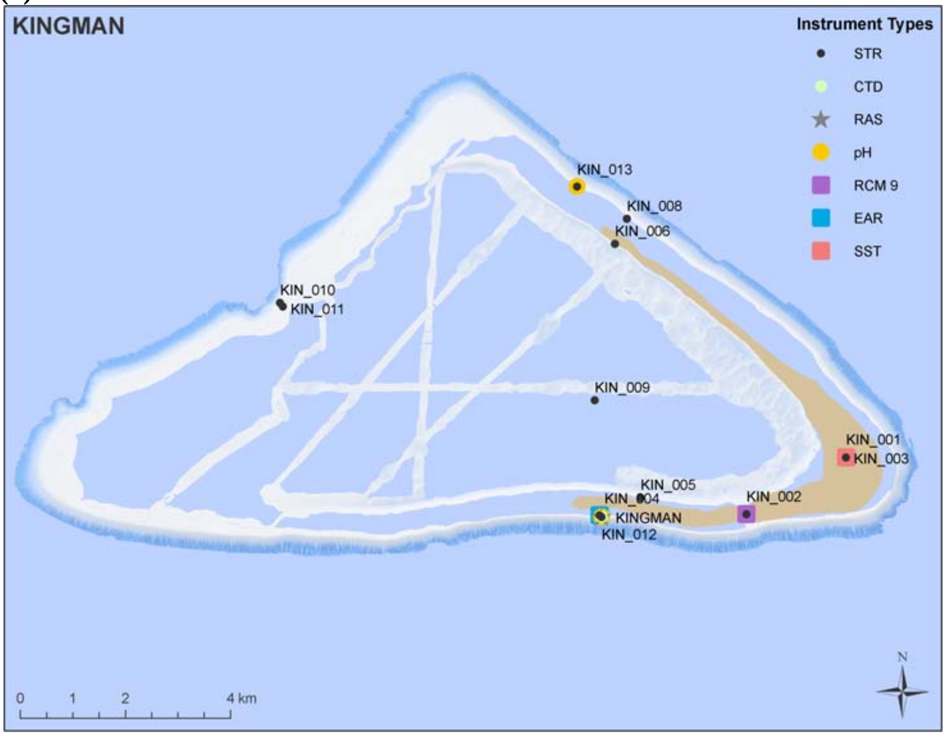


Figure D.1.1. Moored instruments (*a*) retrieved and (*b*) deployed at Kingman Reef during cruise HA-10-01, Leg 3.

Table D.1.1. Geographic coordinates and sensor depths of the moored instruments that were retrieved or deployed at Kingman Reef during cruise HA-10-01, Leg 3.

Mooring Site	Instrument Type	Latitude	Longitude	Sensor Depth (m)
Retrievals				
KIN-002	RCM 9	6.38269	–162.35929	6.4
KIN-002	STR	6.38269	–162.35929	6.7
KIN-003	STR	6.39242	–162.34221	7
KIN-004	EAR	6.38250	–162.38439	7
KIN-004	STR	6.38250	–162.38439	7
KIN-005	STR	6.38553	–162.37740	3.7
KIN-006	STR	6.42893	–162.38178	5.2
KIN-008	STR	6.43323	–162.37972	7.9
KIN-009	STR	6.40219	–162.38522	10.1
KIN-010	STR	6.41887	–162.43914	33.5
KIN-011	STR	6.41823	–162.43863	17.7
KINGMAN	CTD	6.38226	–162.38407	11
KINGMAN	RAS	6.38226	–162.38407	11
Deployments				
KIN-001	SST	6.39242	–162.34221	0.2
KIN-002	RCM 9	6.38269	–162.35927	6.7
KIN-002	STR	6.38269	–162.35927	6.7
KIN-003	STR	6.39242	–162.34221	7
KIN-004	EAR	6.38250	–162.38439	7
KIN-004	STR	6.38250	–162.38439	7
KIN-005	STR	6.38553	–162.37740	3.7
KIN-006	STR	6.42893	–162.38178	5.2
KIN-008	STR	6.43323	–162.37972	7.9
KIN-009	STR	6.40219	–162.38522	10.1
KIN-010	STR	6.41887	–162.43914	33.5
KIN-011	STR	6.41823	–162.43863	17.7
KIN-012	pH sensor	6.38220	–162.38406	14
KIN-012	STR	6.38220	–162.38406	13.4
KIN-013	pH sensor	6.43872	–162.38824	13.1
KIN-013	STR	6.43872	–162.38824	13.1
KINGMAN	CTD	6.38226	–162.38407	11
KINGMAN	RAS	6.38226	–162.38407	11

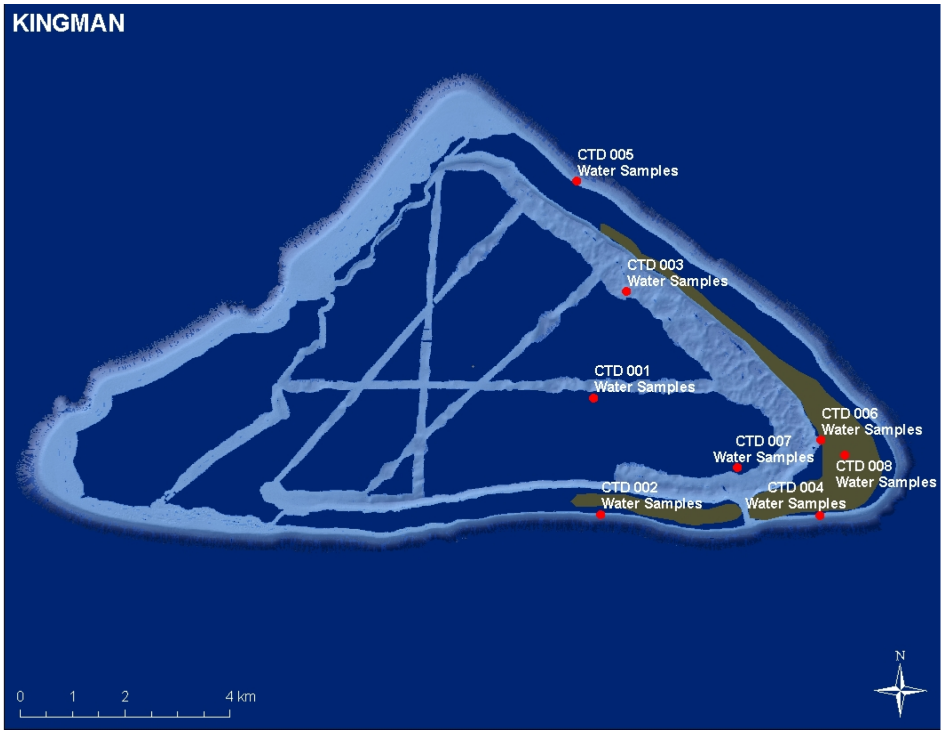


Figure D.1.2. Locations of shallow-water CTD casts performed at Kingman Reef during cruise HA-10-01, Leg 3. At all 8 nearshore cast locations, water samples for analyses of nutrient and Chl-*a* concentrations were collected.

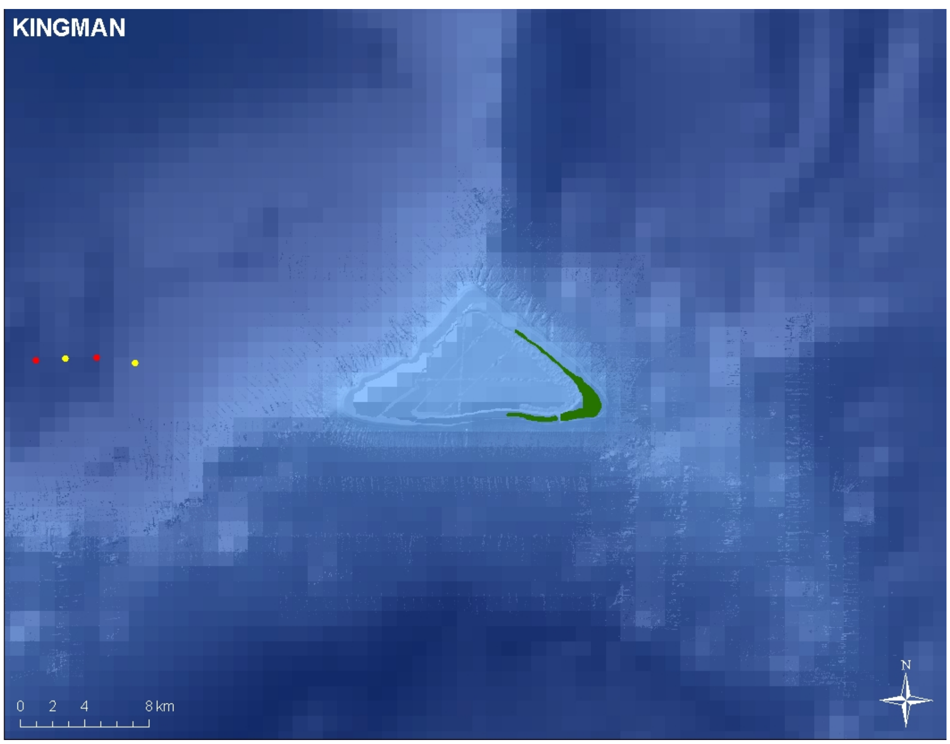


Figure D.1.3. Locations of deepwater CTD casts conducted at Kingman Reef from the NOAA Ship *Hi`ialakai* to a depth of 500 m. Shipboard water samples for analyses of nutrient and Chl-*a* concentrations were collected in concert with the casts conducted at the 2 locations displayed in red. Satellite data: SIO, NOAA, U.S. Navy, NGA, GEBCO (Becker, 2009; Smith and Sandwell, 1997). © 2008 The Regents of the University of California. All Rights Reserved.

Preliminary Results: Temperatures

Temperature data recorded at various depths from 8 locations around Kingman Reef are shown in Figure D.1.4. At all locations, a seasonal warming of temperatures was recorded in summer or fall 2008 before a seasonal cooling in January 2009. Beginning in winter 2009 and extending into November 2009, a general warming pattern was observed in the temperature record, rising ~ 3°C at all depths and all locations around this atoll. Warming of equatorial ocean temperature is typical of forcing from the El Niño-Southern Oscillation, and, as such, it is presumed the anomalous warming pattern observed was a result of the El Niño conditions observed in 2009 and 2010. An anomalous cooling event was recorded at Kingman in September 2008. For ~ 3 weeks, temperatures dropped ~ 2°C at all depths in all locations around this atoll. The physical forcing mechanism behind this cooling event is presently unknown without additional data analysis.

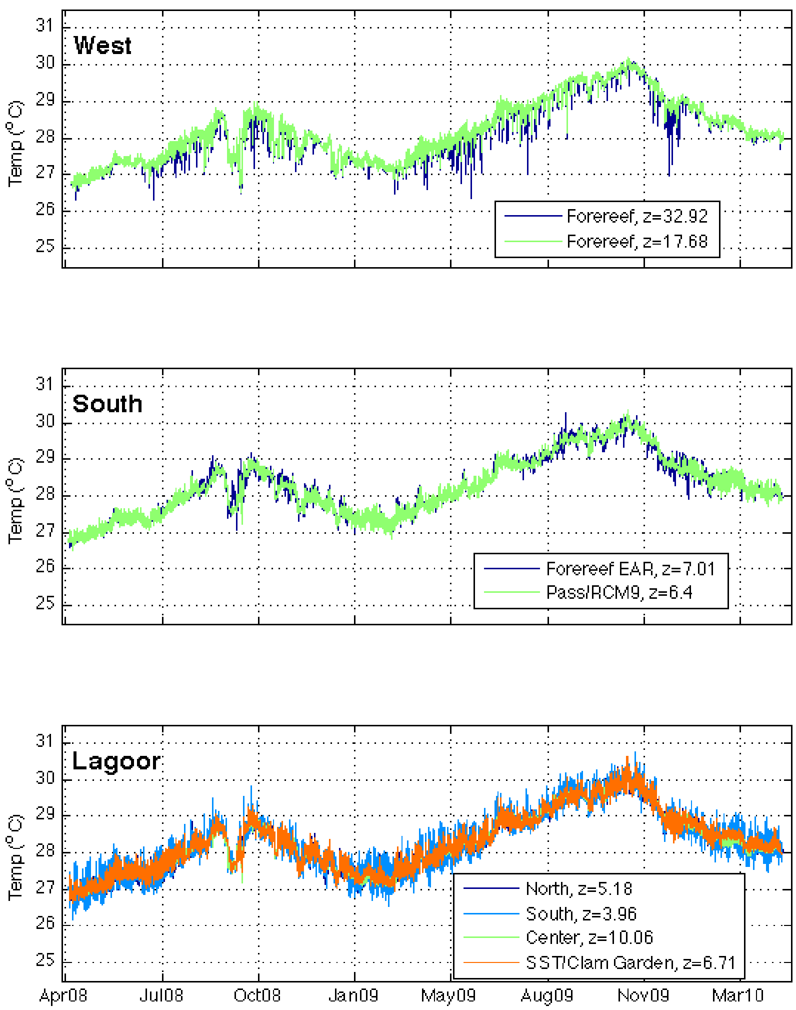


Figure D.1.4. Time-series observations of temperatures from the period of April 2008 to April 2010 collected from moored oceanographic instruments at 8 locations at Kingman Reef.

D.2. Benthic Environment

During HA-10-01, Leg 3, CRED conducted Rapid Ecological Assessment (REA) benthic surveys, using the line-point-intercept and belt-transect methods, at 16 sites at Kingman Reef to assess coral and algal community structure and disease and benthic composition (Fig. D.2.1 and Table D.2.1).

A total of 21 towed-diver surveys were completed at Kingman Reef, covering 42.9 km of ocean floor (Figure D.2.2). The mean survey length was 2.0 km with a range of 1.6–2.6 km. The mean survey depth was 15.1 m with a range of 4.6–18.6 m. The mean temperature on these surveys was 27.9 °C with a range of 27.9°C–28.1°C.

Various samples were collected at several REA sites (Table D.2.1), including 170 algal specimens at 12 sites and 24 microbial water samples at 11 sites and along a transect. Additional microbial collections included plankton tows at 2 locations. Non-coral invertebrate samples included 13 arms from seastars (*Linkia multifora*). A total of 3 coral cores (30–35 cm in length) were recovered from *Porites lobata* at 2 REA sites. The cores will be sent to Woods Hole Oceanographic Institute to measure calcification rates. For a full list of collections made at these REA sites, see Table E.1 in Appendix E: "Biological Collections."

A total of 108 samples of 35 coral species were collected at the same 16 REA sites in support of the NOAA status review of 82 coral species in response to a petition by the Center of Biological Diversity (CBD) to list them under the *Endangered Species Act* (ESA). For an ESA collections list, see Table E.2 in Appendix E.

At 8 select REA sites at Kingman Reef, a total of 50 CAUs were deployed (Fig. D.1.1), with 1 array of 5 CAUs installed at each site for long-term monitoring and, at each of 2 sites, 1 additional array of 5 CAUs installed for Scripps Institution of Oceanography for short-term monitoring. These CAU deployments are the first undertaken by CRED, along with those installations made at other islands in the Pacific Remote Islands Marine National Monument and American Samoa during the cruises HA-10-01, Legs 1, 2, and 3.

A total of 9 autonomous reef monitoring structures (ARMS) were recovered and installed near 3 REA sites (Table D.2.1).

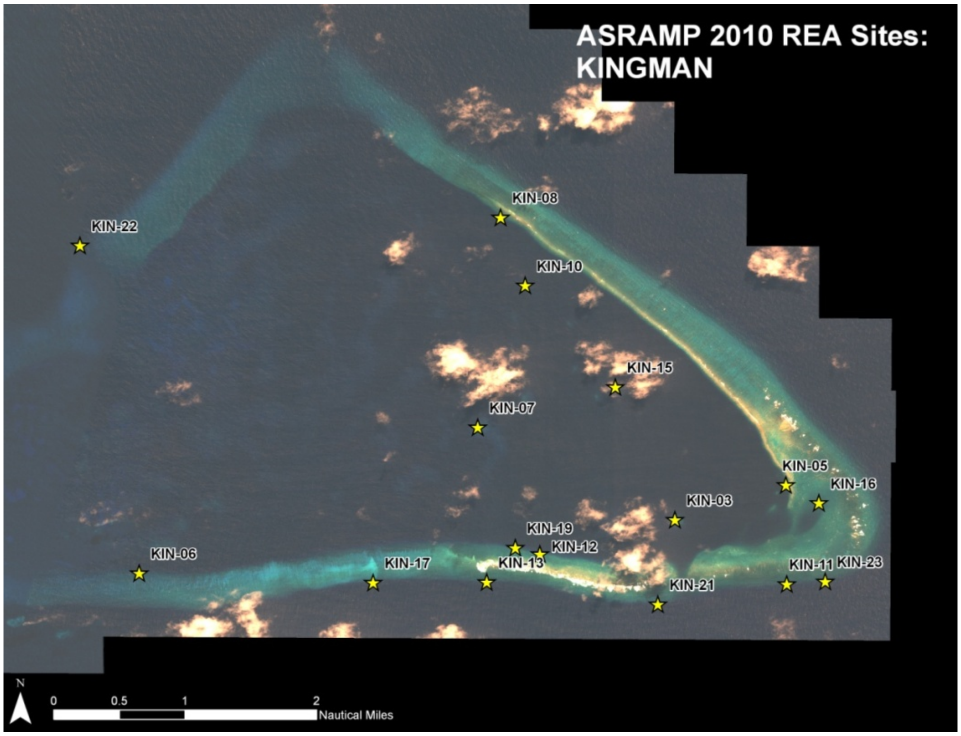


Figure D.2.1. Locations of REA benthic sites surveyed at Kingman Reef during cruise HA-10-01, Leg 3 (IKONOS Carterra Geo Data, 2003).

Table D.2.1. Summary of REA benthic surveys, deployments and retrievals of moored biological installations, and sample collections performed at REA sites at Kingman Reef during cruise HA-10-01, Leg 3. The line-point-intercept (LPI) method was used to estimate percentage of cover of algae, corals, and other invertebrates. Photoquadrat surveys (Photo) recorded digital images of benthos for later analysis of benthic cover. Surveys of coral community structure and condition (Corals) were performed using the belt-transect method. Belt-transect surveys of other invertebrates and roving-diver surveys of algae were not conducted. This table does not include the coral specimens for taxonomic verification that were collected by U.S. Fish and Wildlife Service biologist James Maragos.

REA Site	Date	Latitude	Longitude	REA Surveys			Deployments and Retrievals		Sample Collections	
				LPI	Photo	Corals	CAUs	ARMS	Algae	Microbial Samples
KIN-11	14-Apr	6.3820	–162.3462	×	×	×	×	—	×	—
KIN-13	14-Apr	6.3822	–162.3843	×	×	×	×	×	×	×
KIN-17	14-Apr	6.3822	–162.3987	×	×	×	—	—	×	—
KIN-12	15-Apr	6.3858	–162.3775	×	×	×	—	—	×	×
KIN-21	15-Apr	6.3794	–162.3626	×	×	×	—	—	×	—
KIN-23	15-Apr	6.3823	–162.3413	×	×	×	—	×	×	×
KIN-03	16-Apr	6.3903	–162.3604	×	×	×	×	—	×	—
KIN-04	16-Apr	6.4387	–162.3882	—	—	—	×	—	—	—
KIN-07	16-Apr	6.4022	–162.3855	×	×	×	×	—	×	×
KIN-16	16-Apr	6.3924	–162.3421	×	×	×	×	—	—	×
KIN-05	17-Apr	6.3947	–162.3463	×	×	×	×	×	×	—
KIN-08	17-Apr	6.4291	–162.3826	×	×	×	—	—	×	×
KIN-10	17-Apr	6.4204	–162.3794	×	×	×	×	—	×	×
KIN-15	18-Apr	6.4073	–162.3680	×	×	×	—	—	×	×
KIN-19	18-Apr	6.3867	–162.3807	×	×	×	—	—	—	×
KIN-06	19-Apr	6.3834	–162.4285	×	×	×	—	—	—	×
KIN-22	19-Apr	6.4255	–162.4360	×	×	×	—	—	—	×

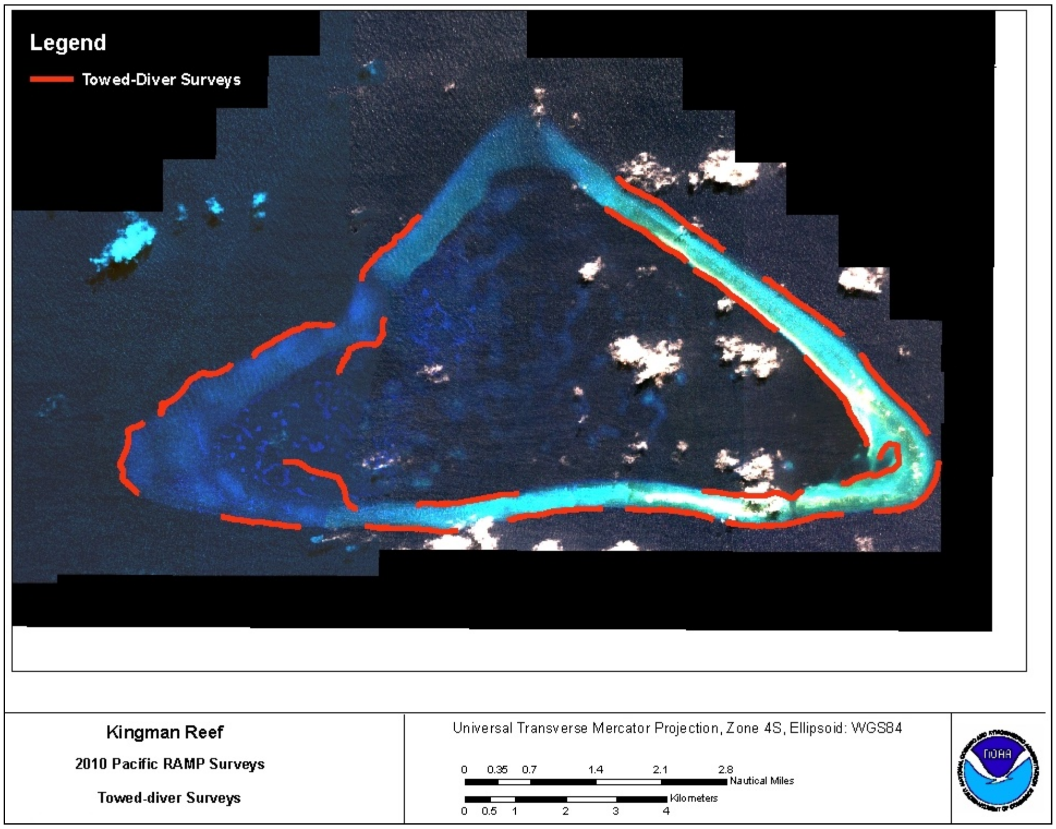


Figure D.2.2. Tracks of towed-diver surveys (fish and benthic) conducted at Kingman Reef during cruise HA-10-01, Leg 3 (IKONOS Carterra Geo Data, 2003).

D.3. Reef Fish Community

During cruise HA-10-01, Leg 3, CRED conducted REA fish surveys, using a stratified random design and stationary-point-count method, at 33 REA sites at Kingman Reef over 3 different habitat strata: deep, moderate, and shallow forereef (Fig. D.3.1 and Table D.3.1). The fish team made no collection efforts at Kingman Reef

In addition, CRED completed 21 towed-diver surveys at Kingman Reef as described in section D.2 of this report (Figure D.2.2.).

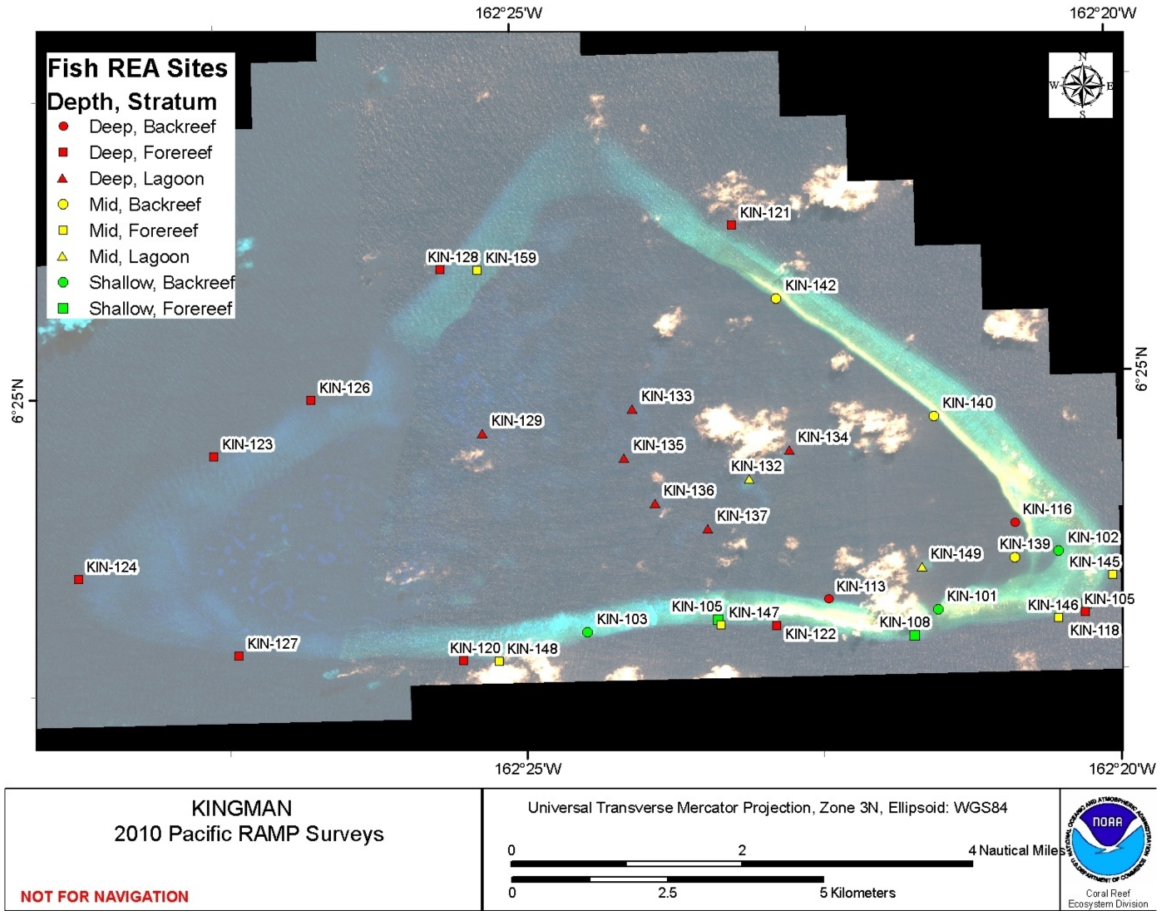


Figure D.3.1. Locations of REA fish sites surveyed around Kingman Reef during cruise HA-10-01, Leg 3. All of these REA sites were selected using a stratified random design (IKONOS Carterra Geo Data, 2003).

Table D.3.1. Summary of sites where REA fish surveys were conducted around Kingman Reef during cruise HA-10-10, Leg 3.

REA Site	Date	Depth, Stratum Description	Depth (m)	Latitude	Longitude
KIN-103	14-Apr	Shallow, Backreef	5	6.38196926	–162.407961
KIN-105	14-Apr	Shallow, Forereef	5	6.38317608	–162.3895933
KIN-120	14-Apr	Deep, Forereef	23	6.37849588	–162.4255317
KIN-147	14-Apr	Moderate, Forereef	13	6.38240637	–162.3892745
KIN-148	14-Apr	Moderate, Forereef	13	6.37823621	–162.4205093
KIN-101	15-Apr	Shallow, Backreef	6	6.38373432	–162.3587386
KIN-106	15-Apr	Shallow, Forereef	5	6.3839722	–162.3378922
KIN-108	15-Apr	Shallow, Forereef	6	6.38015893	–162.3621004
KIN-118	15-Apr	Deep, Forereef	23	6.38279337	–162.3380862
KIN-122	15-Apr	Deep, Forereef	24	6.38208325	–162.3814006
KIN-145	15-Apr	Moderate, Forereef	15	6.38795838	–162.3340871
KIN-146	15-Apr	Moderate, Forereef	14	6.38214352	–162.3419165
KIN-149	15-Apr	Moderate, Lagoon	14	6.38977214	–162.3607279
KIN-121	16-Apr	Deep, Forereef	24	6.4384093	–162.3861333
KIN-128	16-Apr	Deep, Forereef	24	6.4333318	–162.427215
KIN-129	16-Apr	Deep, Lagoon	25	6.41016874	–162.4218631
KIN-133	16-Apr	Deep, Lagoon	22	6.41298833	–162.4007331
KIN-140	16-Apr	Moderate, Backreef	14	6.41082211	–162.3585786
KIN-142	16-Apr	Moderate, Backreef	14	6.42794693	–162.3801776
KIN-159	16-Apr	Moderate, Forereef	9	6.43303491	–162.4220302
KIN-102	17-Apr	Shallow, Backreef	6	6.39141642	–162.3416053
KIN-116	17-Apr	Deep, Backreef	22	6.39561173	–162.3476436
KIN-134	17-Apr	Deep, Lagoon	23	6.40655933	–162.3788781
KIN-139	17-Apr	Moderate, Backreef	18	6.39069306	–162.3477261
KIN-113	18-Apr	Deep, Backreef	23	6.38560197	–162.3740682
KIN-132	18-Apr	Moderate, Lagoon	14	6.40269209	–162.3845702
KIN-135	18-Apr	Deep, Lagoon	23	6.40609212	–162.4020479
KIN-136	18-Apr	Deep, Lagoon	25	6.39966287	–162.3979179
KIN-137	18-Apr	Deep, Lagoon	24	6.39588774	–162.390575
KIN-123	19-Apr	Deep, Forereef	20	6.40797067	–162.4596993
KIN-124	19-Apr	Deep, Forereef	20	6.39142522	–162.4792086
KIN-126	19-Apr	Deep, Forereef	22	6.41556552	–162.4458551
KIN-127	19-Apr	Deep, Forereef	23	6.38003304	–162.4570058

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APPENDIX E: BIOLOGICAL COLLECTIONS

Biological samples were collected at Jarvis Island, Palmyra Atoll, Kingman Reef, and their surrounding waters for multiple research purposes. A complete listing of these collections are presented here in Table E.1, excluding targeted coral diversity collections by U.S. Fish and Wildlife Service biologist James Maragos; these coral samples are reported in this appendix in Table E.2.

Table E.1. Biological samples collected around Jarvis Island, Palmyra Atoll, and Kingman Reef during cruise HA-10-01, Leg 3, April 1–April 19, 2010. At each REA site included in this table, for each species of *Halimeda* listed, 5 samples were collected (for other algal species listed, 1 sample was collected). Multiple samples of the seastar *Linckia multifora* were collected at each REA site noted for invertebrate collections.

REA Site	Island	Date	Latitude	Longitude	Specimen Collected	Depth (m)
Algal Collections: Voucher Specimens						
JAR-02	Jarvis	2-Apr	0.38173	–160.00864	*Halimeda fragilis*	12–15
JAR-03	Jarvis	2-Apr	0.36200	–160.00079	*Halimeda fragilis*	12–15
JAR-09	Jarvis	2-Apr	0.36494	–160.00601	*Halimeda fragilis*	12–15
JAR-01	Jarvis	3-Apr	0.36787	–159.97919	*Halimeda fragilis*	12–15
JAR-08	Jarvis	3-Apr	0.36314	–159.991389	*Carpopeltis sp.*	12–15
JAR-08	Jarvis	3-Apr	0.36314	–159.991389	*Cyanobacteria*	12–15
JAR-08	Jarvis	3-Apr	0.36314	–159.991389	*Halimeda fragilis*	12–15
JAR-08	Jarvis	3-Apr	0.36314	–159.991389	*Peysonnelia sp.*	12–15
JAR-08	Jarvis	3-Apr	0.36314	–159.991389	*Unidentified red*	12–15
JAR-04	Jarvis	4-Apr	0.38227	–160.00299	*Dictyoata sp.*	12–15
JAR-04	Jarvis	4-Apr	0.38227	–160.00299	*Halimeda fragilis*	12–15
JAR-12	Jarvis	4-Apr	0.38228	–159.98396	*Halimeda fragilis*	12–15
PAL-05	Palmyra	7-Apr	5.98582	–162.13795	*Halimeda taenicola*	12–15
PAL-05	Palmyra	7-Apr	5.98582	–162.13795	*Halimeda taenicola*	12–15
PAL-12	Palmyra	7-Apr	5.89713	–162.10785	*Halimeda taenicola*	12–15
PAL-12	Palmyra	7-Apr	5.89713	–162.10785	*Halimeda fragilis*	12–15
PAL-12	Palmyra	7-Apr	5.89713	–162.10785	*Halimeda opuntia*	12–15
PAL-21	Palmyra	7-Apr	5.89556	–162.086	*Halimeda opuntia*	12–15
PAL-21	Palmyra	7-Apr	5.89556	–162.086	*Halimeda taenicola*	12–15
PAL-11	Palmyra	8-Apr	5.88341	–162.13344	*Halimeda fragilis*	12–15
PAL-11	Palmyra	8-Apr	5.88341	–162.13344	*Halimeda opuntia*	12–15
PAL-11	Palmyra	8-Apr	5.88341	–162.13344	*Halimeda taenicola*	12–15
PAL-26	Palmyra	8-Apr	5.864145	–162.12698	*Halimeda fragilis*	12–15
PAL-26	Palmyra	8-Apr	5.864145	–162.12698	*Halimeda opuntia*	12–15
PAL-26	Palmyra	8-Apr	5.864145	–162.12698	*Halimeda taenicola*	12–15
PAL-10	Palmyra	9-Apr	5.86605	–162.04868	*Halimeda fragilis*	12–15
PAL-10	Palmyra	9-Apr	5.86605	–162.04868	*Halimeda opuntia*	12–15
PAL-10	Palmyra	9-Apr	5.86605	–162.04868	*Halimeda taenicola*	12–15
PAL-25	Palmyra	9-Apr	5.86384	–162.03055	*Halimeda fragilis*	12–15
PAL-25	Palmyra	9-Apr	5.86384	–162.03055	*Halimeda opuntia*	12–15
PAL-25	Palmyra	9-Apr	5.86384	–162.03055	*Halimeda taenicola*	12–15
PAL-19	Palmyra	10-Apr	5.86630	–162.10956	*Halimeda fragilis*	12–15
PAL-19	Palmyra	10-Apr	5.86630	–162.10956	*Halimeda opuntia*	12–15

REA Site	Island	Date	Latitude	Longitude	Specimen Collected	Depth (m)
PAL-19	Palmyra	10-Apr	5.86630	–162.10956	*Halimeda taenicola*	12–15
PAL-09	Palmyra	11-Apr	5.86742	–162.09558	*Halimeda fragilis*	12–15
PAL-09	Palmyra	11-Apr	5.86742	–162.09558	*Halimeda opuntia*	12–15
PAL-09	Palmyra	11-Apr	5.86742	–162.09558	*Halimeda taenicola*	12–15
PAL-01	Palmyra	12-Apr	5.86802	–162.06927	*Halimeda fragilis*	12–15
PAL-01	Palmyra	12-Apr	5.86802	–162.06927	*Halimeda opuntia*	12–15
PAL-02	Palmyra	13-Apr	5.88258	–162.13142	*Halimeda fragilis*	12–15
PAL-02	Palmyra	13-Apr	5.88258	–162.13142	*Halimeda opuntia*	12–15
PAL-02	Palmyra	13-Apr	5.88258	–162.13142	*Halimeda taenicola*	12–15
KIN-11	Kingman	14-Apr	6.81950	–162.34637	*Halimeda fragilis*	12–15
KIN-17	Kingman	14-Apr	6.38220	–162.39861	*Halimeda fragilis*	12–15
KIN-13	Kingman	14-Apr	6.38227	–162.38414	*Halimeda fragilis*	12–15
KIN-11	Kingman	14-Apr	6.81950	–162.34637	*Halimeda opuntia*	12–15
KIN-11	Kingman	14-Apr	6.81950	–162.34637	*Halimeda taenicola*	12–15
KIN-13	Kingman	14-Apr	6.38227	–162.38414	*Halimeda opuntia*	12–15
KIN-13	Kingman	14-Apr	6.38227	–162.38414	*Halimeda taenicola*	12–15
KIN-17	Kingman	14-Apr	6.38220	–162.39861	*Halimeda opuntia*	12–15
KIN-17	Kingman	14-Apr	6.38220	–162.39861	*Halimeda taenicola*	12–15
KIN-12	Kingman	15-Apr	3.38602	–162.37776	*Halimeda fragilis*	12–15
KIN-12	Kingman	15-Apr	3.38602	–162.37776	*Halimeda opuntia*	12–15
KIN-12	Kingman	15-Apr	3.38602	–162.37776	*Halimeda taenicola*	12–15
KIN-21	Kingman	15-Apr	6.37952	–162.36273	*Halimeda opuntia*	12–15
KIN-23	Kingman	15-Apr	6.38228	–162.34137	*Halimeda fragilis*	12–15
KIN-23	Kingman	15-Apr	6.38228	–162.34137	*Halimeda opuntia*	12–15
KIN-23	Kingman	15-Apr	6.38228	–162.34137	*Halimeda taenicola*	12–15
KIN-03	Kingman	16-Apr	6.39029	–162.36066	*Halimeda fragilis*	12–15
KIN-03	Kingman	16-Apr	6.39029	–162.36066	*Halimeda opuntia*	12–15
KIN-03	Kingman	16-Apr	6.39029	–162.36066	*Halimeda taenicola*	12–15
KIN-07	Kingman	16-Apr	6.40214	–162.38525	*Halimeda fragilis*	12–15
KIN-07	Kingman	16-Apr	6.40214	–162.38525	*Halimeda opuntia*	12–15
KIN-07	Kingman	16-Apr	6.40214	–162.38525	*Halimeda taenicola*	12–15
KIN-05	Kingman	17-Apr	6.39320	–162.34741	*Halimeda fragilis*	12–15
KIN-05	Kingman	17-Apr	6.39320	–162.34741	*Halimeda opuntia*	12–15
KIN-05	Kingman	17-Apr	6.39320	–162.34741	*Halimeda taenicola*	12–15
KIN-08	Kingman	17-Apr	6.42929	–162.38261	*Halimeda fragilis*	12–15
KIN-08	Kingman	17-Apr	6.42929	–162.38261	*Halimeda opuntia*	12–15
KIN-08	Kingman	17-Apr	6.42929	–162.38261	*Halimeda taenicola*	12–15
KIN-10	Kingman	17-Apr	6.42040	–162.37956	*Halimeda fragilis*	12–15
KIN-10	Kingman	17-Apr	6.42040	–162.37956	*Halimeda opuntia*	12–15
KIN-10	Kingman	17-Apr	6.42040	–162.37956	*Halimeda taenicola*	12–15
KIN-15	Kingman	18-Apr	6.40749	–162.3683	*Halimeda fragilis*	12–15
KIN-15	Kingman	18-Apr	6.40749	–162.3683	*Halimeda opuntia*	12–15
KIN-15	Kingman	18-Apr	6.40749	–162.3683	*Halimeda taenicola*	12–15
Non-coral Invertebrate Collections						
JAR-04	Jarvis	4-Apr	0.38227	–160.00299	*Linckia multifora*	14
JAR-11	Jarvis	5-Apr	0.36899	–160.00813	*Linckia multifora*	14

REA Site	Island	Date	Latitude	Longitude	Specimen Collected	Depth (m)
KIN-05	Kingman	17-Apr	6.3932	–162.34741	*Linckia multifora*	13
Microbial Collections: Water Samples						
JAR-04	Jarvis	1-Apr	0.38227	–160.00299	8-L water sample	14
JAR-09	Jarvis	2-Apr	0.36494	–160.00601	8-L, 70-L water samples	14
JAR-08	Jarvis	3-Apr	0.36314	–159.99139	8-L water sample	12
JAR-04	Jarvis	4-Apr	0.38227	–160.00299	70-L water sample	14
JAR-10	Jarvis	4-Apr	0.38128	–159.00299	8-L water sample	11
JAR-11	Jarvis	5-Apr	0.36899	–160.00813	8-L water sample	14
PAL-12	Palmyra	7-Apr	5.89713	–162.10785	8-L water sample	13
PAL-17	Palmyra	8-Apr	5.87531	–162.13901	8-L, 70-L water samples	19
PAL-25	Palmyra	9-Apr	5.86384	–162.03055	8-L water sample	13
PAL-19	Palmyra	10-Apr	5.86630	–162.10956	8-L water sample	12
PAL-09	Palmyra	11-Apr	5.86742	–162.09558	8-L water sample	12
PAL-16	Palmyra	11-Apr	5.87160	–162.11247	8-L water sample	2
PAL-01	Palmyra	12-Apr	5.86802	–162.06927	8-L water sample	13
KIN-13	Kingman	14-Apr	6.38227	–162.38414	8-L water sample	12
KIN-12	Kingman	15-Apr	3.38602	–162.37776	8-L water sample	13
KIN-23	Kingman	15-Apr	6.38228	–162.34137	8-L water sample	15
KIN-07	Kingman	16-Apr	6.40214	–162.38525	8-L water sample	11
KIN-16	Kingman	16-Apr	6.3924	–162.34210	8-L water sample	5
Transect	Kingman	16-Apr	6.39503	–162.36026	0.6-L water samples	2
KIN-08	Kingman	17-Apr	6.42929	–162.38261	8-L water sample	13
KIN-10	Kingman	17-Apr	6.42040	–162.37956	8-L, 70-L water samples	14
KIN-15	Kingman	18-Apr	6.40749	–162.36830	8-L water sample	12
KIN-19	Kingman	18-Apr	6.38655	–162.38072	8-L water sample	13
KIN-06	Kingman	19-Apr	6.38354	–162.42812	8-L water sample	12
KIN-22	Kingman	19-Apr	6.42500	–162.43364	8-L water sample	15
Coral Core Collections						
JAR-07	Jarvis	4-Apr	-0.37627	-160.01388	1 coral core	23
JAR-07	Jarvis	4-Apr	-0.37612	-160.01394	1 coral core	45
JAR-11	Jarvis	4-Apr	-0.36896	-160.00818	1 coral core	55
JAR-11	Jarvis	4-Apr	-0.3689	-160.00819	1 coral core	61
JAR-11	Jarvis	4-Apr	-0.36912	-160.00823	1 coral core	42
JAR-11	Jarvis	4-Apr	-0.36889	-160.00808	1 coral core	28
PAL-19	Palmyra	13-Apr	5.86635	-162.10966	1 coral core	45
PAL-19	Palmyra	13-Apr	5.86636	-162.10954	1 coral core	41
PAL-19	Palmyra	13-Apr	5.86638	-162.10945	1 coral core	45
KIN-07	Kingman	18-Apr	6.40214	-162.38533	1 coral core	34
KIN-07	Kingman	18-Apr	6.40221	-162.38557	1 coral core	37
KIN-10	Kingman	18-Apr	6.42032	-162.37946	1 coral core	37
KIN-10	Kingman	18-Apr	6.42017	-162.37932	1 coral core	33
KIN-10	Kingman	18-Apr	6.42062	-162.37934	1 coral core	34

Table E.2. Number of coral samples, by species and island, collected by U.S. Fish and Wildlife Service biologist James Maragos around Johnston Atoll, Howland Island, and Baker Island during cruise HA-10-01, Leg 1, January 21–February 14, 2010.

Sampled Coral Species	Jarvis Island	Palmyra Atoll	Kingman Reef	Totals by Species
Acropora acuminata	–	3	4	**7**
Acropora cytherea	1	3	3	**7**
Acropora humilis-gemmifera	–	2	2	**4**
Acropora microclados	–	3	–	**3**
Acropora muricata	–	1	–	**1**
Acropora rosaria	–	3	2	**5**
Acropora sp. [Line & Phoenix]	–	2	–	**2**
Acropora sp. [slanted cones]	–	–	1	**1**
Acropora valida	4	4	3	**11**
Cyphastrea ocellina	–	–	2	**2**
Distichopora sp.	–	2	4	**6**
Echinophyllia aspera	1	–	–	**1**
Favia stelligera	4	3	3	**10**
Leptastrea pruinosa	1	–	2	**3**
Leptoseris incrustans	4	–	–	**4**
Leptoseris mycetoseroides	3	6	3	**12**
Montipora aequituberculata	2	–	6	**8**
Montipora caliculata	6	2	3	**11**
Montipora capitata	–	3	4	**7**
Montipora cf. incrassata	–	4	4	**8**
Montipora dilatata	–	3	–	**3**
Montipora efflorescens	–	1	5	**6**
Montipora flabellata	–	3	1	**4**
Montipora hoffmeisteri	–	–	3	**3**
Montipora monasteriata	–	–	–	**0**
Montipora patula	–	4	3	**7**
Montipora sp. [tiny tubes]	–	2	–	**2**
Montipora venosa	2	–	–	**2**
Pavona chiriquiensis	2	–	1	**3**
Pavona clavus	3	3	–	**6**
Pavona duerdeni	–	–	3	**3**
Pavona explanulata	2	–	–	**2**
Pavona maldivensis	4	4	3	**11**
Pavona minuta	1	–	–	**1**
Pavona varians	1	–	2	**3**
Pocillopora brevicornis	3	4	–	**7**
Pocillopora eydouxi	3	5	4	**12**
Pocillopora ligulata	4	1	–	**5**
Pocillopora meandrina	3	2	4	**9**
Pocillopora molokensis	3	–	–	**3**
Pocillopora verrucosa	1	3	4	**8**
Pocillopora zelli	4	–	4	**8**
Porites australiensis	3	3	3	**9**
Porites lobata	4	3	2	**9**

Sampled Coral Species	**Jarvis Island**	**Palmyra Atoll**	**Kingman Reef**	**Totals by Species**
Porites lutea	1	4	–	**5**
Porites rus	–	3	3	**6**
Porites solida	2	–	–	**2**
Porites sp. [angular fingers]	–	5	–	**5**
Porites sp. [saucer]	–	–	2	**2**
Porites sp. [smooth fingers]	–	–	8	**8**
Porites superfusa	–	4	3	**7**
Porites vaughani	–	3	–	**3**
Psammocora nierstraszi	–	–	1	**1**
Stylaster sp.	1	3	3	**7**
Tubastraea coccinea	3	2	–	**5**
Totals by Island	**76**	**106**	**108**	**290**