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CRUISE REPORT[1]

VESSEL: NOAA Ship *Hi`ialakai*, Cruise HA-12-01, Legs II and III

CRUISE PERIOD: 1–27 April 2012

AREA OF OPERATION: American Samoa: Tutuila Island, Ofu and Olosega Islands, Ta`u Island, and Rose Atoll

TYPE OF OPERATION: Personnel from the Coral Reef Ecosystem Division (CRED) of the NOAA Pacific Islands Fisheries Science Center, Fagatele National Marine Sanctuary, U.S. Fish and Wildlife Service, and University of Hawai`i at Hilo conducted interdisciplinary Pacific Reef Assessment and Monitoring Program (Pacific RAMP) surveys in waters surrounding American Samoa. All activities described in this report were covered by the following permits: American Samoa Department of Marine and Wildlife Resources Scientific Permit Series No. 2012-57; Fagatele Bay National Marine Sanctuary Research Permit No. FBNMS-2011-002; National Park of American Samoa research permit number NPSA-2012-SCI-0001; and Pacific Reefs National Wildlife Refuge Complex special use permit number 12521-10001.

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.

1 April — Start of cruise; embarked all scientific crew. Departed Pago Pago Harbor, American Samoa, at 0800; deployed and retrieved the following kinds of instruments: subsurface temperature recorder (STR), ecological acoustic recorder (EAR), calcification acidification units (CAUs). Near-shore conductivity, temperature, and depth (CTD) profiles were collected, and water samples procured for chlorophyll-*a* (Chl-*a*), nutrient, dissolved inorganic carbon (DIC), total alkalinity (TA) salinity, and microbial community analyses. Shipboard

[1] PIFSC Cruise Report CR-12-005
Issued 27 July 2012

operations included acoustic Doppler current profiler (ADCP) transects, deepwater CTD casts, and water sampling for Chl-*a*, and nutrient concentrations.

2 April — Conducted field surveys off NW Tutuila; deployed and retrieved 6 STRs, 1 EAR, and CAUs at 3 sites (2 units lost at site TUT-19). Conducted near-shore CTD profiles and collected water for Chl-*a*, nutrient, DIC, TA, and microbial community analyses. Shipboard operations included ADCP transects, deepwater CTD casts, and water sampling for Chl-*a*, and nutrient concentrations.

3 April — Conducted field surveys off SW Tutuila; deployed and retrieved several instruments including sea surface temperature buoy (SST), wave and tide recorder (WTR), STR, and CAUs. Conducted nearshore CTD profiles, and collected water samples for Chl-*a*, nutrient, DIC, TA, salinity, and microbial community analyses. Shipboard operations included ADCP transects, deepwater CTD casts, and water sampling for Chl-*a*, and nutrient concentrations.

4 April — Conducted field surveys off North Tutuila; operations focused on comprehensive REA fish surveys in and around Vatia Bay. In addition, deployed and retrieved several instruments including one EAR and several STRs, and CAUs; no towed-diver surveys. Shipboard operations included acoustic ADCP transects, deepwater CTD casts, and water sampling for Chl-*a* and nutrient concentrations.

5 April — Conducted field surveys off NE Tutuila; one set of CAUs were recovered and redeployed at REA site TUT-17; deployed an SST buoy at Fagasa and retrieved one coral core at site TUT-18. Conducted nearshore CTD profiles and collected water samples for Chl-*a*, nutrient, DIC, TA, salinity, and metagenomic microbial community analyses. No shipboard operations occurred on the night of 5 April.

6 April — Conducted field surveys off N Tutuila; operations focused on comprehensive REA fish surveys in and around Vatia Bay. No towed-diver surveys, instrument deployments, or nearshore CTD cast occurred. No shipboard operations took place on the night of 6 April.

7 April — Conducted field surveys off SE Tutuila; one set of Autonomous Reef Monitoring Structures (ARMS) were recovered and redeployed at REA site TUT-01. Instrument deployments included one ADCP and WTR at Faga’alu Bay, in addition to collecting one coral core. No shipboard operations occurred on the night of 7 April.

8 April — Teams conducted field surveys off SE–SW Tutuila; one set of ARMS was recovered and redeployed at REA site TUT-11. Instrument deployments

included one ADCP, WTR, and SeaBird37 in the reef pass at Faga'alu Bay; one ~ 90 cm coral core was also collected west of Faga'alu Bay. Additionally, water samples for microbial community analyses were collected at Fagatele and Faga'alu Bays. Returned to Pago Harbor; no shipboard operations occurred on the night of 8 April.

9 April — In-port operations; field work focused on intensive fish surveys in and around Faga'alu Bay. The oceanography team deployed a shallow STR on SE Tutuila; no nearshore CTD cast conducted.

10 April — In-port operations; field work focused on intensive fish surveys in and around Faga'alu Bay. The oceanography team deployed a shallow STR on SE Tutuila; no nearshore CTD cast conducted. Ship hosted an education and outreach open house activity for students from various high schools on Tutuila Island.

11 April — In-port at Pago Pago, American Samoa; ship hosted an open education and outreach house activity sponsored by the Fagatele Bay National Marine Sanctuary.

12 April — Embarked Frank Pendleton and conducted field surveys in and around Pago Harbor and south Tutuila; the oceanography team worked at Faga'alu Bay to reposition acoustic instrumentation.

13–16 April — OMAO Ship delay

17 April — Embarked Oliver Vetter; transited to South Bank and conducted field operations; recovered one STR deployed during the ASRAMP 2010 cruise. Departed South Bank en route to Rose Atoll (~ 16 hr transit).

18 April — Arrived at Rose Atoll and conducted field operations. Deployed and recovered the following types of instruments, ARMS, CAUs, SST, and EAR, STRs). Mr. Frank Pendleton (USFWS) met the USFWS terrestrial survey team who arrived on 16 April to conduct inventories and assessments for insects and other Arthropods. No shipboard operations occurred on the night of 18 April.

19 April — Continued field operations at Rose Atoll. Deployed and recovered the following types of instruments: ARMS, CAU, SST, EAR, and WTR, Nearshore CTD profiles were collected and water samples were procured for Chl-*a*, nutrient, DIC, TA, salinity, and microbial community analyses. No shipboard operations occurred on the night of 19 April.

20 April — Continued field operations at Rose Atoll. Deployed and recovered the following types of instruments: ARMS and CAU. Nearshore CTD profiles were collected and water samples were procured for Chl-*a*, nutrient, DIC,

TA, salinity, and microbial community analyses. No shipboard operations occurred on the night of 20 April.

21 April Continued field operations at Rose Atoll. Deployed and recovered the following types of instruments: ARMS, CAU, and SST buoy. One ~ 70 cm coral core was drilled from a *Porites* colony on the NW forereef. Nearshore CTD profiles were collected and water samples procured for Chl-*a*, nutrient, DIC, TA, salinity, and microbial community analyses. At the request of USFWS Refuge Manager, Frank Pendleton, sets of CAUs were deployed at two western, backreef sites; one adjacent to the wreck site ROS-07 and the second one to the south of the first one. Departed Rose Atoll at 1800 h en route to Ta'u Island.

22 April Arrived at Ta’u Island and conducted field operations. Deployed and recovered the following types of instruments: CAU, SST buoy, and STR. Nearshore CTD profiles were conducted and water samples procured for Chl-*a*, nutrients, DIC, TA, and salinity. Successfully repaired a core plug on the large massive *Porites* colony referred to as “Big Mama.” No shipboard CTD operations occurred on the night of 22 April.

23 April Continued operations at Ta’u Island. Deployed and recovered the following types of instruments: CAUs and STRs. Near-shore CTD profiles were conducted and water samples procured for Chl-*a*, nutrients, DIC, TA, and salinity. Departed Ta’u Island en route to Ofu and Olosega Islands; no shipboard CTD operations occurred on the night of 23 April.

24 April Arrived at Ofu and Olosega Islands and conducted field operations at Olosega Island. Deployed and recovered the following types of instruments: ARMS, CAUs and STRs. Nearshore CTD profiles were conducted and water samples procured for Chl-*a*, nutrients, DIC, TA, salinity, and microbial community analyses. No shipboard CTD operations occurred on the night of 24 April.

25 April Continued operations at Ofu Island. Deployed and recovered the following types of instruments: ARMS, CAUs, SST, and STRs. Nearshore CTD profiles were conducted and water samples procured for Chl-*a*, nutrients, DIC, TA, salinity, and microbial community analyses. No shipboard CTD operations occurred on the night of 25 April**.**

26 April Continued operations at Ofu Island. Deployed and recovered the following types of instruments: ARMS, CAUs, and STRs. Nearshore CTD profiles were conducted and water samples procured for Chl-*a*, nutrients, DIC, TA, salinity, and microbial community analyses. Departed Ofu Island at 1800 h en route to Pago Harbor No shipboard CTD operations occurred on the night of 26 April.

27 April Arrived at Pago Harbor, Tutuila Island. End of cruise. Disembarked Bernardo Vargas-Ángel, Cristi Richards, Adel Heenan, Matthew Dunlap, Marc Nadon, Kerry Grimshaw, Russell Reardon, Frank Pendleton, and Senifa Annandale.

MISSIONS:

A. Conducted ecosystem monitoring of the species composition, abundance, percentage of cover, size distribution, and general health of the fishes, corals, target macroinvertebrates, and algae of the shallow-water ($\leq$ 30 m) coral reef ecosystems of American Samoa.

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

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

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

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

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

G. Conducted spatially comprehensive benthic characterization surveys at Faga'alu Bay to support the project entitled "Inter-disciplinary study of flow dynamics and sedimentation effects on corals at Faga'alu Bay, American Samoa"

H. Conducted intensive fish survey efforts at Vatia and Faga'alu Bays, Tutuila Island, American Samoa, to support the project "Spatially comprehensive ecological status assessment of coral reef resources in priority watersheds."

RESULTS:

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

Table 1.--Statistics for the Pacific RAMP 2012 cruise to American Samoa (HA-12-01, Legs II and III), including Tutuila Island (TUT), South Bank (SOB), Rose Atoll (ROS), Ta'u Island (TAU), and Ofo and Olosega Islands (OFU). The numbers in the first row for towed-diver surveys include calibration surveys, but the numbers in the separate rows for benthic and fish surveys do not. The totals for scuba dives include all dives carried out for all activities at each island.

Research Activity	**TUT**	**SOB**	**ROS**	**TAU**	**OFU**	**Total**
Scuba Dives	551	3	206	125	156	1041
Biological Surveys						
Towed-diver Surveys: Benthic and Fish	27	0	10	11	10	58
Combined Length (km) of Towed-diver Surveys	58.7	0	21.6	22.5	21.2	124
Towed-diver Surveys: Benthic	27	0	10	11	10	58
Towed-diver Surveys: Fish	27	0	9	11	10	57
REA Sites: Benthic	22	0	12	6	9	49
REA Sites: Fish	153	0	48	22	30	253
Biological Sample Collections						
Algal Voucher Specimens	23	0	2	3	1	29
Halimeda Samples (calcification analysis)	20	0	50	10	40	120
Halimeda Samples (isotope analysis)	12	0	30	0	18	60
Coral Voucher Specimens	0	0	0	0	9	9
Coral Core Samples	6	0	1	0	0	7
Microbial Water Samples	21	0	18	8	12	59
Microbial Benthic Samples	10	0	15	0	10	35
Biological Monitoring Installations						
ARMS Retrieved	9	0	12	0	9	30
ARMS Deployed	9	0	9	0	9	27
CAUs Retrieved	47	0	48	35	44	174
CAUs Deployed	50	0	60	30	35	175
EARs Retrieved	3	0	1	0	0	4
EARs Deployed	0	0	1	0	0	1
Oceanographic Moored Instruments						
SST Buoys Retrieved	1	0	1	1	1	4
SST Buoys Deployed	2	0	1	0	0	3
STRs Retrieved	10	1	7	4	7	29
STRs Deployed	10	0	12	6	8	36
WTRs Retrieved	1	0	1	0	0	2
WTRs Deployed	2	0	0	0	0	2
Temperature and Salinity Sensors (SBE 37) Retrieved	1	0	0	0	0	1
Temperature and Salinity Sensors (SBE 37) Deployed	3	0	0	0	0	3
ADPs Retrieved	1	0	0	0	0	1
ADPs Deployed	3	0	0	0	0	3
Hydrographic Surveys						
Shallow-water CTD Casts	10	0	10	7	10	37
Deepwater CTD Casts	32	0	1	0	0	33
Total Length (km) of ADCP Transects	80	0	0	0	0	80
Water-quality Sampling						
Shallow-water Nutrient Water Samples	20	0	20	14	22	76
Shallow-water Chl-*a* Water Samples	20	0	20	14	22	76
Shallow-water Salinity Water Samples	20	0	20	14	22	76
Shallow-water DIC Water Samples	20	0	20	14	22	76
Deepwater Chl-*a* Water Samples	20	0	5	0	0	25

The coral reef ecosystems of American Samoa are surveyed biennially through CRED's Pacific RAMP. The cruise HA-12-01 marked this program's fifth expedition around the islands of Tutuila, Ofu and Olosega, and Ta'u and Rose Atoll. Here, we present highlights, by island, from our observations during this latest expedition.

Tutuila Island

- The majority of benthic surveys revealed reef conditions similar to surveys in previous years. Surveys did not indicate any major changes in coral disease prevalence at the benthic REA sites visited.
- Considerable quantities of trash and man-made debris noted in and around Faga'alu Bay.
- Increased crown-of-thorns seastars (COTS) densities and signs of predation were noted on several tow segments offshore of the airport.
- REA and towed divers reported moderate infestation of the corallimorph *Rhodactis* at Tafeu Cove, and between Leloaloa and Vatia Bay. Although the corallimorph was observed in this area during the 2010 ASRAMP surveys, this year's assessment suggests an increase in cover of the invasive species.

Rose Atoll

- The majority of benthic surveys revealed reef conditions similar to surveys in previous years. Surveys did not indicate any major changes in coral disease prevalence at the benthic REA sites visited.
- A remarkable reduction in levels of cyano-bacteria and an observable increase in encrusting coralline algal cover were noted at the shipwreck site ROS-07, compared to surveys conducted between 2006 and 2010.

Ta'u Island

- The majority of benthic surveys revealed reef conditions similar to surveys in previous years. Surveys did not indicate any major changes in coral disease prevalence at the benthic REA sites visited.
- Verified, and took new waypoints, for 2 locations of volcanic gas escape from the seafloor.
- Repaired a coral core plug on the large mounding *Porites* known as "Big Mama," as requested by scientists from Stanford University, the American Samoan government, and NOAA.

Ofu and Olosega Islands

The majority of benthic surveys revealed reef conditions similar to surveys in previous years. Surveys did not indicate any major changes in coral disease prevalence at the benthic REA sites visited.

The following data and samples were collected during this expedition:

REA Benthic Surveys:

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

REA Fish Surveys:

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

Towed-diver Surveys:

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

Shipboard Oceanography:

- Deepwater CTD profiles to a depth of 500 m
- Nutrient and Chl-*a* concentrations from water samples collected at variable depths
- Dissolved oxygen, turbidity, fluorescence, and pH measurements recorded by CTD sensor
- Transects of profiles of ocean current velocity and direction collected using a shipboard ADCP unit

- Solar radiation, air temperature, barometric pressure, and wind speed and direction
- Select surface measurements of partial pressure of carbon dioxide (pCO_2)
- Surface temperature and salinity measurements

Nearshore Oceanography from Small Boats:

- Shallow-water CTD profiles to depths ≤ 30 m, including all the REA sites where CAUs were installed, with dissolved oxygen measurements
- Concentrations of nutrients, Chl-*a*, salinity, DIC, and TA from water samples collected in concert with shallow-water (≤ 30 m) CTD casts
- Nutrient concentrations from water samples collected at additional REA sites

Biological Monitoring Installations:

- Environmental acoustics of reefs, marine mammals, and boat traffic from EARs
- Assessment of taxonomic diversity of coral reef species by collection of invertebrate specimens from retrieved ARMS
- Installation and recovery of CAUs for the assessment of calcification rates of crustose coralline red algae and hard corals

Oceanographic Moored 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
- ADP current profiles and wave spectra
- WTRs
- Surface air temperature, wind speed and direction, barometric pressure, and ultraviolet radiation

SCIENTIFIC PERSONNEL:

Bernardo Vargas-Ángel, Chief Scientist, Benthic Team—Coral Populations and Disease, University of Hawai`i (UH)-Joint Institute for Marine and Atmospheric Research (JIMAR), Pacific Islands Fisheries Science Center (PIFSC)-Coral Reef Ecosystem Division (CRED)
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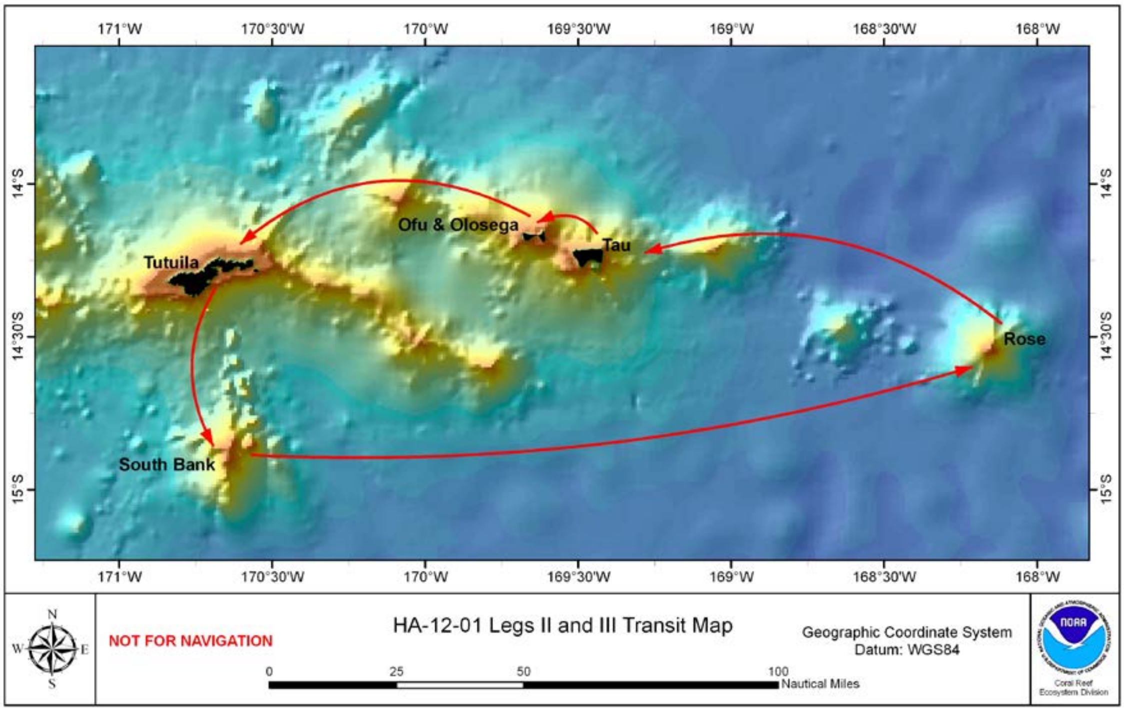

Figure 1.--Track of the NOAA Ship *Hi`ialakai* for the cruise HA-12-01, 1–27 April, 2012, with Tutuila Island, South Bank, Ta`u Island, Ofu and Olosega Islands, and Rose Atoll surveyed. Imagery SIO, NOAA, U.S. Navy, NGA, GEBCO (Becker, 2009; Smith and Sandwell, 1997) © 2008, The Regents of the University of California.

APPENDIX A: METHODS

This appendix describes the methods and procedures used by the Coral Reef Ecosystem Division (CRED) of the NOAA Pacific Islands Fisheries Science Center during its Pacific Reef Assessment and Monitoring Program (Pacific RAMP) cruise HA-12-01 on the NOAA Ship *Hi`ialakai* during the period of 1–27 April 2012. The first quantitative coral reef assessments led by CRED at the islands of Tutuila, Ofu and Olosega, and Ta`u, and Rose Atoll were conducted in 2004.

A.1. Oceanography and Water Quality

(Daniel Merritt, Noah Pomeroy and Charles Young)

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

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

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

1. Vertical, reef-level transects of temperature sensors will be deployed at 1, 5, 15, and 25 m water depth at each island or atoll. The number of vertical transects will depend upon the size of the island or atoll.
2. One meter sensors are only to be deployed in backreef environments or forereef locations that have a high likelihood of survival and retrieval. Deployment should be in water < 2 m deep and should remain submerged through tidal variations and large wave events.
3. Five meter sensors are to be deployed between 4 and 6 m depth range on forereef environments in a location that has a high probability of being accessible during future field missions.
4. Fifteen- and 25-m deployments should be made between 13 and17 m and 23 and 27 m depth ranges, respectively.

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

A.1.1. Moored Instruments for Time-series Observations

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

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

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

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

A.1.2. Hydrographic Surveys

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

Shallow-water (Nearshore) Conductivity, Temperature, and Depth Casts: a CTD profiler deployed from a small boat provided data on temperature, conductivity, which is related to salinity, and pressure, which is related to depth (SBE 19*plus* Seacat Profiler). A transmissometer (C-Star, WET Labs, Philomath, Ore.) provided profiles of beam transmittance, which is related to turbidity. A dissolved oxygen sensor (SBE 43, accuracy of 2% of saturation) also was attached and measurements were made in concert with CTD measurements. A CTD cast was performed at each of the Rapid Ecological Assessment (REA) sites where CAUs were deployed. Data were collected by hand lowering this profiler off a small boat at descent rates of ~ 0.5–0.75 m s^{-1} at depths $\leq$ 30 m.

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

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

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

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

(Jeff Anderson, Wendy Cover, Erin Looney Matthew Dunlap, Frank Pendleton, Cristi Richards, Chris Sullivan, Bernardo Vargas-Ángel, and Rodney Withall)

CRED collected integrated information on the species composition (diversity), condition, abundance, and distribution of communities of corals, algae, and target macroinvertebrates and on benthic habitat complexity and substrates using two primary methodologies: Rapid Ecological Assessment (REA) surveys and towed-diver surveys. Performed at selected hard-bottom locations, REA benthic surveys include multiple methodologies that use two, 25-m transect lines deployed at each REA site as the focal point of surveys. Towed-diver surveys, which follow a depth contour of ~ 15 m and encompass various substrates, cover an area that is much broader than the area surveyed using fine-scale REA techniques. In addition, three types of monitoring installations, autonomous reef monitoring structure (ARMS), CAU, and EAR, serve as mechanisms to quantify: marine invertebrates that are not easily identifiable during REA surveys; accretion rates of crustose coralline red algae and hard corals; and monitor the sounds of marine life and vessel traffic. Note that the sites where REA benthic surveys were conducted typically are different locations from the REA sites selected for fish surveys. REA sites for benthic surveys are selected for long-term monitoring of specific benthic communities over time, whereas REA sites for fish surveys are selected using a stratified random sampling design to provide representative coverage of three depth strata.

A.2.1. Benthic Composition

Using a line-point-intercept (LPI) method at REA sites, hard corals, octocorals, macroalgae, crustose coralline red algae, turf algae, cyanobacteria, and sessile macroinvertebrates were identified to the highest possible taxonomic resolution and recorded, along with sand cover, at 20-cm intervals along two 25-m transect lines set in a single file row (separated by a 5 m inter-transect space). These surveys generate 125 points per transect (250 points per site) that can be used to generate percentage of cover of benthic organisms and sand at each REA site. Additionally, in concert with LPI surveys, still photographs were taken to record the benthos at intervals of 2 m and 5 m along the same two transect lines with a high-resolution digital camera mounted on a pole. This work generates 32 photographs per site that are later analyzed by staff at CRED, using the computer program Coral Point Count with Excel extensions (CPCe), to determine the benthic composition at higher taxonomic levels for each REA site (similar photographs of the benthos taken at REA sites surveyed by the fish team will also be analyzed).

Roving-diver surveys were conducted at each REA site (save for TUT-6, TUT-22, TUT-23), covering a swath of 3–5 m on either side of the transect lines to record algal species richness.

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

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

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

A.2.2. Community Structure and Disease

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

For each coral colony identified during belt-transect surveys, the extent of mortality, both recent and old, was estimated and signs of disease or compromised health were recorded, including type of lesion (bleaching, skeletal growth anomaly, white syndrome, tissue loss other than white syndrome, pigmentation responses, algal overgrowth, or other), extent (percentage of colony affected), and severity (mild, moderate, marked, severe, or acute). Photographic documentation and collection of tissue samples of affected corals was conducted. 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 fungal disease, coralline white band syndrome, coralline target phenomena, and coralline cyanobacterial disease; photographic documentation of affected algae and lesions was conducted.

A.2.3. Installations for Monitoring Marine Life

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

Autonomous Reef Monitoring Structure (ARMS): recovered and deployed at several sites at each island, ARMS provide a mechanism to quantify the cryptic coral reef invertebrate diversity. ARMSs were previously installed on the benthos by pounding stainless steel rods by hand into bare substrate during the ASRAMP 2010 cruise. They remained on the benthos for 2 years, enabling the recruitment and colonization of lesser known, cryptic marine invertebrates. Each ARMS was composed of 10 grey, Type 1 PVC plates (23 × 23 cm) stacked in an alternating series of open and obstructed layers attached to a base plate (35 × 45 cm) that was affixed to a reef.

ARMSs previously deployed during the ASRAMP 2010 cruise were retrieved. First, on the seafloor, the ARMSs were covered in a mesh-lined lid to trap the contents, and then they were removed and transported to the ship. There, each unit was systematically disassembled and photo-documented, and all organisms contained in these structures were preserved in ethanol for later genetic and other molecular analyses. At a subsample of these sites, new ARMS units were deployed onto existing stainless steel rods, with the goal of recovering them during the next ASRAMP cruise scheduled for 2015.

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

Ecosystem Acoustic Recorder (EAR): the EAR is a passive acoustic device developed specifically for monitoring marine mammals, fishes, crustaceans, other sound-producing marine life, and human activity in marine habitats. The EAR is a digital, low-power system that records ambient sounds up to 30 kHz on a programmable schedule and can also respond to transient acoustic events that meet specific criteria, such as motorized vessels or cetaceans passing nearby. This type of subsurface instrument typically was deployed at depths of 5–25 m. Note: information about retrievals and deployments of

EARs are provided along with information about STR installations in the island appendices, since those instruments are sometimes moored to the same anchor and EARs are typically installed by members of the oceanography team.

A.2.4. Coral Core Collections

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

Pneumatic Coral Coring

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

A.2.5. *Halimeda* Collections for Calcification and Isotope Analysis

Species of the green algal genus *Halimeda* are among the most important producers of calcified sediments in reef systems. As the acidity of our oceans increases, calcification rates and the ability of *Halimeda* algae to produce sediments may fall precipitously. To gain a baseline understanding of calcification levels in species of *Halimeda*, a joint project between CRED and the Scripps Institution of Oceanography, University of California San Diego, is sampling *Halimeda* populations across the Pacific to determine ambient levels of $CaCO_3$ among different species from different geographic areas. To accomplish this research, 10 individuals of 3 species of *Halimeda* (when present) will be collected haphazardly by hand from each established REA site visited. Specimens will be dried in an oven after collection and shipped to Scripps for analysis of percentage of calcification.

As algae photosynthesize they take up nutrients available in the water column and incorporate them into their tissue. Isotope radios in the algal tissue can often point to the origin of the nitrogen available, whether it is from an anthropogenic source like land-based source pollution, seabirds, or from the decomposition of marine organisms. Algae such as *Halimeda* grow attached to the substrate and are non-motile, so they reflect the conditions at a given REA site. A joint project between CRED and a lab at the University of California Santa Cruz is investigating the utility of *Halimeda* as a proxy to determine the sources of nitrogen being incorporated into these coral reef ecosystems. Six samples of *Halimeda* were collected from three or four sites around each island and will be dried in an oven before being shipped to UCSD for isotope analysis.

A.2.6. Microbial Communities and Water Chemistry

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A.3. Surveys of Reef Fishes

(Paula Ayotte, Adel Heenan, Kevin Lino, Kaylyn McCoy, Mark Manuel, Marc Nadon, Senifa Annandale, and Jill Zamzow)

Six divers conducted REA fish surveys using the stationary-point-count (SPC) method at preselected REA sites; two separate teams performed these surveys. All REA fish sites visited were selected using a stratified random sampling design in shallow (0–6 m), moderate (6–18 m), or deep (18–30 m) depth strata. Surveys were performed using a 30-m transect line set along a single depth contour. The REA sites selected for fish surveys typically differ in location from the REA sites where benthic surveys were conducted.

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

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

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

In addition to site-specific REA surveys, broad-scale towed-diver surveys were used to characterize the fish communities of shallow-water habitats around each island. A pair of divers, by means similar to a manta-tow technique, was towed 60 m behind a small boat, with one diver quantifying fish populations and the other quantifying the benthos (for more details about towed-divers surveys, see Section A.2.1: “Benthic Composition”).

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

APPENDIX B: TUTUILA ISLAND AND SOUTH BANK

The island of Tutuila is located at 14°19’ S, 172°42’ W in the South Pacific and is part of the Samoa Island chain. South Bank is a submerged atoll reef located 37 miles south of Tutuila. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: “Methods.”

B.1. Oceanography and Water Quality

Oceanographic operations during the cruise HA-12-01, Leg II at Tutuila Island entailed numerous retrievals and deployments of oceanographic moored instruments, calcification acidification units (CAUs), nearshore water sampling, and Conductivity, Temperature, and Depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, shipboard water sampling and CTD casts offshore to a depth of 500 m, and offshore acoustic Doppler current profiler (ADCP) transect lines.

Due to the change in monitoring to the National Coral Reef Monitoring Program (NCRMP) philosophy, two subsurface temperature recorders (STRs) were retrieved and replaced, nine were removed, and eight additional STR moorings were deployed (Fig. B.1.1 and Table B.1.1). Because of limited funding, one SST buoy was recovered, cleaned, and the same buoy redeployed. Three EAR moorings were retrieved and not replaced. As part of a 1-year study in Faga’alu Bay, two wave and tide recorders (WTR), two ADCP, and two SBE37 salinograph moorings were deployed. Three coral cores were collected from Faga’alu Bay using the pneumatic drill. For information about CAU deployments completed at Tutuila Island, see Section B.2: “Benthic Environment.” An STR was also recovered and not replaced from South Bank. No other operations were performed at South Bank.

Six pneumatic coral cores were extracted from mounding *Porites* species around Tutuila Island, three previously mentioned retrieved from Faga’alu Bay plus an additional three.

Shallow-water CTD casts were performed at each of the ten REA sites where CAUs were replaced (Fig. B.1.1). In concert with each CTD cast, two water samples were taken (surface and near reef) to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, dissolved nutrients (PO_4^{3-}, $Si(OH)_4$), and chlorophyll-*a* (Chl-*a*) concentrations. Accounting for losses and microbiological nutrient samples taken alone, a total of 20 DIC and TA, 20 salinity, 20 nutrient, and 20 Chl-*a* water samples were collected.

From the NOAA Ship *Hi`ialakai* four CTD transects were conducted, one to the north, south, east, and west. Each CTD transect included eight sampling stations, to a depth of 300–500 m. CTD operations began at night with first CTD sampling station defined as the closest point to land where the minimum survey depth was achieved. A 2-km interval was established between stations one through six, and a 5-km interval was established between stations six and seven, and stations seven and eight. On the transect reciprocal course, ADCP transect lines were run. Chl-*a* water samples were collected concurrently with the station one CTD cast, at five depths between the surface and 300–500 m. Water sample depths were determined at the time of each CTD cast, as Chl-*a* sample collection was determined by the in-situ chlorophyll-*a* concentration maximum, thus depended upon the depth of mixed layer as measured by the CTD downcast (Fig. B.1.2). Twenty Chl-*a* water samples were collected during shipboard water sampling efforts.

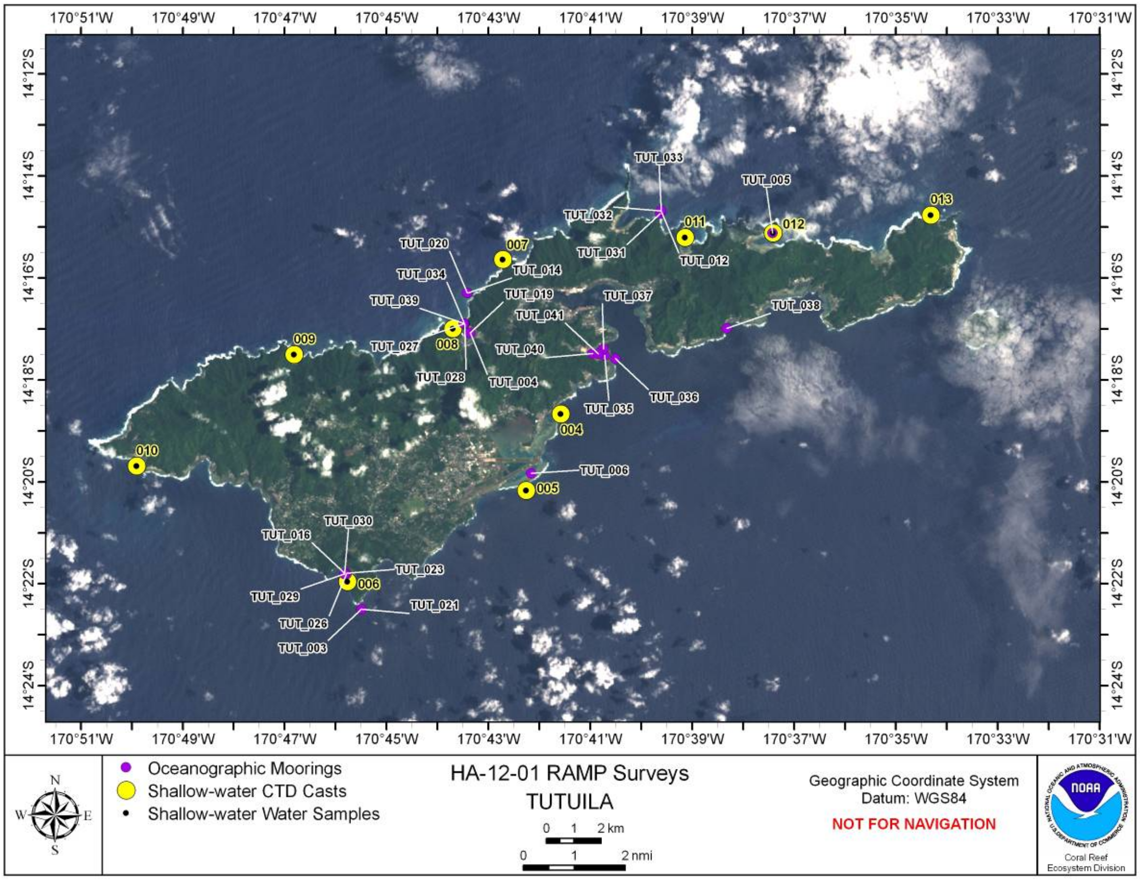

Figure B.1.1.--Mooring sites where oceanographic instruments were retrieved or deployed and REA and CAU sites where nearshore CTD casts and water sampling were performed at Tutuila Island, HA-12-01, Leg II. Landsat satellite imagery data used in this map figure are available from the U.S. Geological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

Table B.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments that were retrieved or deployed at Tutuila Island and South Bank during cruise HA-12-01, Legs II and III.

Mooring Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
TUT_006	1-Apr	STR	–14.33044	–170.70267	2.1	1	–
TUT_016	1-Apr	EAR	–14.36327	–170.76359	19.5	1	–
TUT_016	1-Apr	STR	–14.36327	–170.76359	19.5	1	–
TUT_023	1-Apr	STR	–14.36311	–170.76306	6.25	1	1
TUT_026	1-Apr	STR	–14.36350	–170.76315	14.3	1	1
TUT_004	2-Apr	SST	–14.28458	–170.72268	0.3	1	–
TUT_014	2-Apr	EAR	–14.27152	–170.72344	18	1	–
TUT_014	2-Apr	STR	–14.27152	–170.72344	18	1	–
TUT_019	2-Apr	STR	–14.28458	–170.72268	14.6	1	–
TUT_020	2-Apr	STR	–14.27148	–170.72370	30.2	1	–
TUT_027	2-Apr	STR	–14.28154	–170.72460	15.2	–	1
TUT_028	2-Apr	STR	–14.28173	–170.72444	5.5	–	1
TUT_039	2-Apr	STR	–14.28147	–170.72473	24.1	–	1
TUT_003	3-Apr	WTR	–14.37493	–170.75833	21.6	1	–
TUT_021	3-Apr	STR	–14.37496	–170.75813	32.3	1	–
TUT_029	3-Apr	SST	–14.36335	–170.76379	0.3	–	1
TUT_030	3-Apr	STR	–14.36335	–170.76379	25.3	–	1
TUT_012	4-Apr	EAR	–14.24479	–170.66011	12.8	1	–
TUT_012	4-Apr	STR	–14.24479	–170.66011	12.8	1	–
TUT_031	4-Apr	STR	–14.24558	–170.66046	5.8	–	1
TUT_032	4-Apr	STR	–14.24468	–170.66017	15.5	–	1
TUT_033	4-Apr	STR	–14.24461	–170.66012	24.7	–	1
TUT_005	5-Apr	STR	–14.25193	–170.62374	6.1	1	–
TUT_034	5-Apr	SST	–14.28150	–170.72461	0.3	–	1
TUT_035	7-Apr	WTR	–14.29198	–170.67864	0.9	–	1
TUT_040	7-Apr	ADP	–14.29132	–170.68251	0.6	–	1
TUT_040	7-Apr	SBE37	–14.29132	–170.68251	0.6	–	1
TUT_036	8-Apr	WTR	–14.29298	–170.67515	13.4	–	1
TUT_037	8-Apr	ADP	–14.28977	–170.67895	14.9	–	1
TUT_037	8-Apr	SBE37	–14.28977	–170.67895	14.9	–	1
TUT_040	8-Apr	ADP	–14.29135	–170.68252	1.2	1	–
TUT_040	8-Apr	SBE37	–14.29135	–170.68252	1.2	1	–
TUT_038	9-Apr	STR	–14.28303	–170.63871	0.9	–	1
TUT_041	12-Apr	ADP	–14.29143	–170.68072	2.4	–	1
TUT_041	12-Apr	SBE37	–14.29143	–170.68072	2.4	–	1
SOB_001	17-Apr	STR	–14.89423	–170.63248	30.8	1	–

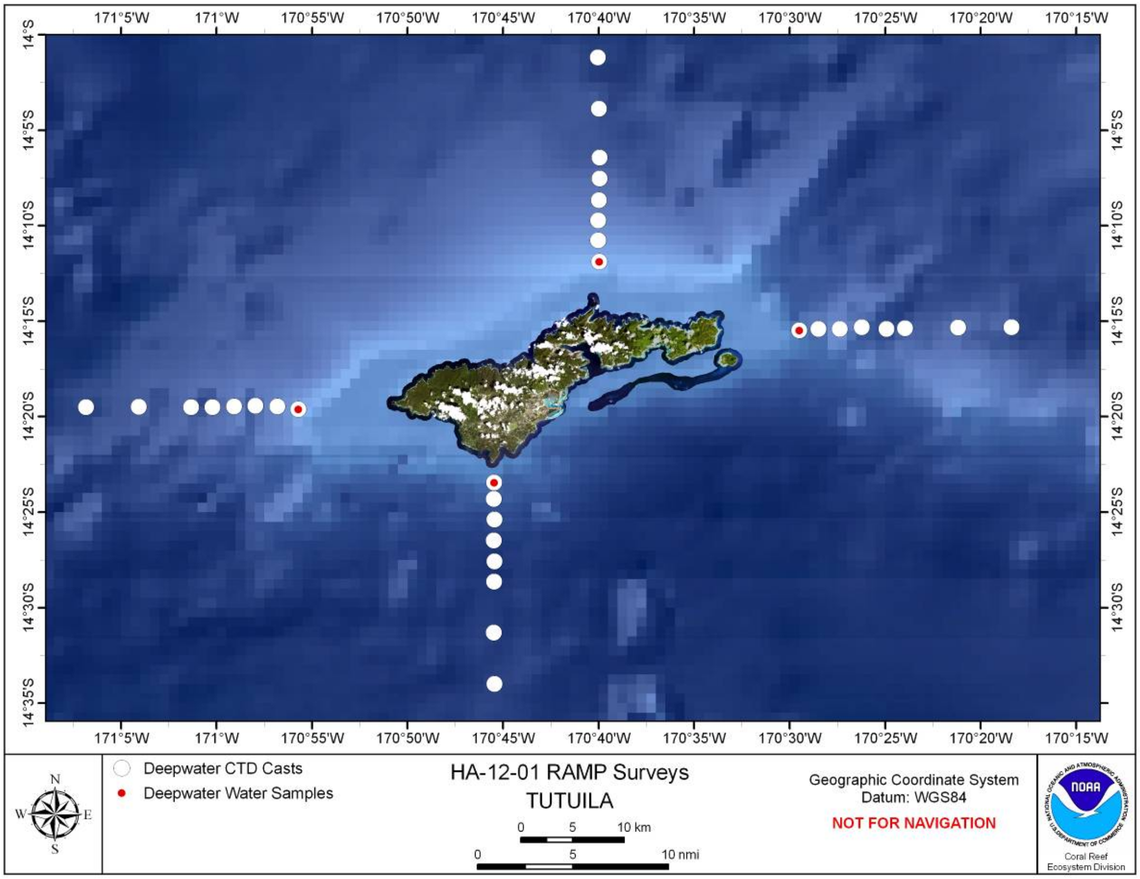

Figure B.1.2. --Locations of deepwater CTD casts and water sampling performed at Tutuila Island during cruise HA-12-01, Leg II. Island satellite image IKONOS Carterra Geo Data, 2003, and background imagery SIO, NOAA, U.S. Navy, NGA, GEBCO (Becker, 2009; Smith and Sandwell, 1997) © 2008 The Regents of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

B.2. Benthic Environment

Belt-transect and line-point-intercept (LPI) surveys were conducted with photographs taken along transect lines at 22 REA sites around Tutuila (with roving-diver surveys at 18) to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. B.2.1 and Table B.2.1).

Various samples were collected at 14 REA sites (Table B.2.2): 23 algal voucher specimens at seven REA sites for taxonomic identification, 20 individuals of the algal genus *Halimeda* at two REA sites for calcification analysis and 12 at two sites for isotope analysis, six coral cores from *Porites* coral heads for calcification research, and 21 water samples for microbial analyses at seven REA sites with two water samples of 2 L each at each site (four at TUT-22), two water samples of 20 L each at TUT-17, and three water samples of 80 L each at TUT-969. Additional microbial work included benthic grabs of coral rubble and unidentified macroalgae at TUT-17. For more information about collections made at REA sites, see Table F.1.1 in Appendix F: "Biological Collections."

Nine autonomous reef monitoring structures (ARMS) were recovered: Three ARMS each from TUT-01, TUT-11 and TUT-22 (Table B.2.2). Nine ARMS were deployed with three ARMS each at TUT-01, TUT-11 and TUT-22. At 10 select REA sites, an array of 5 CAUs were deployed for a total of 50 CAUs installed, and 47 were recovered from the previous deployments in 2010 (Table B.2.2). For information about EAR installations, see Section B.2: "Oceanography and Water Quality."

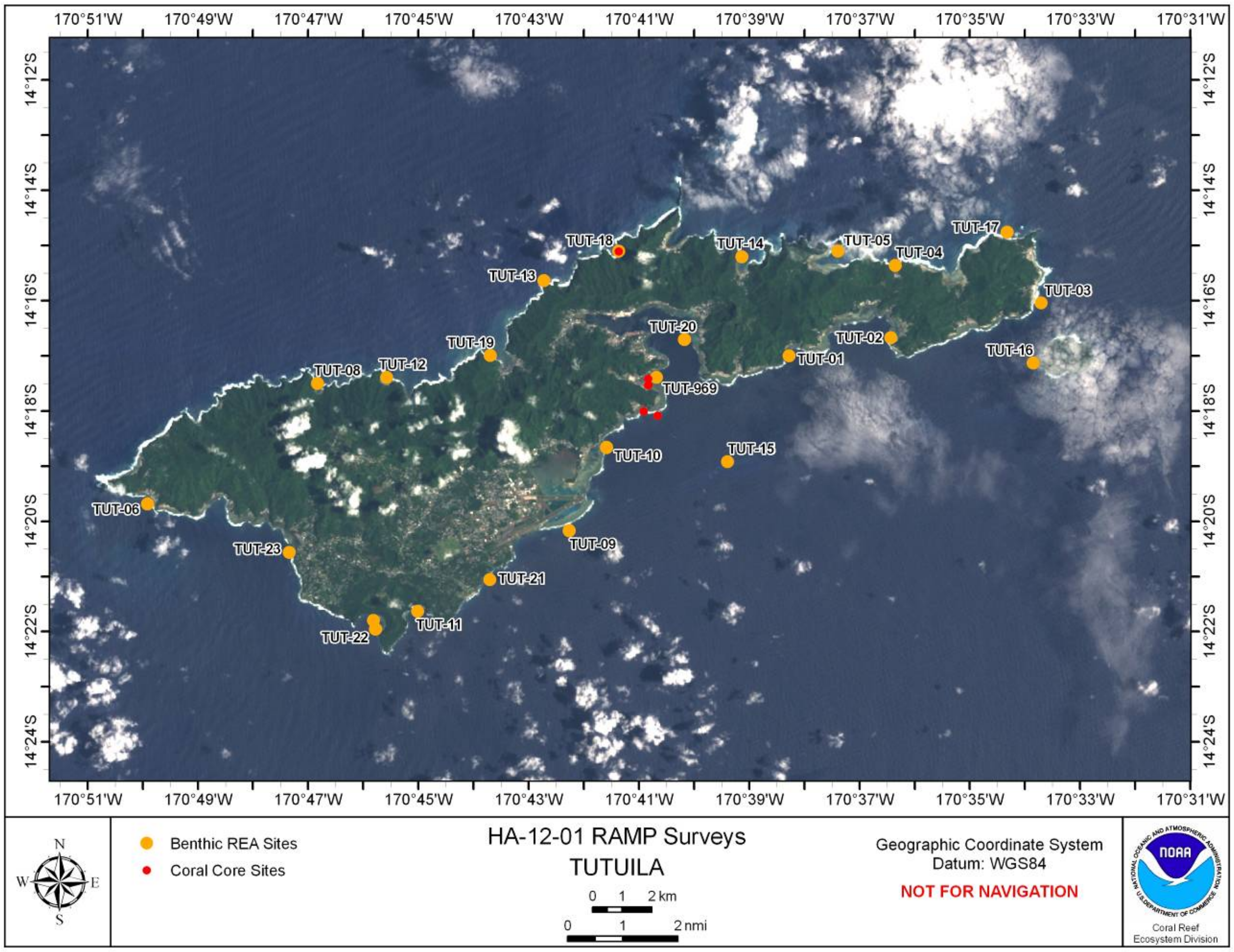

Figure B.2.1.--Locations of REA benthic sites surveyed at Tutuila during cruise HA-12-01 Leg II. Landsat satellite imagery data used in this map figure are available from the U.S. Geological Survey.

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

REA Site	Date	Latitude	Longitude	REA Surveys		
				LPI	**Roving Diver**	**Corals**
TUT-09	1-Apr	–14.33615	–170.70436	x	x	x
TUT-10	1-Apr	–14.31098	–170.69307	x	x	x
TUT-21	1-Apr	–14.35095	–170.72829	x	x	x
TUT-08	2-Apr	–14.29167	–170.78042	x	x	x
TUT-13	2-Apr	–14.26055	–170.71205	x	x	x
TUT-19	2-Apr	–14.28319	–170.72825	x	x	x
TUT-06	3-Apr	–14.32813	–170.83185	x	–	x
TUT-22	3-Apr	–14.36585	–170.76291	x	–	x
TUT-23	3-Apr	–14.34276	–170.78904	x	–	x
TUT-05	4-Apr	–14.25169	–170.62309	x	x	x
TUT-14	4-Apr	–14.25334	–170.65219	x	x	x
TUT-18	4-Apr	–14.25169	–170.68942	x	x	x
TUT-03	5-Apr	–14.26732	–170.56165	x	x	x
TUT-04	5-Apr	–14.25606	–170.60579	x	x	x
TUT-17	5-Apr	–14.24600	–170.57196	x	x	x
TUT-12	6-Apr	–14.28982	–170.75951	x	x	x
TUT-01	7-Apr	–14.28336	–170.63786	x	x	x
TUT-02	7-Apr	–14.27781	–170.60720	x	x	x
TUT-16	7-Apr	–14.28548	–170.56408	x	x	x
TUT-11	8-Apr	–14.36049	–170.75020	x	x	x
TUT-15	12-Apr	–14.31535	–170.65644	x	x	x
TUT-20	12-Apr	–14.27837	–170.66953	x	x	x

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

REA Site	Date	Latitude	Longitude	Installations and Collections						
				CAU Ret	CAU Dep	ARMS Ret	ARMS Dep	Algae	Microbial Samples	Coral Cores
TUT-10	29-Mar	–14.29214	–170.68043	0	0	0	0	0	0	1
TUT-10	29-Mar	–14.29211	–170.68041	0	0	0	0	0	0	1
TUT-10	29-Mar	–14.29011	–170.68046	0	0	0	0	0	0	1
TUT-09	1-Apr	–14.33608	–170.70438	5	5	0	0	0	0	0
TUT-10	1-Apr	–14.31101	–170.69303	5	5	0	0	0	0	0
TUT-22	1-Apr	–14.36588	–170.76284	4	5	0	0	0	2	0
TUT-08	2-Apr	–14.29167	–170.78042	3	5	0	0	0	2	0
TUT-13	2-Apr	–14.26055	–170.71205	5	5	0	0	0	0	0
TUT-19	2-Apr	–14.28319	–170.72825	5	5	0	0	16	2	0
TUT-06	3-Apr	–14.32810	–170.83183	5	5	0	0	0	0	0
TUT-22	3-Apr	–14.36585	–170.76291	0	0	3	3	0	0	0
TUT-05	4-Apr	–14.25169	–170.62309	5	5	0	0	0	2	0
TUT-14	4-Apr	–14.25334	–170.65219	5	5	0	0	18	0	0
TUT-18	4-Apr	–14.25169	–170.68942	0	0	0	0	2	0	0
TUT-04	5-Apr	–14.25606	–170.60579	0	0	0	0	1	0	0
TUT-13	5-Apr	–14.25168	–170.68935	0	0	0	0	0	0	1
TUT-17	5-Apr	–14.24600	–170.57196	5	5	0	0	0	14	0
TUT-12	6-Apr	–14.28982	–170.75951	0	0	0	0	9	0	0
TUT-01	7-Apr	–14.28336	–170.63786	0	0	3	3	5	0	0
TUT-02	7-Apr	–14.27781	–170.60720	0	0	0	0	2	0	0
TUT-10	7-Apr	–14.30126	–170.67759	0	0	0	0	0	0	1
TUT-10	8-Apr	–14.30004	–170.68190	0	0	0	0	0	0	1
TUT-11	8-Apr	–14.36049	–170.75020	0	0	3	3	0	0	0
TUT-22	8-Apr	–14.36325	–170.76357	0	0	0	0	0	2	0
TUT-969	8-Apr	–14.28983	–170.67797	0	0	0	0	0	5	0
TUT-20	12-Apr	–14.27837	–170.66953	0	0	0	0	2	2	0

During cruise HA-12-01, Leg II, CRED completed 27 towed-diver surveys at Tutuila Island, covering a total length of 58.7 km (an area of 58.7 ha) on the ocean floor (Fig. B.2.2). The mean survey length was 2.2 km with a range of 0.5–2.7 km. The mean survey depth was 14.8 m with a range of 12.7–16.0 m. The mean temperature from data recorded during these surveys was 29.1°C with a range of 29.0°C–29.3°C.

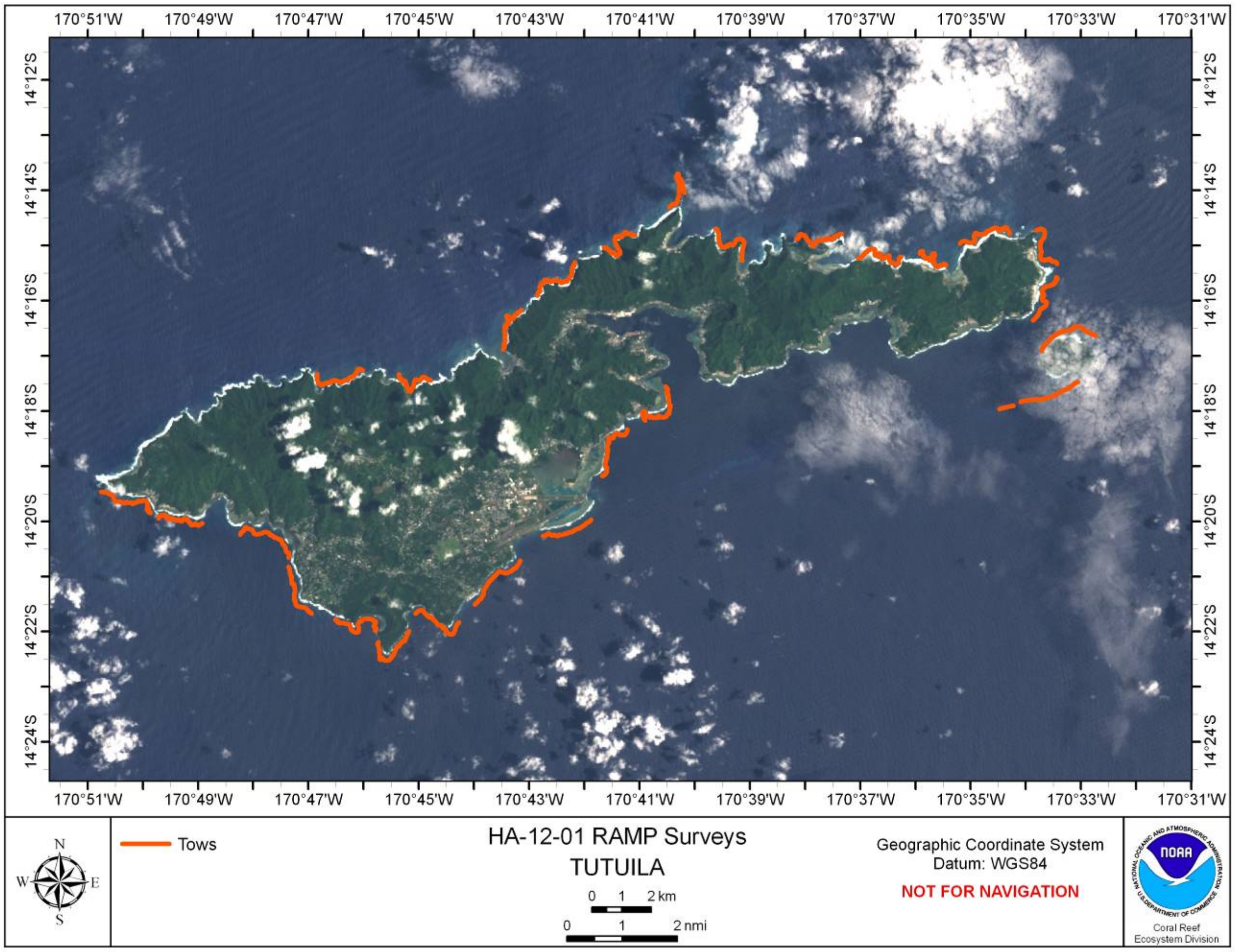

Figure B.2.2.--Track locations of towed-diver surveys conducted at Tutuila during cruise HA-12-01, Leg II. Landsat satellite imagery data used in this map figure are available from the U.S. Geological Survey.

B.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 153 REA sites at Tutuila Island over three different habitat strata: deep forereef, moderate forereef, and shallow forereef (Table B.3.1 and Fig. B.3.1). No fishes were collected during these surveys. Comprehensive characterization of the fish communities at Faga'alu and Vatia Bays were conducted during cruise HA-12-01 (Figs. B.3.2. and B.3.3)

In addition, CRED completed 27 towed-diver surveys at Tutuila Island, as described previously in Section B.2 of this appendix.

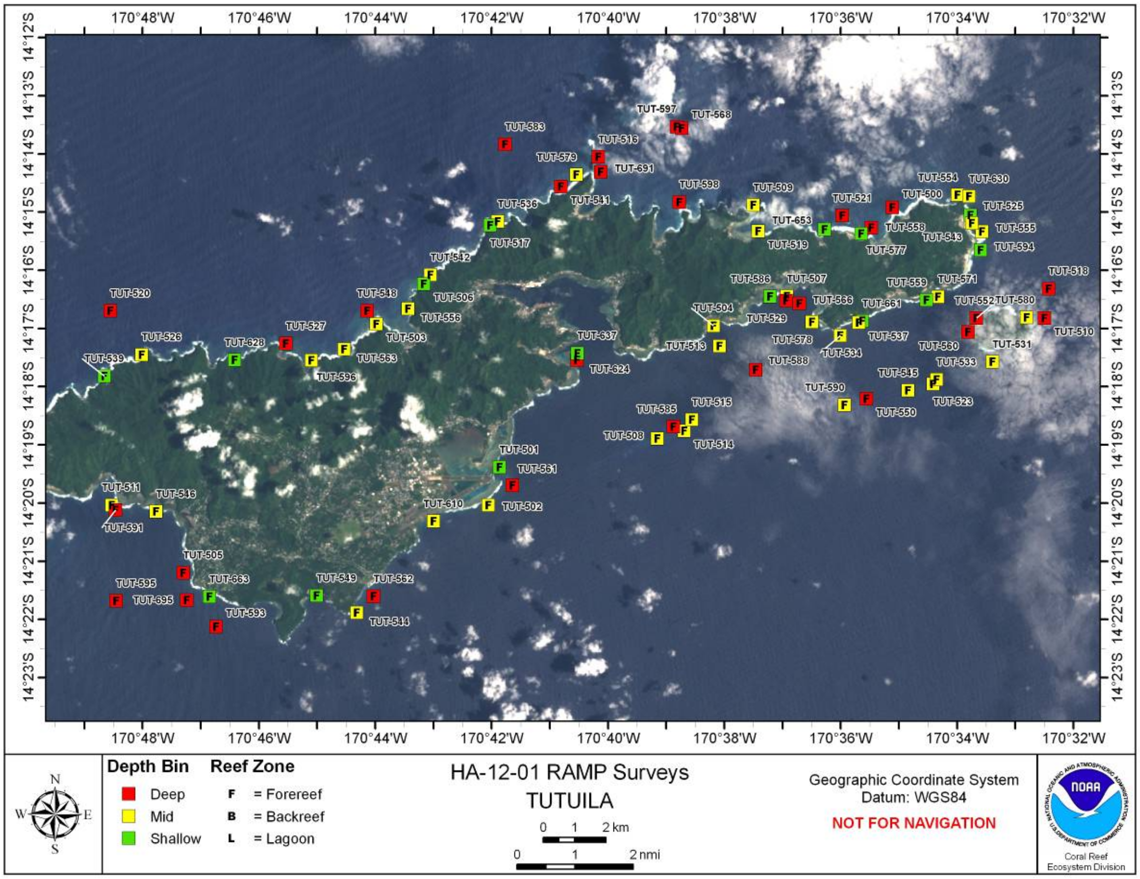

Figure B.3.1.--Locations of REA fish sites surveyed at Tutuila Island during cruise HA-12-01, Leg II. All of these REA sites were selected using a stratified random design. Landsat satellite imagery data used in this map figure are available from the U.S. Geological Survey.

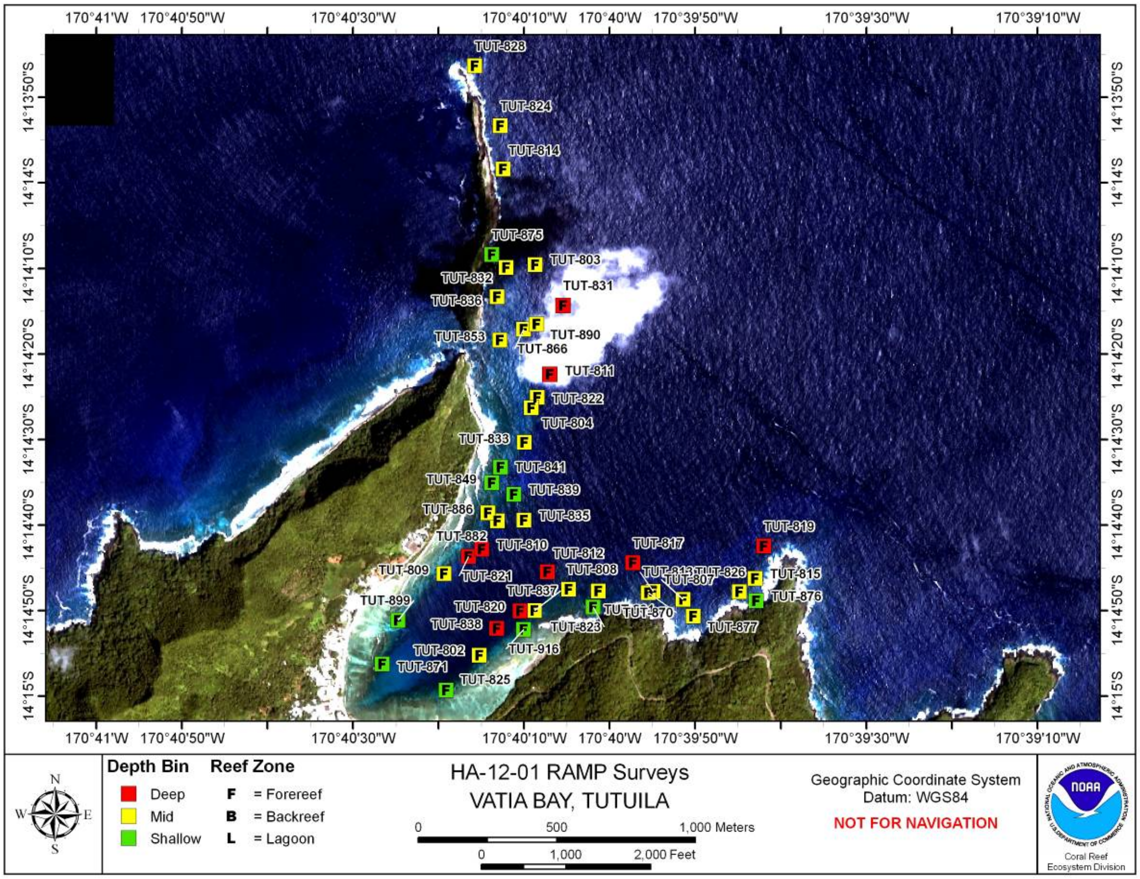

Figure B.3.2.--Locations of REA fish sites surveyed at Vatia Bay, Tutuila during cruise HA-12-01, Leg II. All of these REA sites were selected using a stratified random design. Satellite image IKONOS Carterra Geo Data, 2003

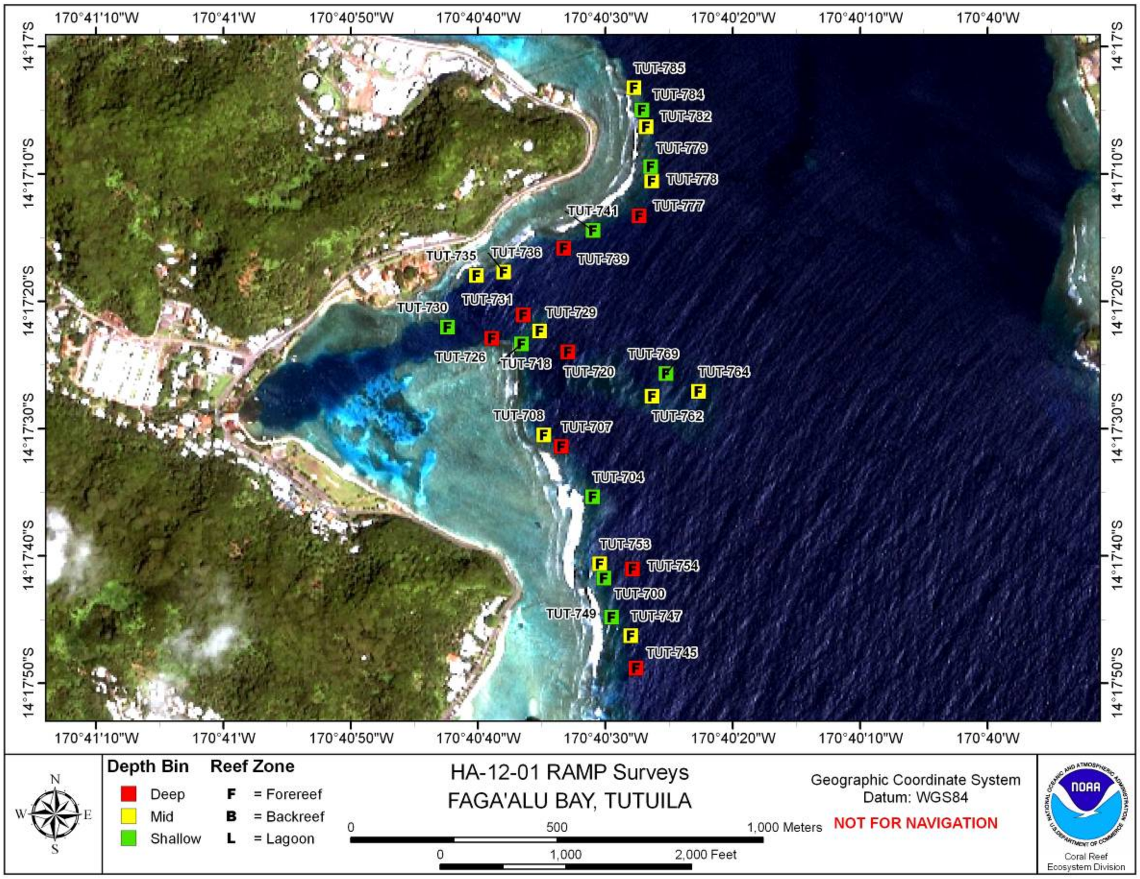

Figure B.3.3.--Locations of REA fish sites surveyed at Faga'alu Bay, Tutuila during cruise HA-12-01, Leg II. All of these REA sites were selected using a stratified random design. Island satellite image IKONOS Carterra Geo Data, 2003.

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

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
TUT-501	1-Apr	Shallow	Forereef	2.1	–14.32306	–170.69777
TUT-502	1-Apr	Moderate	Forereef	7.6	–14.33394	–170.70095
TUT-504	1-Apr	Moderate	Forereef	12.7	–14.28248	–170.63649
TUT-508	1-Apr	Moderate	Forereef	13.6	–14.31482	–170.65252
TUT-513	1-Apr	Moderate	Forereef	12.7	–14.28834	–170.63475
TUT-514	1-Apr	Moderate	Forereef	15.5	–14.31263	–170.64486
TUT-515	1-Apr	Moderate	Forereef	14.3	–14.30945	–170.64268
TUT-561	1-Apr	Deep	Forereef	26.4	–14.32822	–170.69406
TUT-586	1-Apr	Shallow	Forereef	2.6	–14.27413	–170.62023
TUT-588	1-Apr	Deep	Forereef	23.5	–14.29513	–170.62432
TUT-610	1-Apr	Moderate	Forereef	13.3	–14.33854	–170.71665
TUT-503	2-Apr	Moderate	Forereef	8.3	–14.28200	–170.73301
TUT-506	2-Apr	Shallow	Forereef	6.1	–14.27050	–170.71940
TUT-517	2-Apr	Shallow	Forereef	5	–14.25374	–170.70042
TUT-520	2-Apr	Deep	Forereef	24	–14.27827	–170.80919

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
TUT-526	2-Apr	Moderate	Forereef	8.8	–14.29078	–170.80027
TUT-527	2-Apr	Deep	Forereef	25.4	–14.28766	–170.75897
TUT-536	2-Apr	Moderate	Forereef	7.3	–14.25261	–170.69825
TUT-539	2-Apr	Shallow	Forereef	4.6	–14.29694	–170.81097
TUT-542	2-Apr	Moderate	Forereef	10.7	–14.26790	–170.71757
TUT-548	2-Apr	Deep	Forereef	27.4	–14.27825	–170.73566
TUT-556	2-Apr	Moderate	Forereef	13.9	–14.27761	–170.72395
TUT-563	2-Apr	Moderate	Forereef	13	–14.28919	–170.74226
TUT-596	2-Apr	Moderate	Forereef	10.7	–14.29242	–170.75163
TUT-628	2-Apr	Shallow	Forereef	4.3	–14.29236	–170.77363
TUT-505	3-Apr	Deep	Forereef	21	–14.35328	–170.78839
TUT-511	3-Apr	Moderate	Forereef	11	–14.33389	–170.80880
TUT-544	3-Apr	Moderate	Forereef	15.8	–14.36472	–170.73862
TUT-546	3-Apr	Moderate	Forereef	13.6	–14.33572	–170.79619
TUT-549	3-Apr	Shallow	Forereef	7	–14.35984	–170.75014
TUT-562	3-Apr	Deep	Forereef	25.5	–14.36002	–170.73380
TUT-591	3-Apr	Deep	Forereef	22	–14.33530	–170.80775
TUT-593	3-Apr	Deep	Forereef	29.6	–14.36869	–170.77892
TUT-595	3-Apr	Deep	Forereef	24	–14.36132	–170.80754
TUT-663	3-Apr	Shallow	Forereef	8.5	–14.36010	–170.78081
TUT-695	3-Apr	Deep	Forereef	30	–14.36109	–170.78735
TUT-516	4-Apr	Deep	Forereef	22.6	–14.23416	–170.66949
TUT-691	4-Apr	Deep	Forereef	26.8	–14.23845	–170.66872
TUT-801	4-Apr	Moderate	Forereef	8.5	–14.24658	–170.66704
TUT-802	4-Apr	Moderate	Forereef	11	–14.24867	–170.67090
TUT-808	4-Apr	Moderate	Forereef	8	–14.24652	–170.66800
TUT-810	4-Apr	Deep	Forereef	19.3	–14.24522	–170.67082
TUT-811	4-Apr	Deep	Forereef	26.9	–14.23955	–170.66861
TUT-813	4-Apr	Moderate	Forereef	13.1	–14.24660	–170.66525
TUT-814	4-Apr	Moderate	Forereef	15	–14.23288	–170.67013
TUT-815	4-Apr	Moderate	Forereef	12.2	–14.24618	–170.66194
TUT-817	4-Apr	Deep	Forereef	22.6	–14.24567	–170.66591
TUT-819	4-Apr	Deep	Forereef	27.6	–14.24512	–170.66166
TUT-821	4-Apr	Deep	Forereef	19	–14.24546	–170.67126
TUT-823	4-Apr	Shallow	Forereef	5.5	–14.24710	–170.66721
TUT-824	4-Apr	Moderate	Forereef	17.4	–14.23148	–170.67022
TUT-825	4-Apr	Shallow	Forereef	3.2	–14.24980	–170.67197
TUT-826	4-Apr	Moderate	Forereef	9.8	–14.24661	–170.66245
TUT-828	4-Apr	Moderate	Forereef	13.3	–14.22953	–170.67105
TUT-831	4-Apr	Deep	Forereef	24.5	–14.23731	–170.66818
TUT-837	4-Apr	Moderate	Forereef	12.2	–14.24721	–170.66910
TUT-838	4-Apr	Deep	Forereef	22.3	–14.24779	–170.67033
TUT-871	4-Apr	Shallow	Forereef	4	–14.24895	–170.67405
TUT-875	4-Apr	Shallow	Forereef	8	–14.23566	–170.67050
TUT-876	4-Apr	Shallow	Forereef	5.2	–14.24690	–170.66191
TUT-500	5-Apr	Deep	Forereef	26.2	–14.24864	–170.58520

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
TUT-509	5-Apr	Moderate	Forereef	10.4	–14.24795	–170.62508
TUT-519	5-Apr	Moderate	Forereef	11.3	–14.25544	–170.62369
TUT-521	5-Apr	Deep	Forereef	24.8	–14.25093	–170.59951
TUT-525	5-Apr	Shallow	Forereef	3.1	–14.25079	–170.56281
TUT-541	5-Apr	Deep	Forereef	21	–14.24259	–170.68012
TUT-554	5-Apr	Moderate	Forereef	12.1	–14.24501	–170.56652
TUT-558	5-Apr	Deep	Forereef	25	–14.25439	–170.59125
TUT-577	5-Apr	Shallow	Forereef	5	–14.25610	–170.59417
TUT-579	5-Apr	Moderate	Forereef	15.2	–14.23926	–170.67577
TUT-583	5-Apr	Deep	Forereef	27.3	–14.23050	–170.69618
TUT-630	5-Apr	Moderate	Forereef	17	–14.24541	–170.56329
TUT-653	5-Apr	Shallow	Forereef	4.9	–14.25492	–170.60462
TUT-568	6-Apr	Deep	Forereef	29.4	–14.22591	–170.64551
TUT-597	6-Apr	Deep	Forereef	25.6	–14.22548	–170.64703
TUT-598	6-Apr	Deep	Forereef	22.5	–14.24707	–170.64620
TUT-803	6-Apr	Moderate	Forereef	16.5	–14.23599	–170.66908
TUT-804	6-Apr	Moderate	Forereef	7.3	–14.24063	–170.66921
TUT-807	6-Apr	Moderate	Forereef	12	–14.24685	–170.66428
TUT-809	6-Apr	Moderate	Forereef	7.5	–14.24601	–170.67204
TUT-812	6-Apr	Deep	Forereef	22	–14.24596	–170.66869
TUT-820	6-Apr	Deep	Forereef	20.6	–14.24722	–170.66958
TUT-822	6-Apr	Moderate	Forereef	14.8	–14.24030	–170.66901
TUT-832	6-Apr	Moderate	Forereef	9.5	–14.23608	–170.67003
TUT-833	6-Apr	Moderate	Forereef	9	–14.24176	–170.66944
TUT-835	6-Apr	Moderate	Forereef	11.6	–14.24428	–170.66945
TUT-836	6-Apr	Moderate	Forereef	7	–14.23703	–170.67032
TUT-839	6-Apr	Shallow	Forereef	11.9	–14.24345	–170.66978
TUT-841	6-Apr	Shallow	Forereef	4.5	–14.24256	–170.67021
TUT-849	6-Apr	Shallow	Forereef	4	–14.24307	–170.67049
TUT-853	6-Apr	Moderate	Forereef	8.8	–14.23844	–170.67022
TUT-866	6-Apr	Moderate	Forereef	12.6	–14.23808	–170.66946
TUT-870	6-Apr	Moderate	Forereef	10	–14.24664	–170.66542
TUT-877	6-Apr	Moderate	Forereef	9.7	–14.24740	–170.66395
TUT-882	6-Apr	Moderate	Forereef	7	–14.24430	–170.67031
TUT-886	6-Apr	Moderate	Forereef	4.6	–14.24405	–170.67061
TUT-890	6-Apr	Moderate	Forereef	12.8	–14.23792	–170.66904
TUT-899	6-Apr	Shallow	Forereef	3.7	–14.24753	–170.67354
TUT-916	6-Apr	Shallow	Forereef	6	–14.24782	–170.66946
TUT-510	7-Apr	Deep	Forereef	21.3	–14.28035	–170.54165
TUT-518	7-Apr	Deep	Forereef	24.7	–14.27188	–170.54048
TUT-523	7-Apr	Moderate	Forereef	15	–14.29919	–170.57356
TUT-531	7-Apr	Moderate	Forereef	8.8	–14.29286	–170.55654
TUT-533	7-Apr	Moderate	Forereef	17.5	–14.29797	–170.57251
TUT-543	7-Apr	Moderate	Forereef	11.2	–14.25317	–170.56245
TUT-545	7-Apr	Moderate	Forereef	16.7	–14.30105	–170.58071
TUT-552	7-Apr	Deep	Forereef	25	–14.28032	–170.56119

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
TUT-555	7-Apr	Moderate	Forereef	10.5	–14.25552	–170.55954
TUT-559	7-Apr	Shallow	Forereef	3.5	–14.27516	–170.57548
TUT-571	7-Apr	Moderate	Forereef	8.5	–14.27418	–170.57212
TUT-580	7-Apr	Moderate	Forereef	12.7	–14.28012	–170.54670
TUT-594	7-Apr	Shallow	Forereef	5	–14.26082	–170.55996
TUT-661	7-Apr	Shallow	Forereef	4.5	–14.28113	–170.59382
TUT-534	8-Apr	Moderate	Forereef	19	–14.28527	–170.60012
TUT-537	8-Apr	Moderate	Forereef	15.2	–14.28159	–170.59485
TUT-550	8-Apr	Deep	Forereef	24.2	–14.30339	–170.59264
TUT-560	8-Apr	Deep	Forereef	27	–14.28437	–170.56357
TUT-578	8-Apr	Moderate	Forereef	23	–14.28140	–170.60821
TUT-585	8-Apr	Deep	Forereef	22.5	–14.31141	–170.64798
TUT-700	8-Apr	Shallow	Forereef	4.5	–14.29493	–170.67503
TUT-707	8-Apr	Deep	Forereef	22	–14.29206	–170.67596
TUT-753	8-Apr	Moderate	Forereef	12.8	–14.29462	–170.67512
TUT-762	8-Apr	Moderate	Forereef	8	–14.29096	–170.67398
TUT-777	8-Apr	Deep	Forereef	23.2	–14.28703	–170.67426
TUT-624	9-Apr	Deep	Forereef	26.5	–14.29231	–170.67552
TUT-704	9-Apr	Shallow	Forereef	2.1	–14.29315	–170.67527
TUT-708	9-Apr	Moderate	Forereef	14.5	–14.29181	–170.67635
TUT-718	9-Apr	Shallow	Forereef	2.3	–14.28982	–170.67683
TUT-729	9-Apr	Moderate	Forereef	11	–14.28954	–170.67643
TUT-735	9-Apr	Moderate	Forereef	9.4	–14.28832	–170.67781
TUT-736	9-Apr	Moderate	Forereef	11.5	–14.28825	–170.67722
TUT-739	9-Apr	Deep	Forereef	25	–14.28773	–170.67591
TUT-745	9-Apr	Deep	Forereef	23.6	–14.29689	–170.67433
TUT-747	9-Apr	Moderate	Forereef	17.7	–14.29618	–170.67445
TUT-749	9-Apr	Shallow	Forereef	2.7	–14.29578	–170.67487
TUT-754	9-Apr	Deep	Forereef	20.7	–14.29473	–170.67441
TUT-764	9-Apr	Moderate	Forereef	7.9	–14.29085	–170.67297
TUT-769	9-Apr	Shallow	Forereef	14.6	–14.29046	–170.67368
TUT-778	9-Apr	Moderate	Forereef	18.2	–14.28626	–170.67399
TUT-779	9-Apr	Shallow	Forereef	2.6	–14.28595	–170.67402
TUT-782	9-Apr	Moderate	Forereef	8.8	–14.28508	–170.67411
TUT-784	9-Apr	Shallow	Forereef	3	–14.28471	–170.67420
TUT-785	9-Apr	Moderate	Forereef	11	–14.28423	–170.67438
TUT-637	10-Apr	Shallow	Forereef	3.6	–14.29039	–170.67546
TUT-720	10-Apr	Deep	Forereef	28.3	–14.28999	–170.67581
TUT-726	10-Apr	Deep	Forereef	19.5	–14.28970	–170.67748
TUT-730	10-Apr	Shallow	Forereef	4	–14.28945	–170.67845
TUT-731	10-Apr	Deep	Forereef	20	–14.28918	–170.67679
TUT-741	10-Apr	Shallow	Forereef	3	–14.28734	–170.67527
TUT-507	12-Apr	Moderate	Forereef	15	–14.27401	–170.61549
TUT-529	12-Apr	Deep	Forereef	25	–14.27533	–170.61561
TUT-566	12-Apr	Deep	Forereef	22.2	–14.27617	–170.61189
TUT-590	12-Apr	Moderate	Forereef	16.5	–14.30526	–170.59894

APPENDIX C: ROSE ATOLL

Rose Atoll, located at 14°33' S, 168° 10' W in the South Pacific, is part of the American Samoa Island chain and is a Marine National Monument. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: "Methods."

C.1. Oceanography and Water Quality

Oceanographic operations during the cruise HA-12-01, Leg III at Rose Atoll entailed numerous retrievals and deployments of oceanographic moored instruments, calcification acidification units (CAUs), nearshore water sampling, Conductivity, Temperature, and Depth (CTD) casts at select Rapid Ecological Assessment (REA) sites, and shipboard water sampling and CTD casts offshore to a depth of 500 m.

Due to the change in monitoring to the National Coral Reef Monitoring Program (NCRMP) philosophy, four subsurface temperature recorders (STRs) were retrieved and replaced in the same place and eight additional STRs were deployed (Fig. C.1.1 and Table C.1.1). One of these STRs was deployed on environmental acoustic recorder (EAR) moorings. Because of limited funding, the one SST buoy was recovered, cleaned, and the same buoy replaced. One EAR mooring was retrieved and replaced. One wave and tide recorder (WTR) mooring was recovered and not replaced. For information about CAU deployments completed at Rose Atoll, see Section C.2: "Benthic Environment."

One pneumatic coral core was extracted from mounding *Porites* species around Rose Atoll.

Shallow-water CTD casts were performed at each of the 10 select REA sites where CAUs were replaced (Fig. C.1.1). In concert with each CTD cast, two water samples were taken (surface and near reef) to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, dissolved nutrients (PO_4^{3-}, $Si(OH)_4$), and chlorophyll-*a* (Chl-*a*) concentrations. Accounting for losses and microbiological nutrient samples taken alone, a total of 20 DIC and TA, 20 salinity, 20 nutrient, and 20 Chl-*a* water samples were collected.

From the NOAA Ship *Hi`ialakai* one CTD transect was conducted to the west. Due to technical issues with the shipboard CTD rosette, further collection of shipboard transect data, CTD casts, or water samples were not possible. CTD operations began at night with the first and only CTD sampling station defined as the closest point to land where the minimum survey depth was achieved (300–500 m). Chl-*a* water samples were collected concurrently with the CTD cast, at five depths between the surface and 300–500 m. Water sample depths were determined at the time of the CTD cast, as Chl-*a* sample collection was determined by the in-situ chlorophyll-*a* concentration maximum, thus depended upon the depth of mixed layer as measured by the CTD downcast (Fig. C.1.2). Five Chl-*a* water samples were collected during shipboard water sampling efforts.

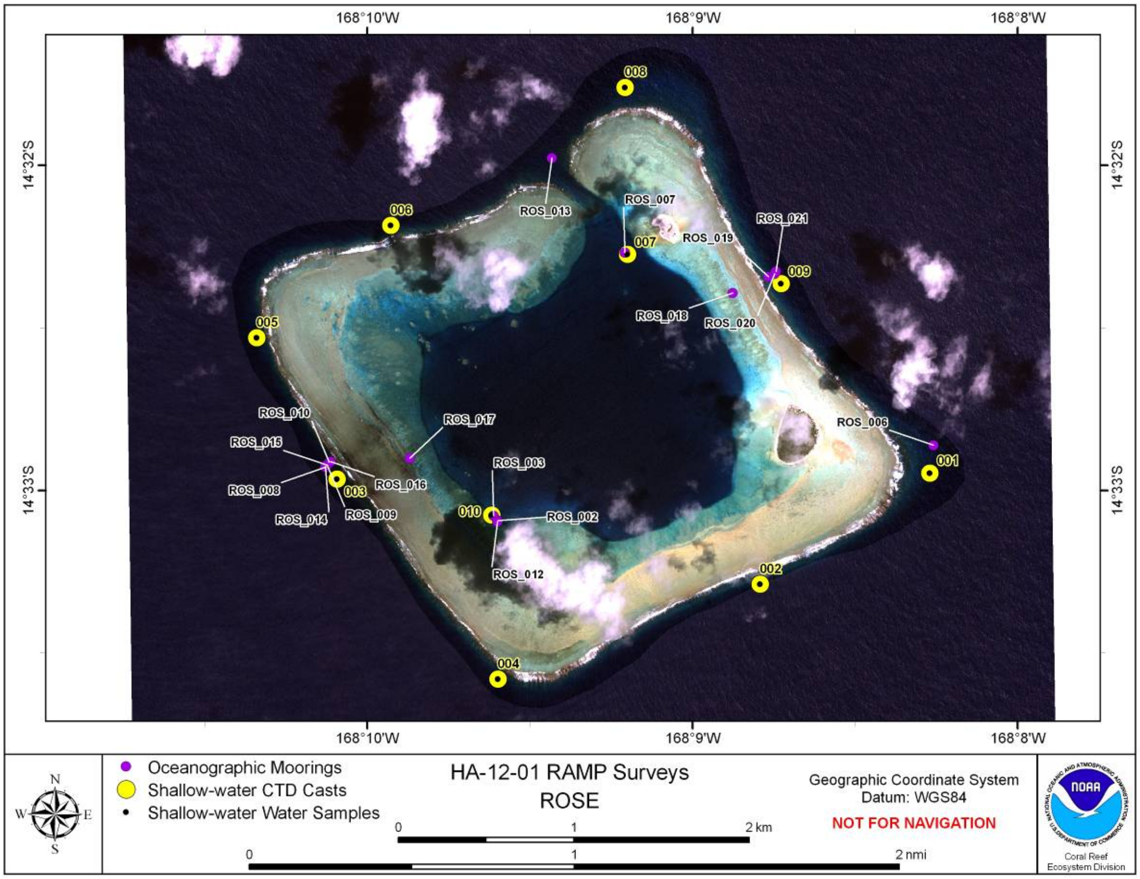

Figure C.1.1.--Mooring sites where oceanographic instruments were retrieved or deployed, and REA and CAU sites where nearshore CTD casts and water sampling were performed. Rose Atoll, HA-12-01, Leg III. Island satellite image IKONOS Carterra Geo Data, 2003.

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

Mooring Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
ROS_002	18-Apr	SST	–14.55159	–168.16000	0.3	1	–
ROS_003	18-Apr	STR	–14.55129	–168.16019	3	1	1
ROS_007	18-Apr	STR	–14.53779	–168.15347	1.8	1	1
ROS_009	18-Apr	STR	–14.54870	–168.16873	15.8	1	–
ROS_010	18-Apr	STR	–14.54855	–168.16864	7.9	1	–
ROS_012	18-Apr	STR	–14.55159	–168.16000	10.4	1	1
ROS_013	18-Apr	EAR	–14.53295	–168.15720	14.9	1	–
ROS_013	18-Apr	STR	–14.53295	–168.15720	14.9	1	1
ROS_015	18-Apr	STR	–14.54870	–168.16873	14.6	–	1
ROS_016	18-Apr	STR	–14.54852	–168.16856	4.9	–	1
ROS_017	18-Apr	STR	–14.54833	–168.16450	0.9	–	1
ROS_018	18-Apr	STR	–14.53986	–168.14794	0.5	–	1
ROS_019	18-Apr	STR	–14.53904	–168.14611	5.8	–	1
ROS_020	18-Apr	STR	–14.53888	–168.14579	15.5	–	1
ROS_021	18-Apr	STR	–14.53876	–168.14572	24.7	–	1
ROS_006	19-Apr	WTR	–14.54767	–168.13766	16.2	1	–
ROS_008	19-Apr	STR	–14.54881	–168.16883	30.5	1	–
ROS_014	19-Apr	EAR	–14.54877	–168.16883	25	–	1
ROS_014	19-Apr	STR	–14.54877	–168.16883	25.6	–	1
ROS_002	21-Apr	SST	–14.55154	–168.15997	0.3	–	1

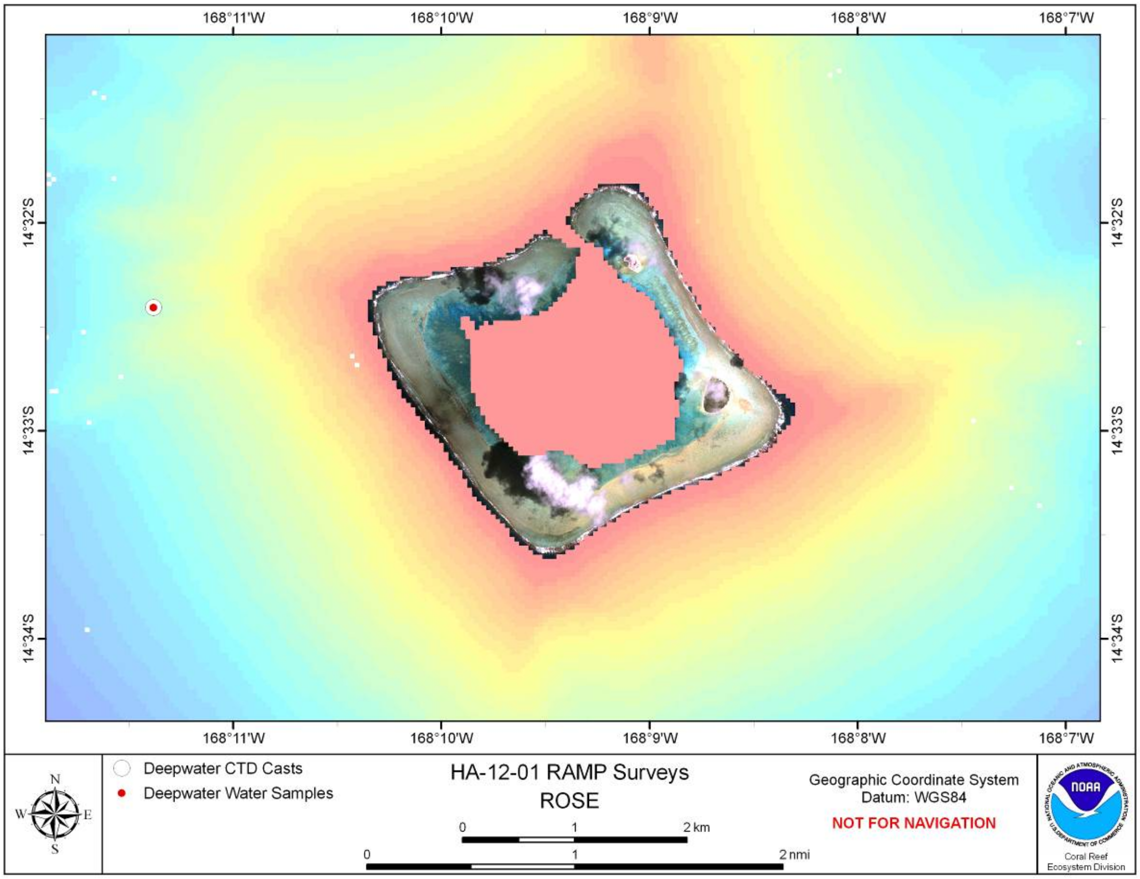

Figure C.1.2.--Location of the deepwater CTD cast and water sampling performed at Rose Atoll during cruise HA-12-01, Leg III, shown over multibeam bathymetry (grid cell size: 40 m). Island satellite image IKONOS Carterra Geo Data, 2003.

C.2. Benthic Environment

Belt-transect, line-point-intercept (LPI), and roving-diver surveys were conducted and photographs were taken along transect lines at 12 REA sites around Rose Atoll to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. C.2.1 and Table C.2.1).

Various samples were collected at 10 REA sites (Table C.2.2): 2 algal voucher specimens for taxonomic identification, 50 individuals of the algal genus *Halimeda* at four REA sites for calcification analysis and 30 for isotope analysis, one coral core from a *Porites* coral head at ROS-23 for calcification research, and 18 water samples for microbial analyses at six REA sites with two water samples of 2 L each at each site and three water samples of 80 L each at ROS-07 and ROS-09. Additional microbial work included benthic grabs of coral rubble and unidentified macroalgae at two REA sites. For more information about collections made at REA sites, see Table F.1.1 in Appendix F: "Biological Collections."

Twelve autonomous reef monitoring structures (ARMS) were recovered: three ARMS each from ROS-04, ROS-09, ROS-19 and ROS-25. (Table C.2.2). Nine ARMS were deployed with three ARMS each at ROS-04, ROS-19 and ROS-25. At 10 select REA sites an array of five CAUs were deployed for a total of 50 CAUs installed, and 48 were recovered from the previous deployments in 2010 (Table C.2.2). An additional two sets of CAUs were deployed at sites ROS-FWS1 and ROS-FWS2 at the request of the U.S. Fish and Wildlife Service. For information about EAR installations, see Section C.2: "Oceanography and Water Quality."

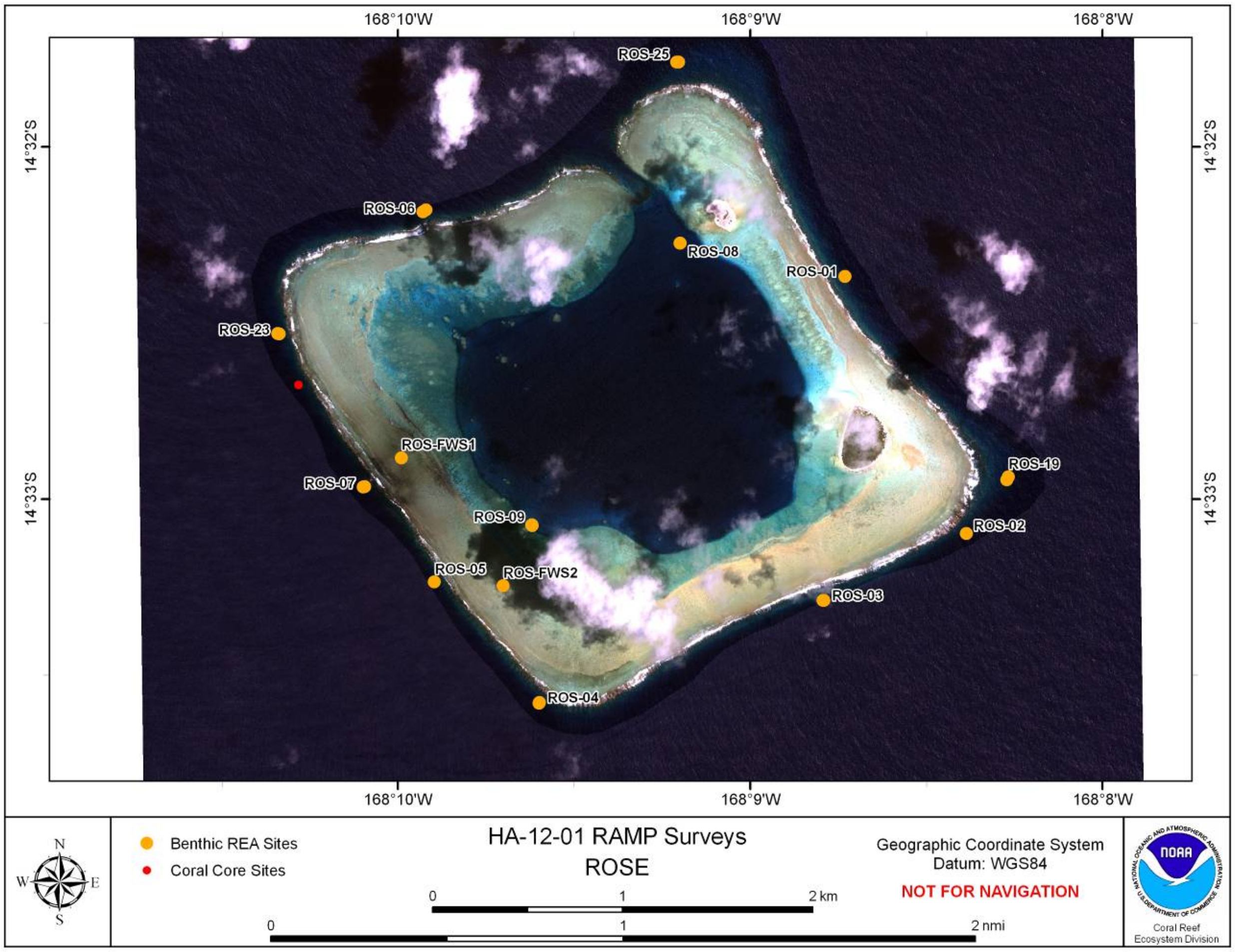

Figure C.2.1.--Locations of REA benthic sites surveyed at Rose Atoll during cruise HA-12-01, Leg III. Island satellite image IKONOS Carterra Geo Data, 2003.

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

REA Site	Date	Latitude	Longitude	REA Surveys		
				LPI	Roving Diver	Corals
ROS-02	18-Apr	–14.55164	–168.13977	x	x	x
ROS-03	18-Apr	–14.55480	–168.14652	x	x	x
ROS-19	18-Apr	–14.54894	–168.13778	x	x	x
ROS-04	19-Apr	–14.55964	–168.15998	x	x	x
ROS-07	19-Apr	–14.54943	–168.16831	x	x	x
ROS-23	19-Apr	–14.54218	–168.17228	x	x	x
ROS-01	20-Apr	–14.53946	–168.14550	x	x	x
ROS-08	20-Apr	–14.53789	–168.15330	x	x	x
ROS-25	20-Apr	–14.52931	–168.15339	x	x	x
ROS-05	21-Apr	–14.55393	–168.16493	x	x	x
ROS-06	21-Apr	–14.53632	–168.16533	x	x	x
ROS-09	21-Apr	–14.55122	–168.16032	x	x	x

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

REA Site	Date	Latitude	Longitude	Installations and Collections						
				CAU Ret	CAU Dep	ARMS Ret	ARMS Dep	Algae	Microbial Samples	Coral Cores
ROS-02	18-Apr	–14.55164	–168.13977	0	0	0	0	1	2	0
ROS-03	18-Apr	–14.55480	–168.14652	0	0	0	0	16	2	0
ROS-19	18-Apr	–14.54894	–168.13778	0	0	3	3	1	0	0
ROS-03	19-Apr	–14.55480	–168.14655	5	5	0	0	0	0	0
ROS-04	19-Apr	–14.55964	–168.15998	0	0	3	3	16	0	0
ROS-07	19-Apr	–14.54943	–168.16831	0	0	0	0	32	0	0
ROS-07	19-Apr	–14.54942	–168.16823	5	5	0	0	0	15	0
ROS-19	19-Apr	–14.54910	–168.13785	5	5	0	0	0	0	0
ROS-01	20-Apr	–14.53946	–168.14550	5	5	0	0	0	2	0
ROS-04	20-Apr	–14.55966	–168.15999	5	5	0	0	0	0	0
ROS-06	20-Apr	–14.53641	–168.16548	4	5	0	0	0	0	0
ROS-08	20-Apr	–14.53789	–168.15330	5	5	0	0	0	2	0
ROS-23	20-Apr	–14.54216	–168.17235	5	5	0	0	0	0	0
ROS-25	20-Apr	–14.52932	–168.15348	5	5	0	0	0	0	0
ROS-25	20-Apr	–14.52931	–168.15339	0	0	3	3	0	0	0
ROS-06	21-Apr	–14.53632	–168.16533	0	0	0	0	16	0	0
ROS-09	21-Apr	–14.55125	–168.16031	4	5	0	0	0	0	0
ROS-09	21-Apr	–14.55122	–168.16032	0	0	3	0	0	10	0
ROS-23	21-Apr	–14.54459	–168.17136	0	0	0	0	0	0	1
ROS-FWS1	21-Apr	–14.54805	–168.16650	0	5	0	0	0	0	0
ROS-FWS2	21-Apr	–14.55410	–168.16168	0	5	0	0	0	0	0

During cruise HA-12-01, Leg III, CRED completed 10 towed-diver surveys at Rose Atoll, covering a total length of 21.6 km (an area of 21.6 ha) on the ocean floor (Fig. C.2.2). The mean survey length was 2.2 km with a range of 1.8–2.5 km. The mean survey depth was 13.4 m with a range of 6.0–19.2 m. The mean temperature from data recorded during these surveys was 29.4°C with a range of 29.2°C–29.7°C.

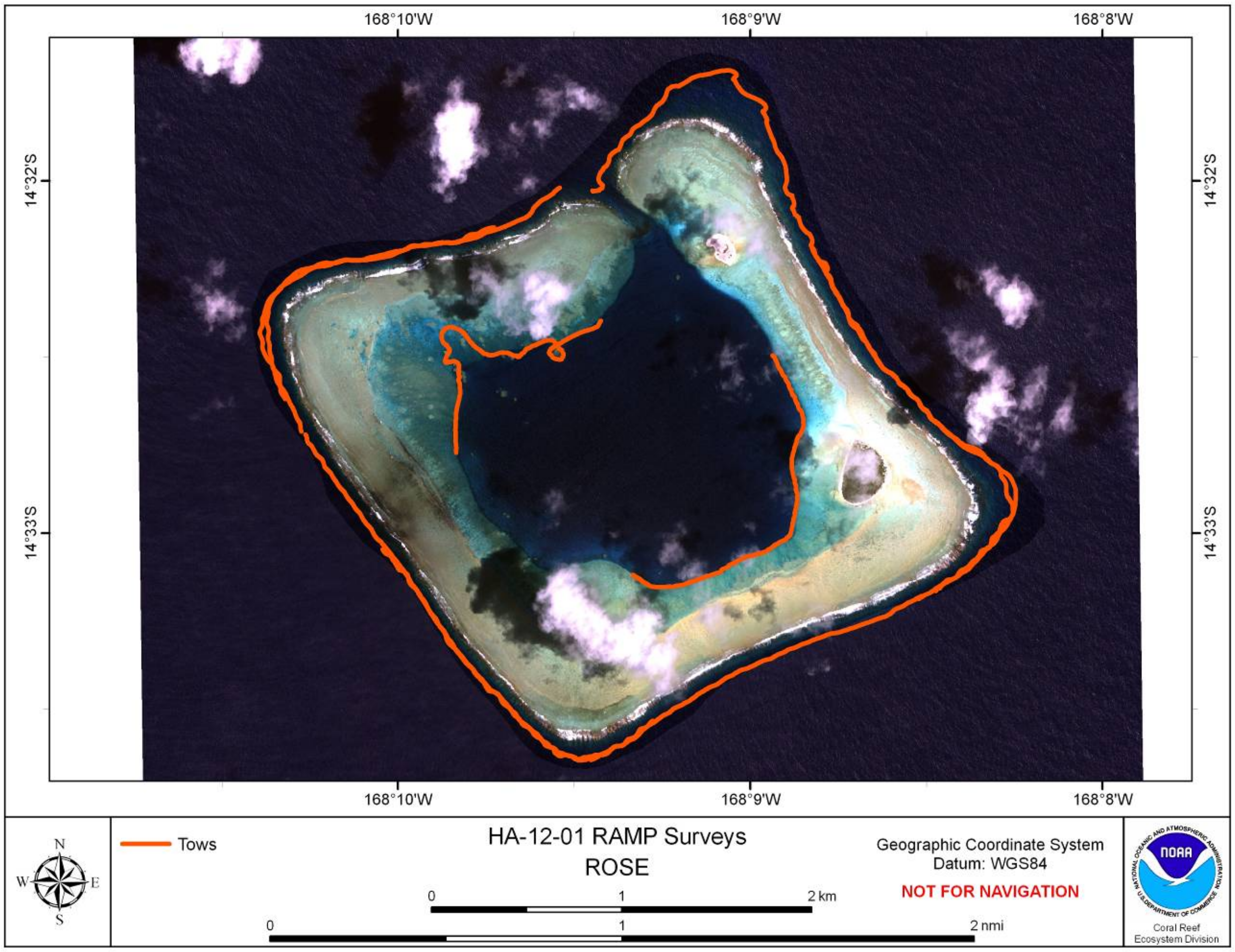

Figure C.2.2.--Track locations of towed-diver surveys conducted at Rose Atoll during cruise HA-12-01, Leg III. Island satellite image IKONOS Carterra Geo Data, 2003.

C.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 48 REA sites at Rose Atoll over 5 different habitat strata: deep forereef, moderate forereef, shallow forereef, moderate backreef, and shallow backreef (Table C.3.1 and Fig.C.3.1). No fishes were collected during these surveys.

In addition, CRED completed 9 towed-diver fish surveys at Rose Atoll, as described previously in Section C.2 of this appendix.

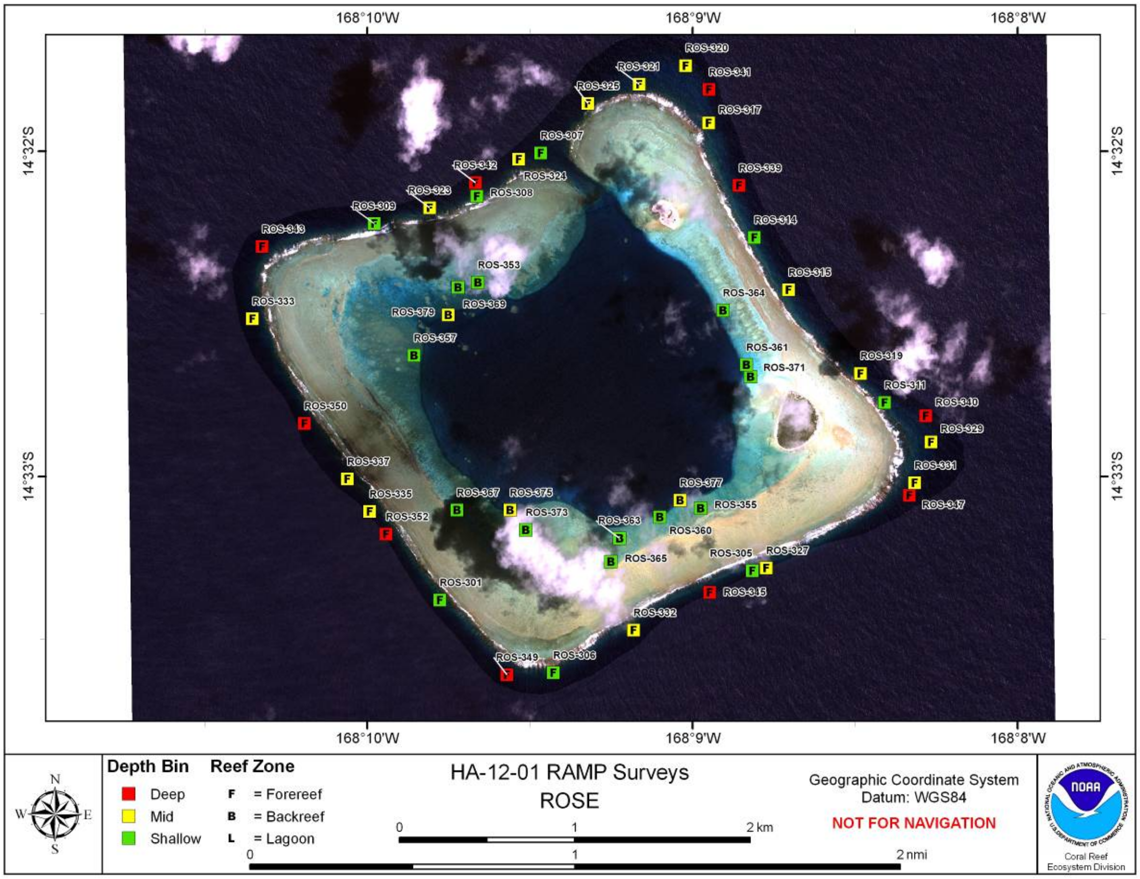

Figure C.3.1.--Locations of REA fish sites surveyed at Rose Atoll during cruise HA-12-01, Leg III. All of these REA sites were selected using a stratified random design. Island satellite image IKONOS Carterra Geo Data, 2003.

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

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
ROS-305	18-Apr	Shallow	Forereef	6.7	–14.55484	–168.14694
ROS-314	18-Apr	Shallow	Forereef	5.2	–14.53775	–168.14683
ROS-315	18-Apr	Moderate	Forereef	11.2	–14.54043	–168.14509
ROS-319	18-Apr	Moderate	Forereef	11	–14.54471	–168.14138
ROS-327	18-Apr	Moderate	Forereef	12.7	–14.55470	–168.14623
ROS-329	18-Apr	Moderate	Forereef	15	–14.54823	–168.13777
ROS-331	18-Apr	Moderate	Forereef	13	–14.55032	–168.13862
ROS-332	18-Apr	Moderate	Forereef	13	–14.55788	–168.15302
ROS-339	18-Apr	Deep	Forereef	26	–14.53508	–168.14761
ROS-345	18-Apr	Deep	Forereef	23	–14.55595	–168.14912
ROS-347	18-Apr	Deep	Forereef	21.3	–14.55097	–168.13888
ROS-349	18-Apr	Deep	Forereef	22	–14.56017	–168.15952
ROS-301	19-Apr	Shallow	Forereef	4.5	–14.55633	–168.16296
ROS-308	19-Apr	Shallow	Forereef	5.5	–14.53564	–168.16107
ROS-309	19-Apr	Shallow	Forereef	5.2	–14.53703	–168.16632
ROS-317	19-Apr	Moderate	Forereef	9.8	–14.53188	–168.14917
ROS-321	19-Apr	Moderate	Forereef	8.5	–14.52988	–168.15274
ROS-323	19-Apr	Moderate	Forereef	16.5	–14.53622	–168.16348
ROS-325	19-Apr	Moderate	Forereef	16	–14.53087	–168.15538
ROS-333	19-Apr	Moderate	Forereef	10	–14.54191	–168.17257
ROS-335	19-Apr	Moderate	Forereef	16	–14.55179	–168.16655
ROS-337	19-Apr	Moderate	Forereef	14	–14.55014	–168.16769
ROS-341	19-Apr	Deep	Forereef	26	–14.53016	–168.14915
ROS-352	19-Apr	Deep	Forereef	21.4	–14.55296	–168.16572
ROS-371	19-Apr	Shallow	Backreef	1.4	–14.54488	–168.14702
ROS-306	20-Apr	Shallow	Forereef	6	–14.56005	–168.15715
ROS-311	20-Apr	Shallow	Forereef	4.8	–14.54620	–168.14015
ROS-320	20-Apr	Moderate	Forereef	12.4	–14.52893	–168.15036
ROS-340	20-Apr	Deep	Forereef	22.3	–14.54688	–168.13805
ROS-350	20-Apr	Deep	Forereef	26.6	–14.54728	–168.16991
ROS-353	20-Apr	Shallow	Backreef	2.3	–14.54005	–168.16100
ROS-355	20-Apr	Shallow	Backreef	1.5	–14.55163	–168.14959
ROS-357	20-Apr	Shallow	Backreef	1.3	–14.54380	–168.16428
ROS-360	20-Apr	Shallow	Backreef	1.5	–14.55208	–168.15169
ROS-361	20-Apr	Shallow	Backreef	1.6	–14.54427	–168.14725
ROS-363	20-Apr	Shallow	Backreef	2	–14.55316	–168.15374
ROS-364	20-Apr	Shallow	Backreef	1	–14.54149	–168.14845
ROS-365	20-Apr	Shallow	Backreef	1	–14.55437	–168.15419
ROS-367	20-Apr	Shallow	Backreef	1	–14.55172	–168.16208
ROS-369	20-Apr	Shallow	Backreef	1.7	–14.54031	–168.16203
ROS-373	20-Apr	Shallow	Backreef	1.2	–14.55275	–168.15855
ROS-375	20-Apr	Moderate	Backreef	8.1	–14.55172	–168.15935
ROS-377	20-Apr	Moderate	Backreef	13.4	–14.55122	–168.15065
ROS-379	20-Apr	Moderate	Backreef	9.6	–14.54171	–168.16253
ROS-307	21-Apr	Shallow	Forereef	4	–14.53341	–168.15778

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
ROS-324	21-Apr	Moderate	Forereef	11	–14.53373	–168.15891
ROS-342	21-Apr	Deep	Forereef	21.3	–14.53493	–168.16112
ROS-343	21-Apr	Deep	Forereef	27.5	–14.53821	–168.17207

APPENDIX D: TA'U ISLAND

The island of Ta'u is located at 14°14' S, 169°28' W in the South Pacific and is part of the American Samoa Island chain. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: "Methods."

D.1. Oceanography and Water Quality

Oceanographic operations during the cruise HA-12-01, Leg III at Ta'u Island entailed numerous retrievals and deployments of oceanographic moored instruments, calcification acidification units (CAUs), nearshore water sampling, and Conductivity, Temperature, and Depth (CTD) casts at select Rapid Ecological Assessment (REA) sites.

Due to the change in monitoring to the National Coral Reef Monitoring Program (NCRMP) philosophy, four subsurface temperature recorders (STRs) were retrieved and four new STR moorings were established (Fig. D.1.1 and Table D.1.1). Because of limited funding, the one SST buoy was recovered and not replaced. For information about CAU deployments completed at Ta'u Island, see Section D.2: "Benthic Environment."

No coral cores were collected by CRED while at Ta'u Island, but the oceanography team did repair a coral core plug on the large mounding *Porites* known as "Big Mama," as requested by scientists from Stanford University, the American Samoan government, and NOAA.

Shallow-water CTD casts were performed at each of the seven select REA sites where CAUs were replaced (Fig. D.1.1). In concert with each CTD cast, two water samples were taken (surface and near reef) to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, dissolved nutrients (PO_4^{3-}, $Si(OH)_4$), and chlorophyll-*a* (Chl-*a*) concentrations. Accounting for losses and microbiological nutrient samples taken alone, a total of 14 DIC and TA, 14 salinity, 14 nutrient, and 14 Chl-*a* water samples were collected.

Due to technical issues with the shipboard CTD rosette, shipboard transects, CTD casts and water samples were not taken near Ta'u Island from the NOAA Ship *Hi`ialakai*.

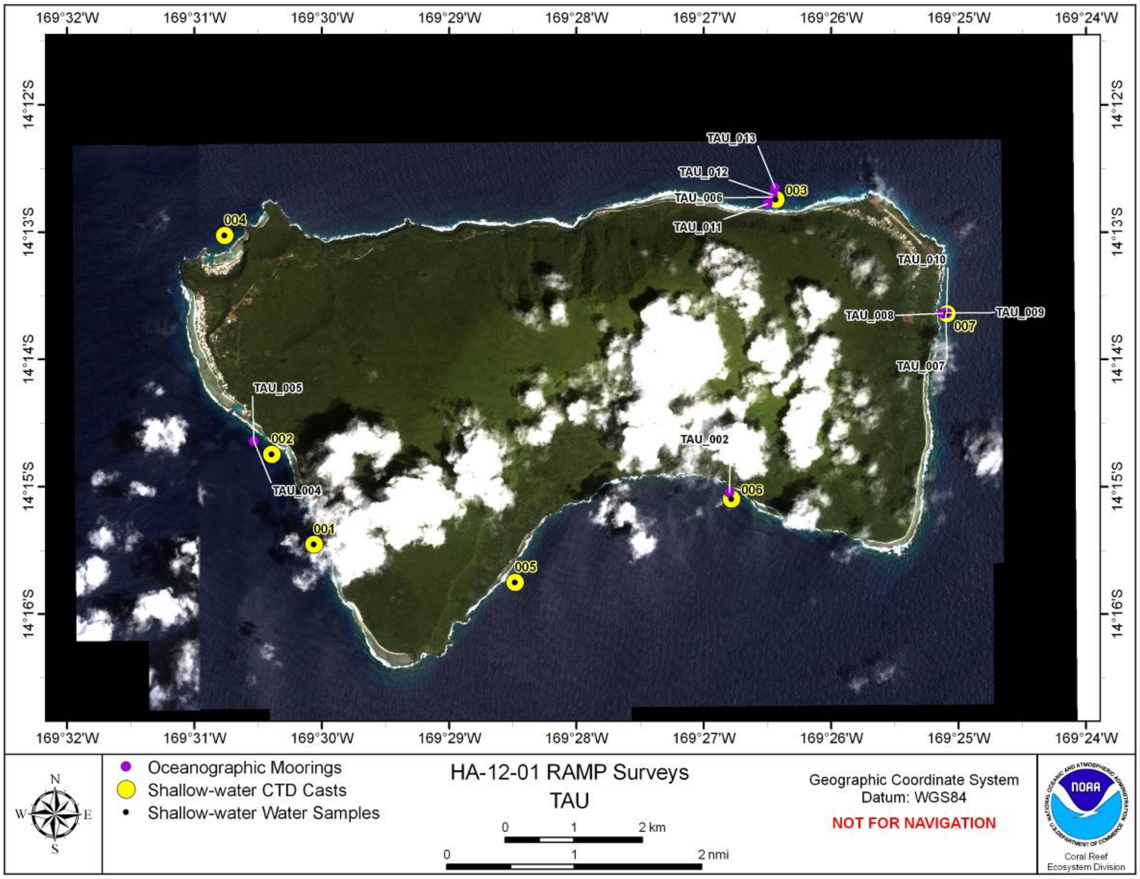

Figure D.1.1.--Mooring sites where oceanographic instruments were retrieved or deployed and REA and CAU sites where nearshore CTD casts and water sampling were performed. Ta'u Island, HA-12-01, Leg III (IKONOS Carterra Geo Data, 2003).

Table D.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments that were retrieved or deployed at Ta'u Island during cruise HA-12-01, Leg III.

Mooring Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
TAU_004	22-Apr	SST	–14.24401	–169.50891	0.3	1	–
TAU_005	22-Apr	STR	–14.24401	–169.50891	14.6	1	–
TAU_006	22-Apr	STR	–14.21207	–169.44111	12.8	1	–
TAU_011	22-Apr	STR	–14.21298	–169.44171	5.8	–	1
TAU_012	22-Apr	STR	–14.21176	–169.44096	14.9	–	1
TAU_013	22-Apr	STR	–14.21082	–169.44068	25	–	1
TAU_002	23-Apr	STR	–14.25069	–169.44666	6.4	1	–
TAU_007	23-Apr	STR	–14.22726	–169.41833	13.1	1	–
TAU_008	23-Apr	STR	–14.22725	–169.41870	5.5	–	1
TAU_009	23-Apr	STR	–14.22722	–169.41815	24.7	–	1
TAU_010	23-Apr	STR	–14.22720	–169.41827	14.9	–	1

D.2. Benthic Environment

Belt-transect, line-point-intercept (LPI), and roving-diver surveys were conducted and photographs were taken along transect lines at 6 REA sites around Ta'u Island to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. D.2.1 and Table D.2.1).

Various samples were collected at 6 REA sites (Table D.2.2): 3 algal voucher specimens at three REA sites for taxonomic identification, 10 individuals of the algal genus *Halimeda* at TAU-12 for calcification analysis and 8 water samples for microbial analyses at 4 REA sites with 2 water samples of 2 L each at each site. For more information about collections made at REA sites, see Table F.1.1 in Appendix F: "Biological Collections."

At six REA sites an array of 5 CAUs were deployed for a total of 30 CAUs installed and 35 were recovered from the previous deployments in 2010 (Table D.2.2).

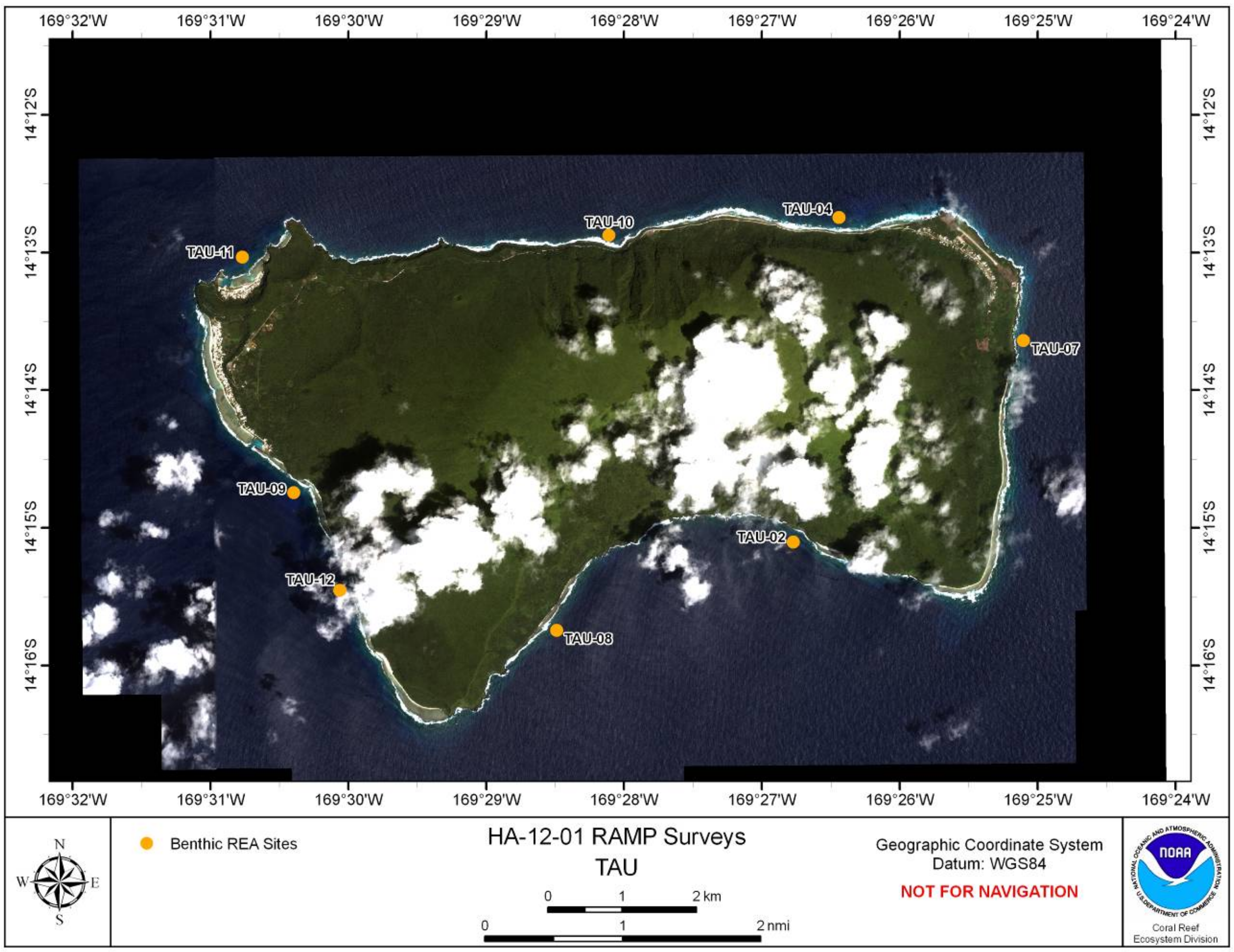

Figure D.2.1.--Locations of REA benthic sites surveyed at Ta'u during cruise HA-12-01, Leg III (IKONOS Carterra Geo Data, 2003).

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

REA Site	Date	Latitude	Longitude	REA Surveys		
				LPI	Roving Diver	Corals
TAU-04	22-Apr	–14.21240	–169.44066	x	x	x
TAU-11	22-Apr	–14.21723	–169.51281	x	x	x
TAU-12	22-Apr	–14.25756	–169.50101	x	x	x
TAU-02	23-Apr	–14.25171	–169.44617	x	x	x
TAU-07	23-Apr	–14.22730	–169.41833	x	x	x
TAU-08	23-Apr	–14.26240	–169.47480	x	x	x

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

REA Site	Date	Latitude	Longitude	Installations and Collections						
				CAU Ret	CAU Dep	ARMS Ret	ARMS Dep	Algae	Coral	Microbial Samples
OFU-01	24-Apr	–14.16445	–169.65573	5	5	0	0	0	0	0
OLO-01	24-Apr	–14.16854	–169.60783	5	5	0	0	0	0	0
OLO-01	24-Apr	–14.16850	–169.60790	0	0	0	0	16	0	0
OLO-04	24-Apr	–14.18173	–169.62661	5	5	0	0	0	0	14
OLO-04	24-Apr	–14.18140	–169.62675	0	0	3	3	0	0	0
OLO-05	24-Apr	–14.16349	–169.62455	0	0	0	0	16	0	0
OLO-05	24-Apr	–14.16343	–169.62465	5	5	0	0	0	0	0
OFU-02	25-Apr	–14.18511	–169.67573	5	0	0	0	11	9	0
OFU-03	25-Apr	–14.18649	–169.66021	5	5	0	0	0	0	0
OFU-04	25-Apr	–14.17766	–169.64950	5	0	3	3	0	0	0
OFU-06	25-Apr	–14.17423	–169.68198	0	0	0	0	0	0	2
OFU-09	25-Apr	–14.15764	–169.67424	5	5	0	0	0	0	2
OFU-01	26-Apr	–14.16445	–169.65571	0	0	0	0	16	0	2
OFU-03	26-Apr	–14.18648	–169.66037	0	0	3	3	0	0	0
OFU-06	26-Apr	–14.17419	–169.68197	4	5	0	0	0	0	0
OFU-09	26-Apr	–14.15761	–169.67408	0	0	0	0	0	0	2

During cruise HA-12-01, Leg III CRED completed 11 towed-diver surveys at Ta'u Island, covering a total length of 22.5 km (an area of 22.5 ha) on the ocean floor (Fig. D.2.2).The mean survey length was 2.0 km with a range of 1.1–2.6 km. The mean survey depth was 15.3 m with a range of 13.4–17.0 m. The mean temperature from data recorded during these surveys was 29.5°C with a range of 29.4°C–29.6°C.

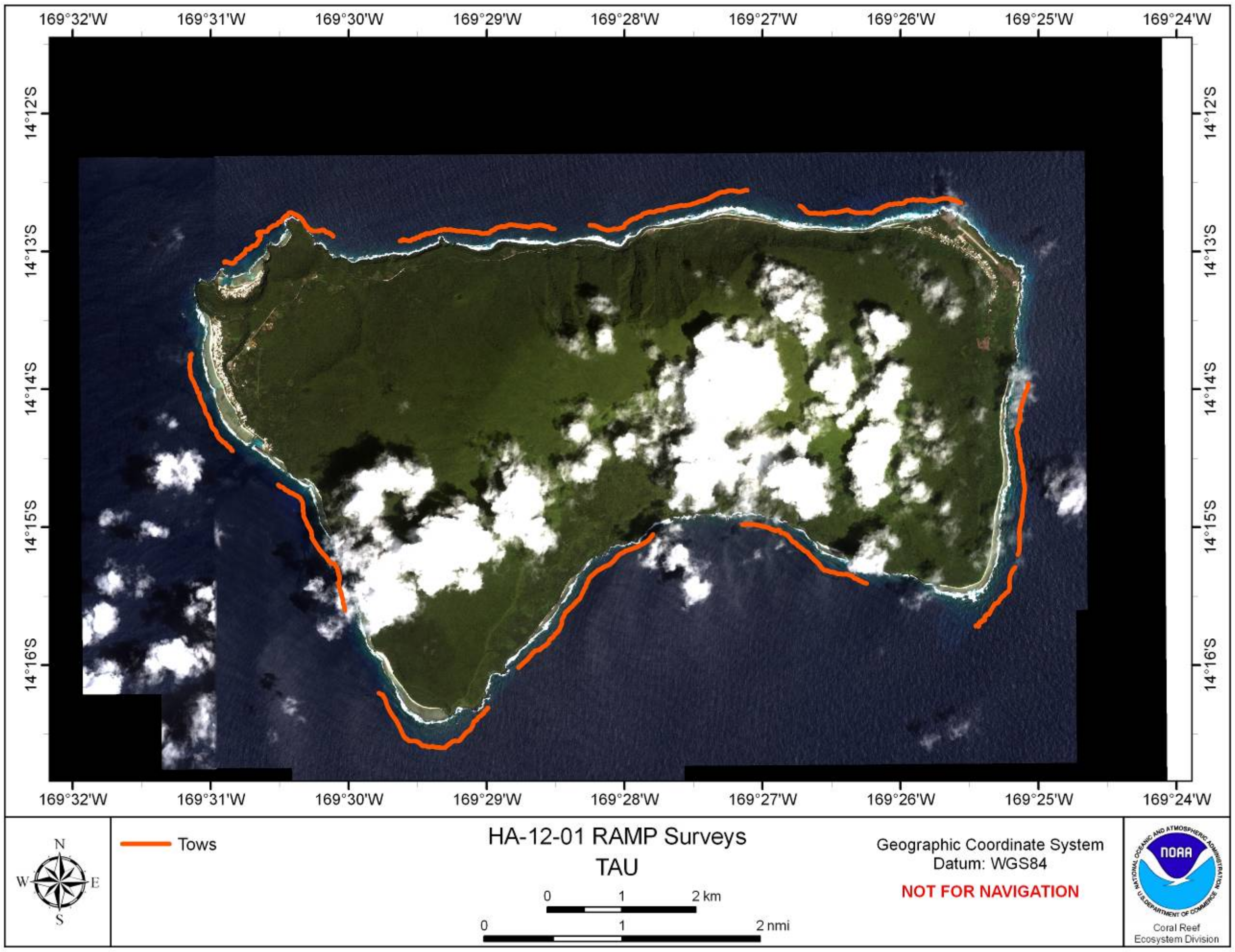

Figure D.2.2.--Track locations of towed-diver surveys conducted at Ta'u during cruise HA-12-01, Leg III (IKONOS Carterra Geo Data, 2003).

D.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 22 REA sites at Ta'u Island over three different habitat strata: deep forereef, moderate forereef, and shallow forereef (Table D.3.1 and Fig. D.3.1). No fishes were collected during these surveys.

In addition, CRED completed 11 towed-diver surveys at Ta'u Island, as described previously in Section D.2 of this appendix.

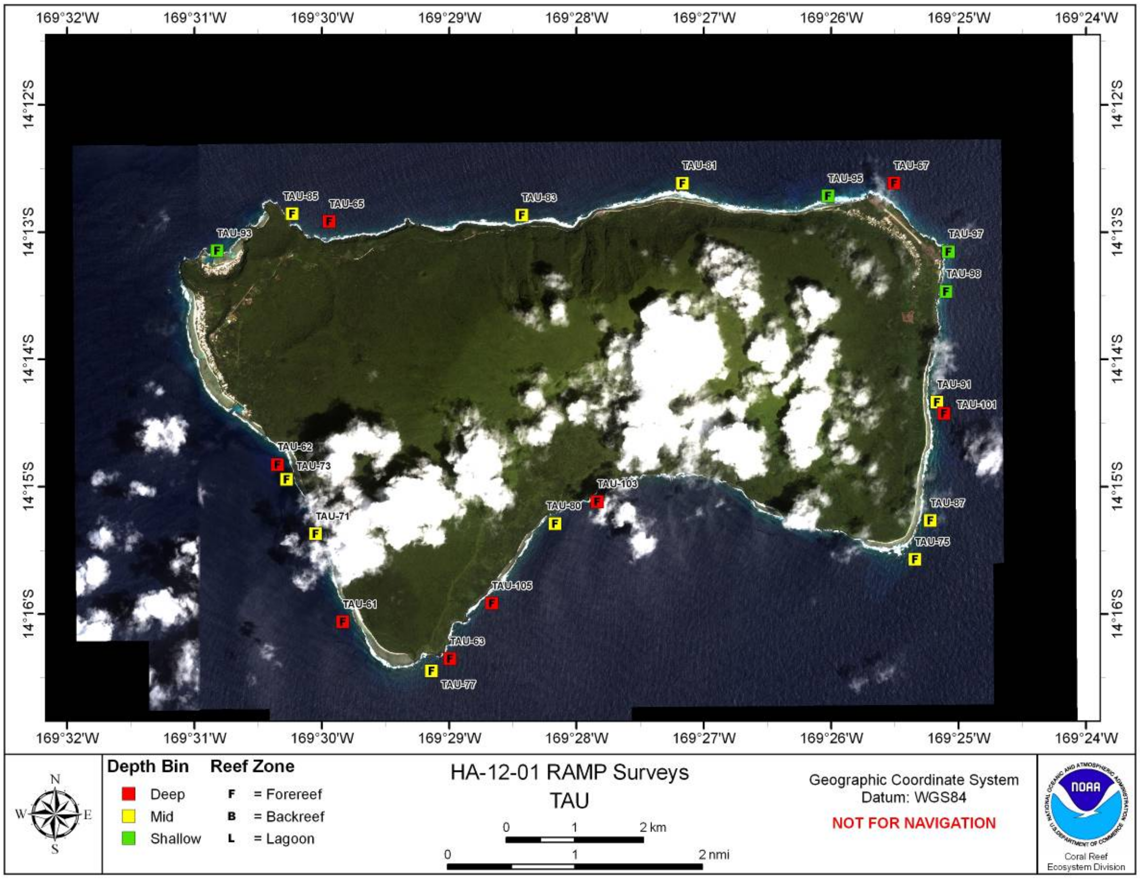

Figure D.3.1.--Locations of REA fish sites surveyed at Ta'u Island during cruise HA-12-01, Leg III. All of these REA sites were selected using a stratified random design (IKONOS Carterra Geo Data, 2003).

Table D.3.1.--Summary of sites where REA fish surveys were conducted at Ta'u Island during cruise HA-12-01, Leg III.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
TAU-61	22-Apr	Deep	Forereef	23.3	–14.26766	–169.49728
TAU-62	22-Apr	Deep	Forereef	24	–14.24708	–169.50579
TAU-65	22-Apr	Deep	Forereef	23	–14.21524	–169.49902
TAU-67	22-Apr	Deep	Forereef	21.6	–14.21025	–169.42511
TAU-71	22-Apr	Moderate	Forereef	11.5	–14.25616	–169.50083
TAU-73	22-Apr	Moderate	Forereef	10.5	–14.24904	–169.50460
TAU-81	22-Apr	Moderate	Forereef	8.5	–14.21025	–169.45280
TAU-83	22-Apr	Moderate	Forereef	10	–14.21442	–169.47382
TAU-85	22-Apr	Moderate	Forereef	14.6	–14.21426	–169.50390
TAU-93	22-Apr	Shallow	Forereef	5	–14.21911	–169.51370
TAU-95	22-Apr	Shallow	Forereef	6	–14.21192	–169.43376
TAU-63	23-Apr	Deep	Forereef	25.5	–14.27251	–169.48324
TAU-75	23-Apr	Moderate	Forereef	12.5	–14.25948	–169.42235
TAU-77	23-Apr	Moderate	Forereef	13.5	–14.27410	–169.48565
TAU-80	23-Apr	Moderate	Forereef	13	–14.25481	–169.46947
TAU-87	23-Apr	Moderate	Forereef	9.8	–14.25440	–169.42038
TAU-91	23-Apr	Moderate	Forereef	11	–14.23890	–169.41950
TAU-97	23-Apr	Shallow	Forereef	5	–14.21921	–169.41797
TAU-98	23-Apr	Shallow	Forereef	5	–14.22442	–169.41830
TAU-101	23-Apr	Deep	Forereef	27.5	–14.24040	–169.41858
TAU-103	23-Apr	Deep	Forereef	25	–14.25193	–169.46394
TAU-105	23-Apr	Deep	Forereef	23	–14.26525	–169.47773

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APPENDIX E: OFU AND OLOSEGA ISLANDS

The islands of Ofu and Olosega are located at 14°10’ S, 169°19’ W in the South Pacific and are part of the American Samoan Island chain. For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: “Methods.”

E.1. Oceanography and Water Quality

Oceanographic operations during the cruise HA-12-01, Leg III at Ofu and Olosega Islands entailed numerous retrievals and deployments of oceanographic moored instruments, calcification acidification units (CAUs), nearshore water sampling, and Conductivity, Temperature, and Depth (CTD) casts at select Rapid Ecological Assessment (REA) sites.

Due to the change in monitoring to the National Coral Reef Monitoring Program (NCRMP) philosophy, two subsurface temperature recorders (STRs) were retrieved and replaced in the same place, five were removed and six additional STRs were deployed at Ofu and Olosega Islands (Fig. E.1.1 and Table E.1.1). Because of limited funding, the one SST buoy was removed and not replaced. For information about CAU deployments completed at Ofu and Olosega Islands, see Section E.2: “Benthic Environment.”

Ten shallow-water CTD casts were performed, nine of which were at the select REA sites where CAUs were replaced (Fig. E.1.1). In concert with each CTD cast at the REA sites, two water samples were taken (surface and near reef) to measure the following parameters: dissolved inorganic carbon (DIC), total alkalinity (TA), salinity, dissolved nutrients (PO_4^{3-}, $Si(OH)_4$), and chlorophyll-*a* (Chl-*a*) concentrations; triplicate samples were collected at CTD cast 010 at site OFU-04. Accounting for losses and microbiological nutrient samples taken alone, a total of 22 DIC and TA, 22 salinity, 22 nutrient, and 22 Chl-*a* water samples were collected.

Due to technical issues with the shipboard CTD rosette, shipboard transects, CTD casts and water samples were not taken near Ofu and Olosega Islands from the NOAA Ship *Hi`ialakai*.

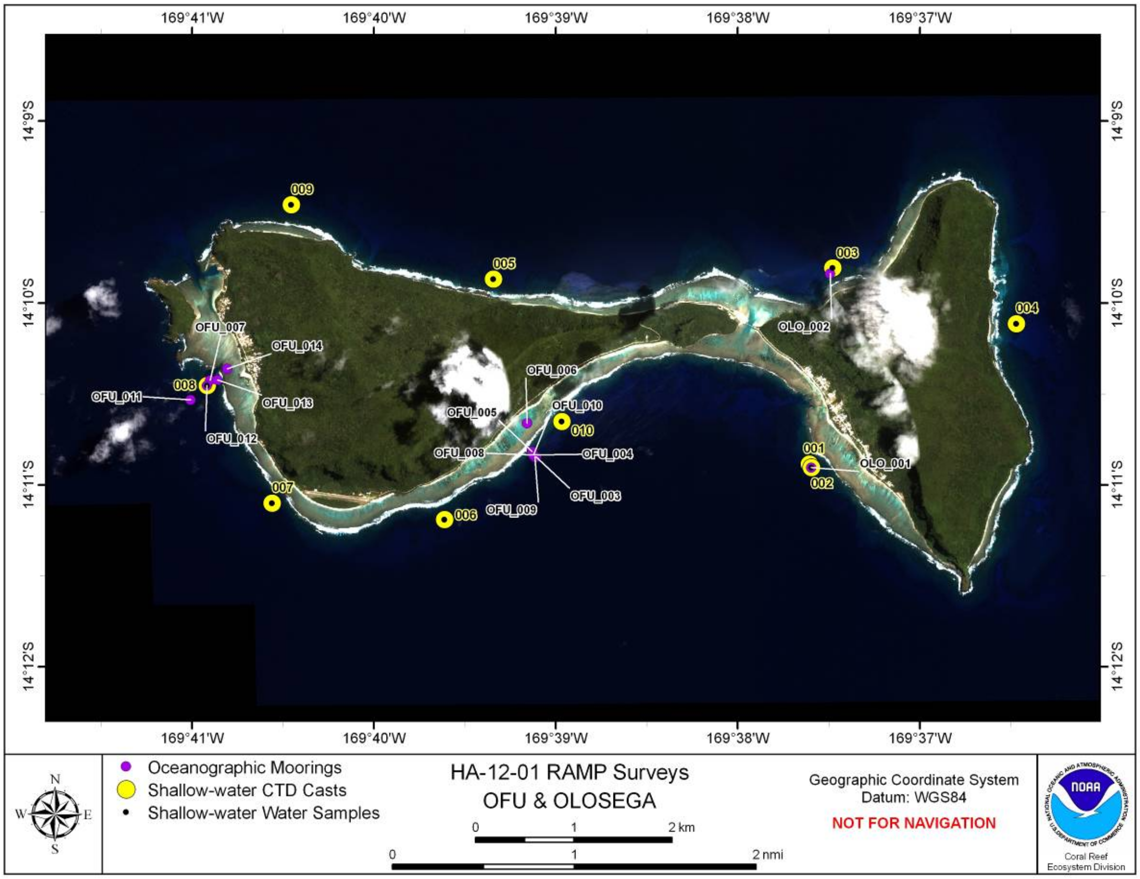

Figure E.1.1.--Mooring sites where oceanographic instruments were retrieved or deployed and REA and CAU sites where nearshore CTD casts and water sampling were performed. Ofu and Olosega Islands, HA-12-01, Leg III (IKONOS Carterra Geo Data, 2003).

Table E.1.1.--Geographic coordinates and sensor depths of the moored oceanographic instruments that were retrieved or deployed at Ofu and Olosega Islands during cruise HA-12-01, Leg III.

Mooring Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
OLO_001	24-Apr	STR	–14.18173	–169.62661	11.3	1	–
OLO_002	24-Apr	STR	–14.16395	–169.62489	6.1	1	–
OFU_003	25-Apr	STR	–14.18077	–169.65179	30.5	1	–
OFU_004	25-Apr	STR	–14.18059	–169.65202	15.2	1	–
OFU_005	25-Apr	STR	–14.18024	–169.65219	5.8	1	1
OFU_007	25-Apr	STR	–14.17372	–169.68169	8.5	1	–
OFU_008	25-Apr	SST	–14.18059	–169.65202	0.3	1	–
OFU_009	25-Apr	STR	–14.18075	–169.65194	24.7	–	1
OFU_010	25-Apr	STR	–14.18057	–169.65206	14.6	–	1
OFU_012	25-Apr	STR	–14.17423	–169.68198	15.2	–	1
OFU_013	25-Apr	STR	–14.17369	–169.68099	4.3	–	1
OFU_006	26-Apr	STR	–14.17767	–169.65263	1.5	1	1
OFU_011	26-Apr	STR	–14.17552	–169.68347	25.3	–	1
OFU_014	26-Apr	STR	–14.17269	–169.68012	0.6	–	1

E.2. Benthic Environment

Belt-transect, line-point-intercept (LPI), and roving-diver surveys were conducted and photographs were taken along transect lines at 9 REA sites around Ofu and Olosega Islands to assess benthic composition, coral and algal community structure, and coral and algal disease (Fig. E.2.1 and Table E.2.1).

Various samples were collected at 7 REA sites (Table E.2.2): 1 algal voucher specimen at OFU-02 for taxonomic identification, 40 individuals of the algal genus *Halimeda* at 4 REA sites for calcification analysis and 18 for isotope analysis and 12 water samples for microbial analyses at 5 REA sites with 2 water samples of 2 L each at each site and a water sample of 80 L at OLO-04. Additional microbial work included benthic grabs of coral rubble and unidentified macroalgae at OLO-04. For more information about collections made at REA sites, see Table F.1.1 in Appendix F: “Biological Collections.”

Nine autonomous reef monitoring structures (ARMS) were recovered: Three ARMS each from OFU-03, OFU-04 and OLO-04 (Table E.2.2). Nine ARMS were deployed with three ARMS each at OFU-03, OFU-04 and OLO-04. At 7 select REA sites, an array of 5 CAUs were deployed for a total of 35 CAUs installed, and 44 were recovered from the previous deployments in 2010 (Table E.2.2).

Figure E.2.1.--Locations of REA benthic sites surveyed at Ofu and Olosega Islands during cruise HA-12-01, Leg III (IKONOS Carterra Geo Data, 2003).

Table E.2.1.--Summary of REA benthic surveys performed at Ofu and Olosega Islands during cruise HA-12-01, Leg III. Indication that an LPI survey was completed also means that photographs were taken along transect lines.

				REA Surveys		
REA Site	**Date**	**Latitude**	**Longitude**	**LPI**	**Roving Diver**	**Corals**
OLO-01	24-Apr	–14.16850	–169.60790	x	x	x
OLO-04	24-Apr	–14.18140	–169.62675	x	x	x
OLO-05	24-Apr	–14.16349	–169.62455	x	x	x
OFU-02	25-Apr	–14.18511	–169.67573	x	x	x
OFU-04	25-Apr	–14.17766	–169.64950	x	x	x
OFU-06	25-Apr	–14.17419	–169.68195	x	x	x
OFU-01	26-Apr	–14.16445	–169.65571	x	x	x
OFU-03	26-Apr	–14.18648	–169.66037	x	x	x
OFU-09	26-Apr	–14.15761	–169.67408	x	x	x

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

REA Site	Date	Latitude	Longitude	Installations and Collections					
				CAU Ret	CAU Dep	ARMS Ret	ARMS Dep	Algae	Microbial Samples
OFU-01	24-Apr	–14.16445	–169.65573	5	5	0	0	0	0
OLO-01	24-Apr	–14.16854	–169.60783	5	5	0	0	0	0
OLO-01	24-Apr	–14.16850	–169.60790	0	0	0	0	16	0
OLO-04	24-Apr	–14.18173	–169.62661	5	5	0	0	0	14
OLO-04	24-Apr	–14.18140	–169.62675	0	0	3	3	0	0
OLO-05	24-Apr	–14.16349	–169.62455	0	0	0	0	16	0
OLO-05	24-Apr	–14.16343	–169.62465	5	5	0	0	0	0
OFU-02	25-Apr	–14.18511	–169.67573	5	0	0	0	11	0
OFU-03	25-Apr	–14.18649	–169.66021	5	5	0	0	0	0
OFU-04	25-Apr	–14.17766	–169.64950	5	0	3	3	0	0
OFU-06	25-Apr	–14.17423	–169.68198	0	0	0	0	0	2
OFU-09	25-Apr	–14.15764	–169.67424	5	5	0	0	0	2
OFU-01	26-Apr	–14.16445	–169.65571	0	0	0	0	16	2
OFU-03	26-Apr	–14.18648	–169.66037	0	0	3	3	0	0
OFU-06	26-Apr	–14.17419	–169.68197	4	5	0	0	0	0
OFU-09	26-Apr	–14.15761	–169.67408	0	0	0	0	0	2

During cruise HA-12-01, Leg III, CRED completed 10 towed-diver surveys at Ofu and Olosega Islands, covering a total length of 21.2 km (an area of 21.2 ha) on the ocean floor (Fig. E.2.2). The mean survey length was 2.1 km with a range of 1.8–2.7 km. The mean survey depth was 15.4 m with a range of 13.7–18.1 m. The mean temperature from data recorded during these surveys was 29.5°C with a range of 29.1°C–29.6°C.

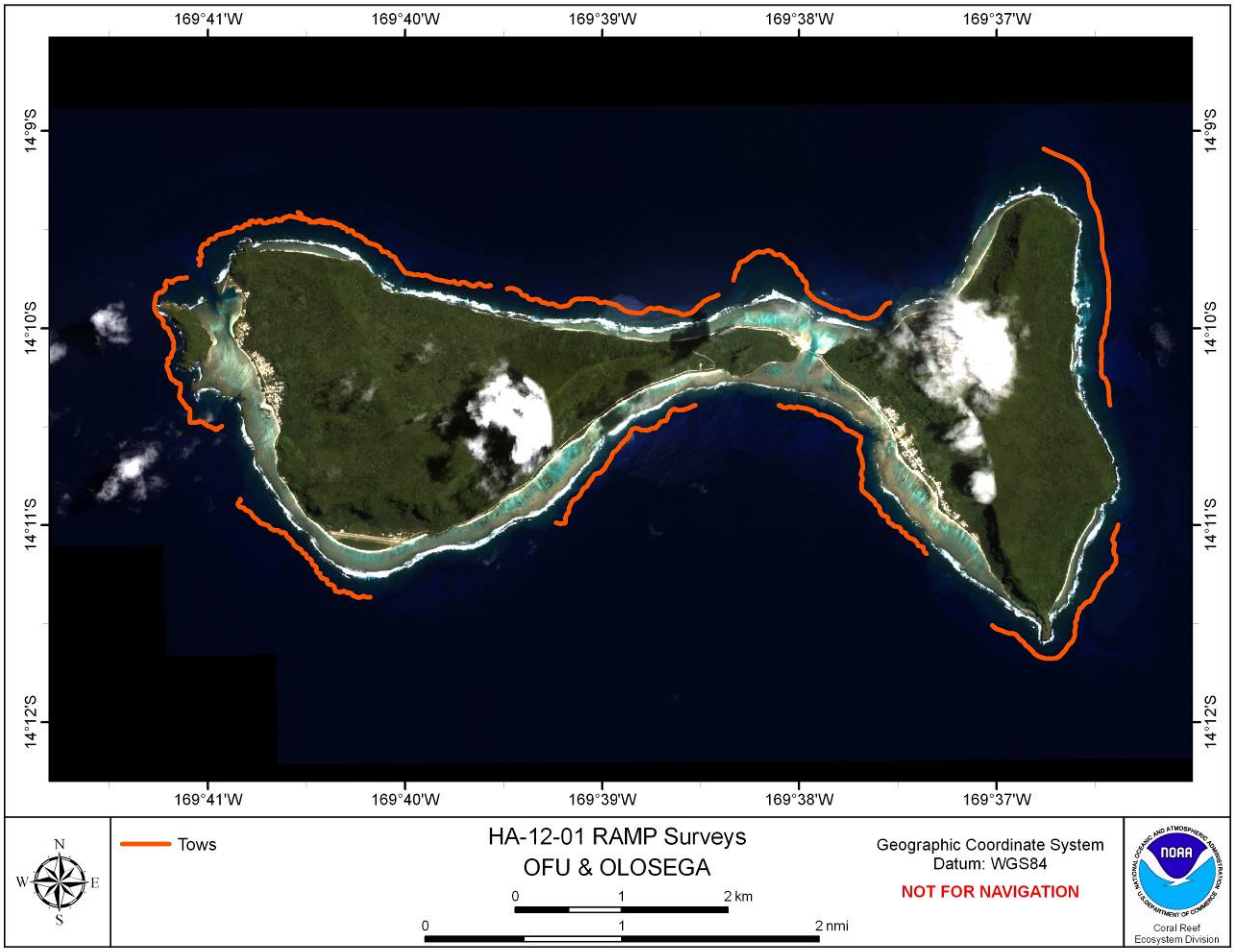

Figure E.2.2.--Track locations of towed-diver surveys conducted at Ofu and Olosega Islands during cruise HA-12-01, Leg III (IKONOS Carterra Geo Data, 2003).

E.3. Reef Fish Community

REA fish survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 30 REA sites at Ofu and Olosega Islands over three different habitat strata: deep forereef, moderate forereef, and shallow forereef (Table E.3.1 and Fig. E.3.1). No fishes were collected during these surveys.

In addition, CRED completed 10 towed-diver surveys at Ofu and Olosega Islands, as described previously in Section E.2 of this appendix.

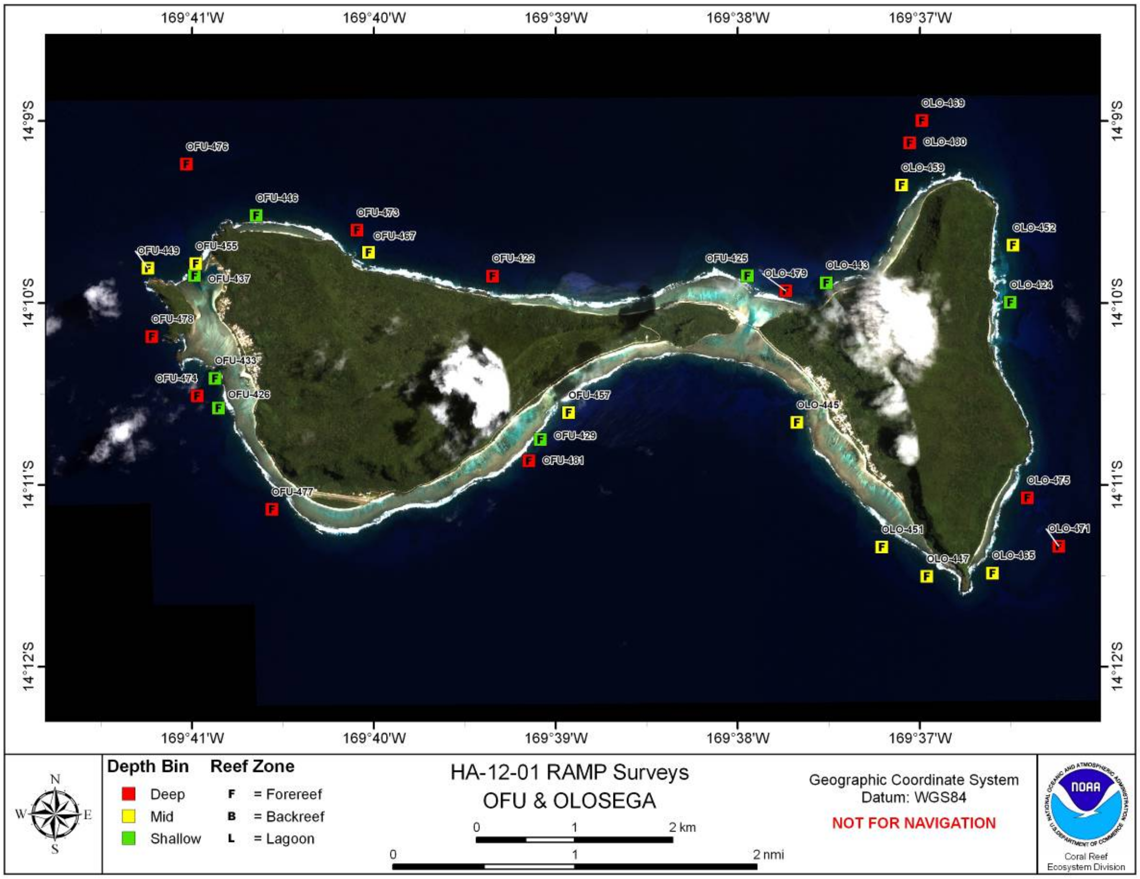

Figure E.3.1.--Locations of REA fish sites surveyed at Ofu and Olosega Islands during cruise HA-12-01, Leg III (IKONOS Carterra Geo Data, 2003). All of these REA sites were selected using a stratified random design.

Table E.3.1.--Summary of sites where REA fish surveys were conducted at Ofu and Olosega Islands during cruise HA-12-01, Leg III.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
OLO-424	24-Apr	Shallow	Forereef	4.8	–14.16661	–169.60838
OLO-443	24-Apr	Shallow	Forereef	2	–14.16482	–169.62522
OLO-447	24-Apr	Moderate	Forereef	10.7	–14.19172	–169.61601
OLO-451	24-Apr	Moderate	Forereef	18	–14.18903	–169.62012
OLO-452	24-Apr	Moderate	Forereef	15.4	–14.16136	–169.60811
OLO-459	24-Apr	Moderate	Forereef	13	–14.15585	–169.61830
OLO-465	24-Apr	Moderate	Forereef	14	–14.19141	–169.60999
OLO-469	24-Apr	Deep	Forereef	22.3	–14.14994	–169.61646
OLO-471	24-Apr	Deep	Forereef	22.4	–14.18895	–169.60391
OLO-475	24-Apr	Deep	Forereef	21.5	–14.18452	–169.60680
OLO-479	24-Apr	Deep	Forereef	20	–14.16555	–169.62893
OFU-426	25-Apr	Shallow	Forereef	4.3	–14.17628	–169.68091
OFU-433	25-Apr	Shallow	Forereef	6.5	–14.17356	–169.68123
OFU-437	25-Apr	Shallow	Forereef	6.1	–14.16414	–169.68310
OFU-446	25-Apr	Shallow	Forereef	6.7	–14.15865	–169.67746
OFU-449	25-Apr	Moderate	Forereef	15.8	–14.16348	–169.68736
OFU-455	25-Apr	Moderate	Forereef	10	–14.16306	–169.68298
OFU-457	25-Apr	Moderate	Forereef	16	–14.17672	–169.64881
OFU-474	25-Apr	Deep	Forereef	24	–14.17517	–169.68287
OFU-477	25-Apr	Deep	Forereef	28.5	–14.18557	–169.67602
OFU-478	25-Apr	Deep	Forereef	22.3	–14.16974	–169.68701
OFU-481	25-Apr	Deep	Forereef	23.5	–14.18112	–169.65246
OFU-422	26-Apr	Deep	Forereef	21.8	–14.16419	–169.65581
OFU-425	26-Apr	Shallow	Forereef	3.5	–14.16418	–169.63244
OFU-429	26-Apr	Shallow	Forereef	6.3	–14.17916	–169.65142
OFU-467	26-Apr	Moderate	Forereef	13.9	–14.16204	–169.66716
OFU-473	26-Apr	Deep	Forereef	21.3	–14.15999	–169.66822
OFU-476	26-Apr	Deep	Forereef	24.4	–14.15394	–169.68387
OLO-445	26-Apr	Moderate	Forereef	15.6	–14.17762	–169.62791
OLO-480	26-Apr	Deep	Forereef	24.3	–14.15197	–169.61758

APPENDIX F: BIOLOGICAL COLLECTIONS

Biological and other samples were collected at Rose Atoll and the islands of Tutuila, Ta'u, Ofu, and Olosega and their surrounding waters for multiple research purposes. These collections are listed here in Table F.1.1.

Table F.1.1.--Samples collected at Tutuila (TUT), Rose Atoll (ROS), Ta'u (TAU), and Ofu and Olosega Islands (OFU) for taxonomic identification, ocean acidification research, or microbial analyses during cruise HA-12-01, Legs II and III.

REA Site	Date	Latitude	Longitude	Specimen Collected	Number of Samples	Depth (m)
Algal Collections: Calcification Analysis						
TUT-19	2-Apr	–14.28319	–170.72825	*Halimeda* sp	10	13.7
TUT-14	4-Apr	–14.25334	–170.65219	*Halimeda* sp	10	13.7
ROS-03	18-Apr	–14.55480	–168.14652	*Halimeda* sp	10	13.7
ROS-04	19-Apr	–14.55964	–168.15998	*Halimeda* sp	10	13.7
ROS-07	19-Apr	–14.54943	–168.16831	*Halimeda* sp	20	13.7
ROS-06	21-Apr	–14.53632	–168.16533	*Halimeda* sp	10	13.7
TAU-12	22-Apr	–14.25756	–169.50101	*Halimeda* sp	10	13.7
OLO-01	24-Apr	–14.16850	–169.60790	*Halimeda* sp	10	13.7
OLO-05	24-Apr	–14.16349	–169.62455	*Halimeda* sp	10	13.7
OFU-02	25-Apr	–14.18511	–169.67573	*Halimeda* sp	10	13.7
OFU-01	26-Apr	–14.16445	–169.65571	*Halimeda* sp	10	13.7
Algal Collections: Isotope Analysis						
TUT-19	2-Apr	–14.28319	–170.72825	*Halimeda* sp	6	13.7
TUT-14	4-Apr	–14.25334	–170.65219	*Halimeda* sp	6	13.7
ROS-03	18-Apr	–14.55480	–168.14652	*Halimeda* sp	6	13.7
ROS-04	19-Apr	–14.55964	–168.15998	*Halimeda* sp	6	13.7
ROS-07	19-Apr	–14.54943	–168.16831	*Halimeda* sp	12	13.7
ROS-06	21-Apr	–14.53632	–168.16533	*Halimeda* sp	6	13.7
OLO-01	24-Apr	–14.16850	–169.60790	*Halimeda* sp	6	13.7
OLO-05	24-Apr	–14.16349	–169.62455	*Halimeda* sp	6	13.7
OFU-01	26-Apr	–14.16445	–169.65571	*Halimeda* sp	6	13.7
Algal Collections: Voucher Specimens						
TUT-14	4-Apr	–14.25334	–170.65219	*Gibsmithia* sp	1	13.7
TUT-14	4-Apr	–14.25334	–170.65219	Red algae	1	13.7
TUT-18	4-Apr	–14.25169	–170.68942	*Botryocladia* sp	1	13.7
TUT-18	4-Apr	–14.25169	–170.68942	Red algae	1	13.7
TUT-04	5-Apr	–14.25606	–170.60579	Red algae	1	13.7
TUT-12	6-Apr	–14.28982	–170.75951	*Liagora* sp	1	13.7
TUT-12	6-Apr	–14.28982	–170.75951	Red algae	8	13.7
TUT-01	7-Apr	–14.28336	–170.63786	Red algae	5	13.7
TUT-02	7-Apr	–14.27781	–170.60720	Red algae	2	13.7
TUT-20	12-Apr	–14.27837	–170.66953	Red algae	2	13.7
ROS-02	18-Apr	–14.55164	–168.13977	*Microdictyon* sp	1	13.7
ROS-19	18-Apr	–14.54894	–168.13778	*Microdictyon* sp	1	13.7
TAU-11	22-Apr	–14.21723	–169.51281	Red algae	1	13.7
TAU-02	23-Apr	–14.25171	–169.44617	Red algae	1	13.7
TAU-07	23-Apr	–14.22730	–169.41833	Red algae	1	13.7

OFU-02	25-Apr	–14.18511	–169.67573	Red algae	1	13.7
Coral Collections: Cores						
TUT-10	29-Mar	–14.29214	–170.68043	*Porites* sp	1	0.9
TUT-10	29-Mar	–14.29211	–170.68041	*Porites* sp	1	1.8
TUT-10	29-Mar	–14.29011	–170.68046	*Porites* sp	1	2.1
TUT-13	5-Apr	–14.25168	–170.68935	*Porites* sp	1	9.1
TUT-10	7-Apr	–14.30126	–170.67759	*Porites* sp	1	10.1
TUT-10	8-Apr	–14.30004	–170.68190	*Porites* sp	1	2.7
ROS-23	21-Apr	–14.54459	–168.17136	*Porites* sp	1	10.1
Coral Collections: Voucher Specimens						
OFU-02	25-Apr	–14.18511	–169.67573	*Porites lichen*	9	13.7
Microbial Collections: Water Samples, Coral Rubble, and Macroalgae						
TUT-22	1-Apr	–14.36588	–170.76284	2 L	2	13.7
TUT-08	2-Apr	–14.29167	–170.78042	2 L	2	13.7
TUT-19	2-Apr	–14.28319	–170.72825	2 L	2	13.7
TUT-05	4-Apr	–14.25169	–170.62309	2 L	2	13.7
TUT-17	5-Apr	–14.24600	–170.57196	2 L	2	12.5
TUT-17	5-Apr	–14.24600	–170.57196	20 L	2	12.5
TUT-17	5-Apr	–14.24600	–170.57196	Unidentified macroalgae	5	18.3
TUT-17	5-Apr	–14.24600	–170.57196	Coral rubble	5	18.3
TUT-22	8-Apr	–14.36325	–170.76357	2 L	2	13.7
TUT-969	8-Apr	–14.28983	–170.67797	2 L	2	13.7
TUT-969	8-Apr	–14.28983	–170.67797	20 L	3	13.7
TUT-20	12-Apr	–14.27837	–170.66953	2 L	2	14.6
ROS-02	18-Apr	–14.55164	–168.13977	2 L	2	12.5
ROS-03	18-Apr	–14.55480	–168.14652	2 L	2	12.2
ROS-07	19-Apr	–14.54942	–168.16823	2 L	2	14.9
ROS-07	19-Apr	–14.54942	–168.16823	20 L	3	14.9
ROS-07	19-Apr	–14.54942	–168.16823	Unidentified macroalgae	5	14.9
ROS-07	19-Apr	–14.54942	–168.16823	Coral rubble	5	14.9
ROS-01	20-Apr	–14.53946	–168.14550	2 L	2	13.7
ROS-08	20-Apr	–14.53789	–168.15330	2 L	2	10.7
ROS-09	21-Apr	–14.55122	–168.16032	2 L	2	6.7
ROS-09	21-Apr	–14.55122	–168.16032	20 L	3	6.7
ROS-09	21-Apr	–14.55122	–168.16032	Coral rubble	5	7.6
TAU-04	22-Apr	–14.21240	–169.44066	2 L	2	12.5
TAU-11	22-Apr	–14.21723	–169.51281	2 L	2	13.7
TAU-02	23-Apr	–14.25171	–169.44617	2 L	2	13.7
TAU-07	23-Apr	–14.22730	–169.41833	2 L	2	13.1
OLO-04	24-Apr	–14.18173	–169.62661	2 L	2	13.7
OLO-04	24-Apr	–14.18173	–169.62661	20 L	2	13.7
OLO-04	24-Apr	–14.18173	–169.62661	Unidentified macroalgae	5	15.2
OLO-04	24-Apr	–14.18173	–169.62661	Coral rubble	5	15.2
OFU-06	25-Apr	–14.17423	–169.68198	2 L	2	13.7
OFU-09	25-Apr	–14.15764	–169.67424	2 L	2	13.1
OFU-01	26-Apr	–14.16445	–169.65571	2 L	2	17.4
OFU-09	26-Apr	–14.15761	–169.67408	2 L	2	14.3