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NATIONAL MARINE FISHERIES SERVICE
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CRUISE REPORT[1]

VESSEL: NOAA Ship *Hi'ialakai*, Cruise HA-16-06, Leg 3

CRUISE PERIOD: 29 August–30 September 2016

AREA OF OPERATION: Northwestern Hawaiian Islands: French Frigate Shoals, Pearl and Hermes Atoll, Kure Atoll and Lisianski Island

TYPE OF OPERATION: Personnel from the Coral Reef Ecosystem Program (CREP) and Scientific Operations Division of the NOAA Pacific Islands Fisheries Science Center, University of Hawai'i at Mānoa (UHM), Scripps Oceanographic Institution (SIO), and San Diego State University (SDSU) conducted interdisciplinary surveys of benthos, fishes, and oceanographic parameters related to climate change in coastal waters across the Northwestern Hawaiian Islands as part of the National Coral Reef Monitoring Plan (NCRMP). All activities described in this report were covered by the following permits and authorizations: Papahānaumokuākea Marine National Monument Permit No. 2016-023 (effective date: 29 August 2016, expiration date: 30 September 2016); Environmental Assessment (PIFSC-20100901); Endangered Species Act, Section 7 consultation (PIR-2015-9580); U. S. Army Corps of Engineers Permit: USACE POH-2009-00083 (effective date: 18 March 2014; expiration date 18 March 2017).

[1] PIFSC Cruise Report CR-17-002
Issued 15 March 2017.

ITINERARY:

Note: This report only highlights work conducted around the Northwestern Hawaiian Islands during HA-16-06 Leg 3. All activities conducted around the main Hawaiian Islands (HA-16-06, Legs 1 & 2) are described in a separate report.

Unless otherwise specified in the following daily summaries, these surveys occurred during each operational day: Benthic Rapid Ecological Assessment (REA) surveys, Fish REA surveys, towed-diver surveys; nearshore conductivity-temperature-depth (CTD) casts; water sample collections for dissolved inorganic carbon (DIC), total alkalinity (TA), and/or microbial analyses; and the deployments and recoveries of oceanographic instrumentation. Furthermore, shipboard multi-beam bathymetry data was collected opportunistically.

August 29 Left Pearl Harbor and sailed for French Frigate Shoals.

August 30 Transited. Conducted ship and Monument orientation and training activities for scientists and crew as needed.

August 31 Arrived at French Frigate Shoals. Launched 3 boats to conduct training (Fish, OCC teams) and REA surveys (Benthic team). No towboard surveys.

September 1 Continued operations at French Frigate Shoals. Retrieved 3 Autonomous Reef Monitoring Structures (ARMS), deployed 3 ARMS; retrieved 4 Bioerosion Monitoring Units (BMUs), deployed 5 BMUs; retrieved 5 Calcification Accretion Units (CAUs), deployed 5 CAUs; retrieved 3 Subsurface Temperature Recorders (STRs), deployed 3 STRs.

September 2 Continued operations at French Frigate Shoals. Retrieved 4 BMUs, deployed 5 BMUs; retrieved 5 CAUs, deployed 5 CAUs; retrieved 2 STRs, deployed 2 STRs.

September 3 Continued operations at French Frigate Shoals. Retrieved 3 ARMS, deployed 3 ARMS; retrieved 3 STRs, 3 deployed STRs.

September 4 Transited to Pearl and Hermes Atoll.

September 5 Transited to Pearl and Hermes Atoll.

September 6 Commenced operations at Pearl and Hermes Atoll. Retrieved 3 ARMS, deployed 3 ARMS; retrieved 4 BMUs, deployed 5 BMUs; retrieved 5 CAUs, deployed 5 CAUs; retrieved 4 STRs, deployed 3 STRs.

September 7 Continued operations at Pearl and Hermes Atoll. Retrieved 3 BMUs; retrieved 3 CAUs, deployed 5 CAUs; retrieved 1 STR, deployed 1 STR.

September 8 Continued operations at Pearl and Hermes Atoll. Retrieved 3 ARMS, deployed 3 ARMS; retrieved 5 STRs, deployed 5 STRs.

September 9 Continued operations at Pearl and Hermes Atoll. Retrieved 5 BMUs, deployed 5 BMUs; retrieved 5 CAUs, deployed 5 CAUs; retrieved 2 STRs, deployed 2 STRs.

September 10 Continued operations at Pearl and Hermes Atoll. Retrieved 3 ARMS, deployed 3 ARMS; retrieved 5 BMUs, deployed 5 BMUs; retrieved 5 CAUs, deployed 5 CAUs; retrieved 2 STRs, deployed 2 STRs.

September 11 Completed operations at Pearl and Hermes Atoll. Retrieved 3 ARMS, deployed 3 ARMS; retrieved 4 BMUs, deployed 5 BMUs; retrieved 4 CAUs, deployed 5 CAUs; retrieved 3 STRs, deployed 3 STRs. Transited overnight to Kure Atoll.

September 12 Commenced operations at Kure Atoll. Retrieved 2 CAUs, deployed 5 CAUs; retrieved 2 STRs, deployed 4 STRs.

September 13 Continued operations at Kure Atoll. Retrieved 2 CAUs, deployed 5 CAUs; retrieved 4 STRs, deployed 5 STRs.

September 14 Continued operations at Kure Atoll. Retrieved 2 CAUs, deployed 10 CAUs; retrieved 3 STRs, deployed 3 STRs.

September 15 Completed operations at Kure Atoll. Retrieved 3 CAUs, deployed 5 CAUs; retrieved 1 STR, deployed 2 STRs.

September 16 Transit to Lisianski.

September 17 Commenced operations at Lisianski. Retrieved 10 CAUs, deployed 10 CAUs; retrieved 4 STRs, deployed 4 STRs.

September 18 Continued operations at Lisianski. Retrieved 5 CAUs, deployed 5 CAUs; retrieved 4 STRs, deployed 4 STRs.

September 19 Continued operations at Lisianski. Retrieved 5 CAUs, deployed 5 CAUs; retrieved 3 STRs, deployed 3 STRs. No benthic surveys; 2 team members sick.

September 20 Continued operations at Lisianski. Retrieved 5 CAUs, deployed 5 CAUs; retrieved 4 STRs, deployed 3 STRs. Deploy Diurnal Suite/ Portable Underwater Collector (PUC). No towboard surveys.

September 21 Completed operations at Lisianski. Conducted benthic surveys at sites associated with weather service buoy grounding. Retrieved Diurnal Suite. No towboard surveys.

September 22 Transited to French Frigate Shoals

September 23 Transited to French Frigate Shoals

September 24 Recommenced operations at French Frigate Shoals. Retrieved 2 ARMS, deployed 3 ARMS; retrieved 2 BMUs, deployed 5 BMUs; retrieved 1 CAU, deployed 5 CAUs; retrieved 3 STRs, deployed 3 STRs.

September 25 Continued operations at French Frigate Shoals. Deployed 3 ARMS; retrieved 6 BMUs, deployed 5 BMUs; retrieved 6 CAUs, deployed 10 CAUs; retrieved 2 STRs, deployed 2 STRs.

September 26 Continued operations at French Frigate Shoals. Retrieved 3 STRs, deployed 1 STR. Recovered 1 set of anchors.

September 27 Completed operations at French Frigate Shoals. Recovered derelict Fish Aggregation Device. No towboard surveys. Begin transit to O'ahu.

September 28 Transited to O'ahu.

September 29 Transited to O'ahu.

September 30 Arrived Pearl Harbor.

MISSION:

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

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

The goals of the HA-16-06 Pacific Reef Assessment and Monitoring Cruise are as follows:

> The ship will support assessment and monitoring operations in the waters surrounding the Hawaiian Archipelago. The scientific objectives of this project follow:
>
> 1. Conduct ecosystem monitoring for benthic cover (community structure), coral populations (species composition, abundance, size distribution, and condition), and fish populations (species composition, abundance and size) of the shallow-water (≤ 30 m) coral reef ecosystems of the Northwestern Hawaiian Islands (French Frigate Shoals, Pearl and Hermes Atoll, Kure Atoll and Lisianski Island).
>
> 2. Deploy, retrieve and/or service an array of Subsurface Temperature Recorders (STRs), Sea Surface Temperature (SST) Buoys, Autonomous Reef Monitoring Structures (ARMS), Calcification Accretion Units (CAUs), Bioerosion Monitoring Units (BMUs), moored Acoustic Doppler Current Profilers (ADCPs) as well as anchored arrays consisting of a portable underwater collector (PUC), a Conductivity Temperature Pressure (CTP) recorder, and a thermistor string to allow remote long-term monitoring of oceanographic and environmental conditions affecting the coral reef ecosystems of the Hawaiian Archipelago. This effort is in support of the Coral Reef Ecosystem Integrated Observing Systems (CREIOS).
>
> 3. Conduct shallow-water CTD hydrocasts and collect discrete water samples for dissolved inorganic carbon (DIC), total alkalinity (TA), and microbial community analyses to depths ≤ 30 m to examine the chemical, physical, and biological linkages supporting the coral reef ecosystems of the main Hawaiian Islands.

4. Collect coral cores to examine calcification/growth rates in recent decades and assess potential early impacts of ocean acidification. Coring operations will be conducted opportunistically (as a scientific dive).

5. Conduct plankton tows to expand upon the documentation of the marine biota on coral reefs.

6. Conduct shipboard Acoustic Doppler Current Profiler (ADCP) surveys around reef ecosystems to examine physical and biological linkages supporting and maintaining the island ecosystems.

7. Continuous ADCP, sea surface temperature (SST), salinity, and fundamental meteorological data, including air temperature, wind speed and direction, barometric pressure, and relative humidity.

8. Collect oceanographic data utilizing ship-based measurement systems (ADCP, ThermoSalinoGraph—TSG, and the Scientific Computer System—SCS) during all transits for the duration of the project.

9. Conduct investigations of marine microbial communities, including the collection of specimens via water sampling and coral biopsies.

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

RESULTS:

This section provides operational totals regarding research activities (Table 1), specifics regarding data collected during cruise HA-16-06, Leg 3 and a summary of important observations made while at sea. For more information pertaining to the data collected, methodology employed at the islands visited, see Appendices A–F.

The coral reef ecosystems of the Northwest Hawaiian Islands have been surveyed biennially since 2000 and triennially starting in 2010 through CREP's Pacific RAMP. Herein, we present highlights from our observations during this latest expedition by island.

French Frigate Shoals (FFS)

- Benthic
  - The most abundant corals overall were *Acropora cytherea* and *Porites lichen*, although their abundances varied spatially.
  - Algal turf and /or macroalgal cover (e.g., *Microdictyon*) were high in most areas.

- Fish
  - FFS appeared to have the highest diversity of fish among the islands visited in the Monument.
  - The fish assemblage at FFS was characterized by a mixture of fish that are commonly observed in the main Hawaiian Islands (e.g., *Acanthurus nigrofuscus, Scarus rubroviolaceus*) as well as those more common in the Northwestern Hawaiian Islands (e.g., *Acanthurus nigroris, Chlorurus perspicillatus*).
- Tow
  - The northwest corner of the atoll had relatively diverse coral assemblage, taxonomically and structurally as well as lots of large tables (*Acropora cytherea*).
  - Many small (~ 1 m) galapagos (*Carcharinus galapagensis*) sharks were observed along the northeast side of the barrier reef.
- Other

  A Fish Aggregation Device (FAD) was discovered on the east side of FFS. This FAD was the 'Q' FAD deployed by the State of Hawai'i Division of Aquatic Resources, and had originally been deployed north of Maui. The chain from the FAD had fouled on the reef in approximately 15 m of water. The buoy was recovered and brought back to Honolulu.

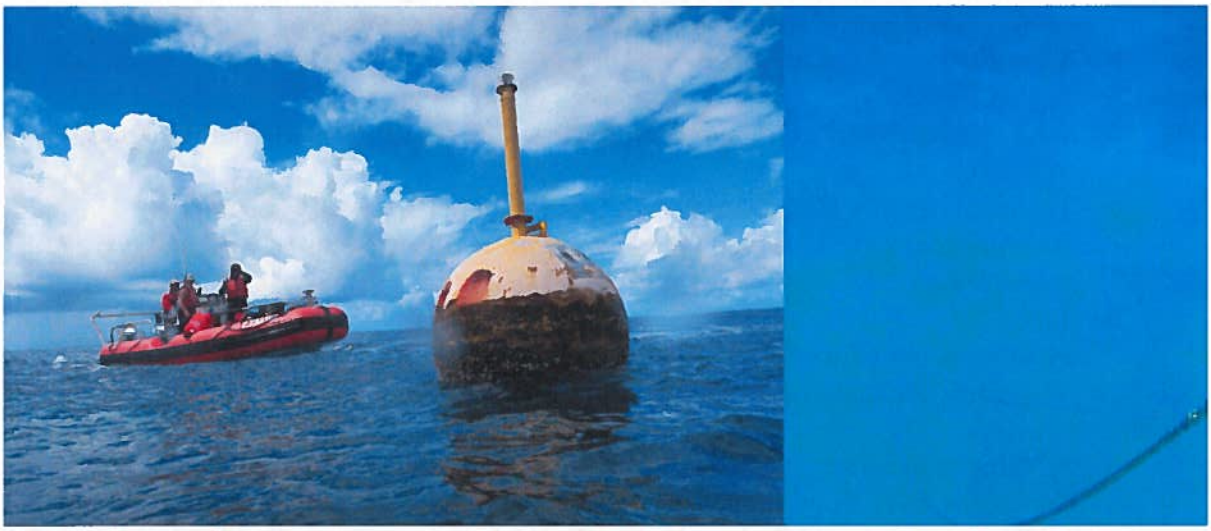

Figure 1.--Surface and subsurface images of the Fish Aggregation Device recovered off east French Frigate Shoals. *Photos by Andrew Gray (left) and Louise Giuseffi (right).*

Kure Atoll

- Benthic
  - Shallow areas were relatively barren with crustose coralline algae, algal turf and a few *Pocillopora meandrina* colonies.
  - The most abundant corals were *Pocillopora ligulata, Pocillopora meandrina,* and *Porites lichen.*

- Fish
  - Galapagos sharks (*Carcharhinus galapagensis*) and gray reef sharks (*Carcharhinus amblyrhynchos)* were observed on more occasions at Kure than other islands visited in the Monument (n = 56, n = 14, respectively).
  - The introduced snapper *Lutjanus. kasmira* was not recorded on REA surveys at Kure, though it was at all other islands visited. It was observed on tow surveys (see below).
- Tow
  - The greatest abundance of large fish (> 50 cm) was observed on reefs on the southwest side of the atoll.
  - Notable fish sightings included *Balistoides polylepis*; several large schools of *L. kasmira* were observed on the southeast side.
  - Lots of old, dead coral colonies (primarily *Pocillopora* spp.) were observed along the northwest side of the atoll.

Lisianski

- Benthic
  - Substantial area of reef had high coral cover and large colonies of *Porites compressa, Porites lutea, Porites lichen,* and *Porites lobata.*
  - Visibility was generally poor
- Fish
  - White tip reef sharks (*Triaenodon obesus*) were observed on numerous occasions (n = 23).
  - The giant trevally (*Caranx ignobilis*) and the bluefin trevally (*Caranx melampygus*) were observed on a large number of occasions (n = 72 and n = 57, respectively)
  - Tow
    Most areas towed were sand flats with large patch reefs interspersed. Divers frequently encountered large schools of *Caranx ignobilis.*
- Other
  - A National Weather Service buoy that had been adrift fouled on the reef in November 2015. It was removed in May 2016, after repeatedly breaking free and fouling again in multiple locations in the southeastern part of the shoal. Teams of CREP survey divers conducted surveys at several locations, and the partner scientist from SIO completed a photomosaic at two of the sites. Scientists observed rubble from broken substrate and overturned corals at these sites.

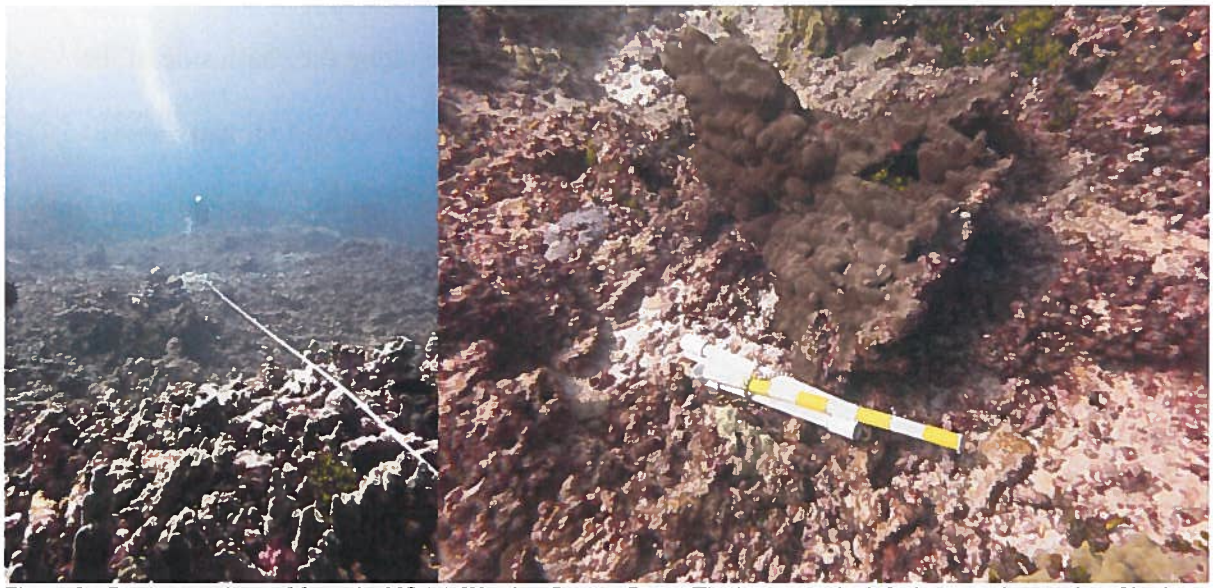

Figure 2.--Damage to the reef from the NOAA Weather Service Buoy. The image on the left shows undamaged reef in the foreground, with a transect tape extending into a damaged area that is now mostly rubble *(Photo credit: Ashley Pugh).* The image on the right shows a large *Porites lutea* colony that was broken off the bottom at different grounding site *(Photo credit: Brett Schumacher).*

Pearl and Hermes (PHR)

- Benthic
  - Vast areas of very low coral cover were shown within all three depth categories.
  - Relatively frequent observations of COTS occurred. However, COTS abundance was not at 'outbreak' levels and was spatially variable.
  - Generally, PHR had high cover of algae, especially *Microdictyon* on windward side.
  - Leeward mid and deep reefs had high abundance of *Pavona duerdeni* with high partial mortality.
- Fish
  - Frequent sightings of gray reef sharks occurred, *Carcharhinus amblyrhynchos* (n = 13, where 'n' indicates the number of occasions on which a particular species was observed, rather than the number of individuals).
  - One manta ray was recorded under "presence data" during an REA survey.
  - White tip sharks (*Triaenodon obesus*) were observed on more occasions (n = 35) at PHR than other islands.
  - Giant trevally (*Caranx ignobilis*) and bluefin trevally (*Caranx melampygus*) were also observed on more occasions than other islands (n = 145 and n = 67, respectively).
  - A school of approximately 1500 *L. kasmira*, an introduced species, was recorded.

- Tow
    - Large numbers of *Caranx ignobilis* were observed along the south side of the atoll.
    - Dense algal cover (primarily *Microdictyon* sp.) was observed in many areas around the atoll.
    - Dense mats and floating "rafts" of a red alga (tentatively identified as a *Laurencia* sp.) were observed on the reef on the north-northeast side of the atoll and at the ARMS site on the southwest corner (PHR-54). This alga was not observed in other areas. Samples were collected for positive ID and further study.

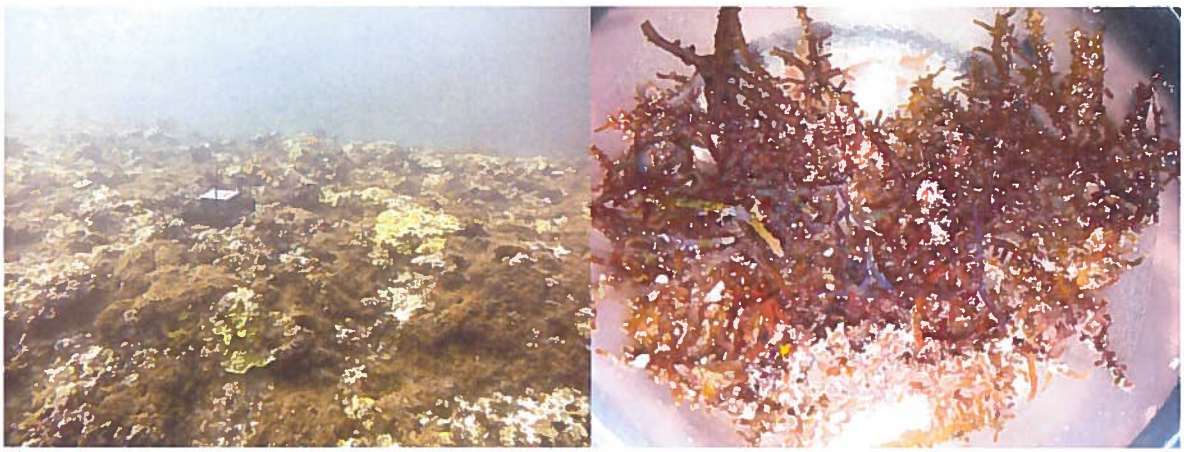

Figure 3.--Left – Dense mats of red algae at the ARMS site (PHR-54) on southwest side of Pearl and Hermes Atoll *Photo by Kerry Reardon*. Right – Close up view of algae in the lab. *Photo by Louise Giuseffi (right).*

Table 1.--Statistics for the Pacific RAMP 2016 cruise to the Northwest Hawaiian Islands (cruise HA-16-06), including French Frigate Shoals (FFS), Kure Atoll (KUR), Lisianski Island (LIS), Pearl and Hermes Atoll (PHR). Totals for scuba dives include all dives carried out for all activities at each island.

Research Activity	FFS	KUR	LIS	PHR	Total
Scuba Dives	310	214	240	313	**1077**
Biological Surveys					
REA sites: Benthic	26	19	19	20	**84**
REA sites: Fish	47	39	40	56	**182**
Towed-diver Surveys (TDS) Fish & Benthic	23	13	12	31	**78**
Combined Length (km) of TDS	52.8	30.2	29.2	74.8	**187**
Benthic Photomosaic Surveys	5	4	4	5	18
Biological Sample Collections					
Coral-Algal Microbial Biopsies	2	3	4	4	**13**
Microbial Water Samples (2-liter)	11	12	11.5	9	**43.5**
Metagenome Water Samples (20-liter)	0	4	4	3	**11**
Plankton Tows	0	5	5	6	16
Biological Monitoring Installations					
ARMS Retrieved	8	0	0	12	**20**
ARMS Deployed	12	0	0	12	**24**
CAUs Retrieved	17	9	25	21	**73**
CAUs Deployed	25	25	25	25	**100**
BMUs Deployed	20	0	0	20	**40**
BMUs Retrieved	16	0	0	21	**37**
Oceanographic Moored Instruments					
STRs Retrieved	16	10	15	17	**58**
STRs Deployed	14	14	14	16	**58**
Hydrographic Surveys					
Shallow-water CTD Casts	15	11	19	17	**62**
Water-quality Sampling					
Shallow-water Salinity Water Samples	19	25	33	22	**99**
Shallow-water DIC Water Samples	19	25	33	22	**99**
Microbial Water Chemistry Samples	6	9	9	5	29

The following data and samples were collected during this expedition:

Climate and Ocean Acidification Monitoring
Oceanographic Instrumentation and Biological Installations:

- Seawater temperature at 1-, 5-, 15-, and 25-m depths
- Assessment of taxonomic diversity of coral reef species by collection of invertebrate specimens from retrieved ARMS
- Installation of CAUs to allow for future assessment of $CaCO_3$ deposition rates once they are retrieved in about 3 years
- Installation of BMUs to allow for future assessment of bioerosion rates once they are retrieved in about 3 years
- Water samples and coral samples at select REA sites for microbial studies

Nearshore Oceanography from Small Boats:

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

Shipboard Oceanography:

- Transects of profiles of ocean current velocity and direction collected using a shipboard ADCP unit
- Solar radiation, air temperature, barometric pressure, and wind speed and direction
- Surface seawater temperature and salinity measurements from real-time flow through shipboard instrumentation

Biological Monitoring
Benthic REA surveys:

- Digital still photographs of overall site character and typical benthos
- Digital still photographs of the benthos along transect lines
- Number, species or genus, size, and condition of all coral colonies observed within belt transects of known area
- Digital still photographs of diseased corals and coralline algae

Fish REA 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

SCIENTIFIC PERSONNEL:

Brett Schumacher, Chief Scientist, Benthic Tow/ Benthic REA Diver, University of Hawai`i (UH)-Joint Institute for Marine and Atmospheric Research (JIMAR), Pacific Islands Fisheries Science Center (PIFSC)-Coral Reef Ecosystems Program (CREP)
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Jeanette Clark, OCC/ Instrumentation Diver, UH-JIMAR, PIFSC-CREP
Joao Garriques, Operations Lead /Benthic Tow/ Benthic REA Diver, UH-JIMAR, PIFSC-CREP
Louise Giuseffi, Fish REA Diver, PIFSC-SOD
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Kaylyn McCoy, Fish Tow/Fish REA Diver, UH-JIMAR, PIFSC-CREP
Katie Mahaffey, Chamber Operator / Dive Master, NOAA Dive Program
James Morioka, OCC/ Instrumentation Diver, UH-JIMAR, PIFSC-CREP
Thomas Oliver, OCC/ Instrumentation Diver, UH-JIMAR, PIFSC-CREP
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Andrew Purves, Fish REA Diver, Temporary Hire
Kristin Raja, Fish REA Diver, OCC/ Instrumentation Diver/Fish REA Diver, PIFSC-SOD
Kerry Reardon, OCC/ Instrumentation Diver, UH-JIMAR, PIFSC-CREP
Brandon Reyes, Microbial Diver, San Diego State University
Chris Sullivan, Photomosaic diver, Scripps Institute of Oceanography, University of California San Diego
Dione Swanson, Benthic REA Diver, UH-JIMAR, PIFSC-CREP
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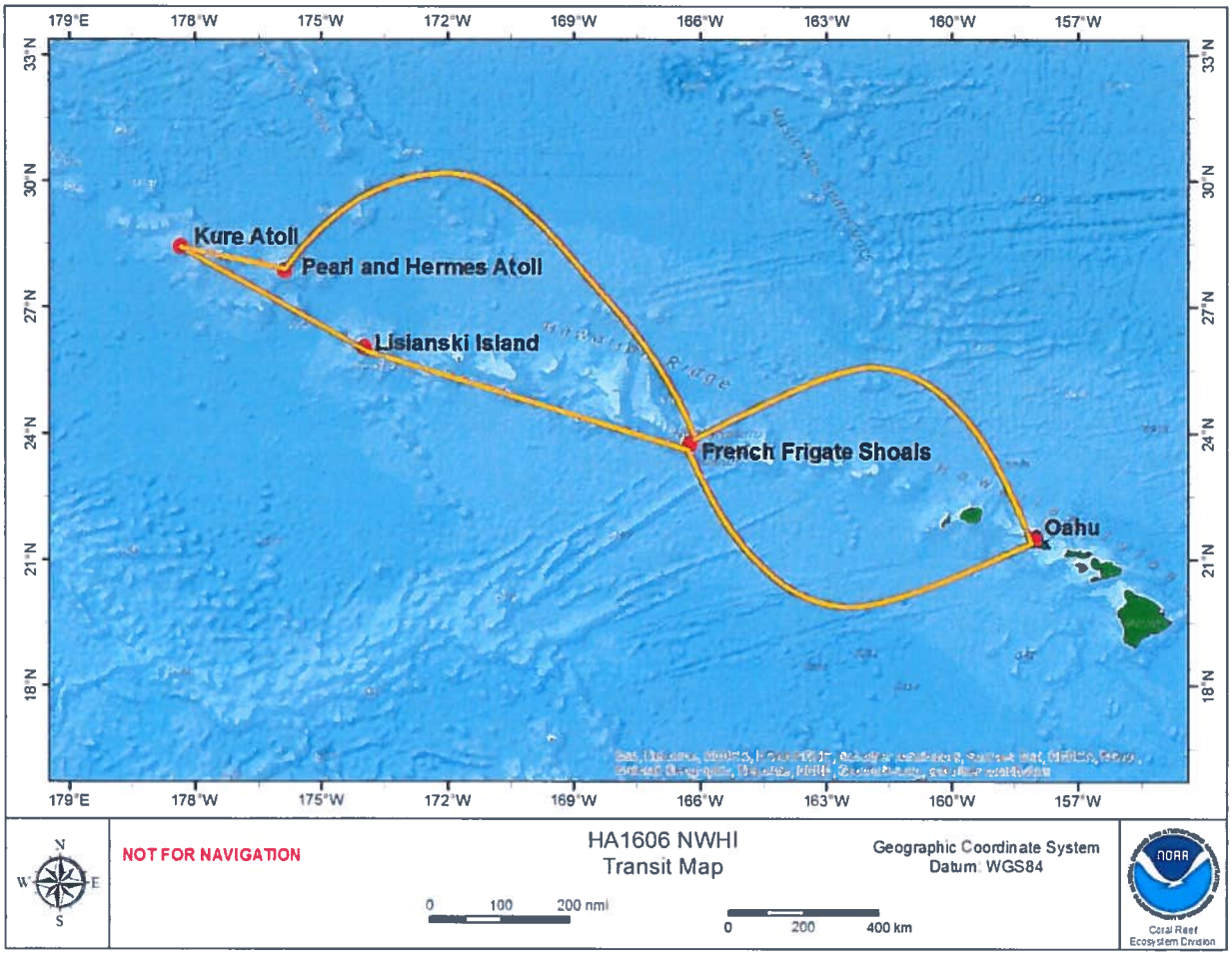

Figure 4.--Track of the NOAA Ship *Hi'ialakai* for the cruise HA-16-06 Leg III, 29 August – 30 September 2016, in the Northwestern Hawaiian Islands. Satellite image: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors.

APPENDIX A: METHODS

This appendix describes the methods and procedures used by the Coral Reef Ecosystem Program (CREP) of the NOAA Pacific Islands Fisheries Science Center during its Pacific Reef Assessment and Monitoring Program (Pacific RAMP) cruise HA-16-06 on the NOAA Ship *Hi'ialakai* during the 29 August – 30 September 2016 period.

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

(Evan Barba, Jeanette Clark, Thomas Oliver, Kristin Raja, Brandon Reyes, Kerry Reardon, Chris Sullivan)

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

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

- Class 0 sites: Only discrete water samples are collected and analyzed for dissolved inorganic carbon (DIC) and total alkalinity (TA).
- Class 1 sites: Only subsurface temperature recorders (STRs), SBE 56 temperature loggers (Sea-Bird Electronics, Inc., Bellevue, Wash.), are deployed.
- Class 2 sites: Include collection of discrete water for DIC and TA; STR deployments; benthic community surveys and benthic still photograph records. Biological installations, including Calcification Accretion Units (CAUs), Bioerosion Monitoring Units (BMUs), Autonomous Reef Monitoring Structures (ARMS), and coral coring are added.
- Class 3 sites: A MAPpCO2 buoy system is added to the Class 2 site setup.

Most of the CRED's efforts focus on establishing Class 0 and Class 2 sites at select locations distributed along the four cardinal directions around each island surveyed. For "Class 2 sites" and above, thermal structure measurements are obtained based on the deployment of subsurface temperature recorders (STRs; SBE 56) along a perpendicular fore-reef transect at 1-, 5-, 15-, and 25-m depth; each SBE 56 records the near-reef water temperature at the same time, on a 5-min interval, for the duration of the instrument's deployment. Within this context, a permanent water quality, temperature, and biological survey/sampling site, designated as *NCRMP Monitoring Station*, is established at the 15-m depth STR location, at select islands. In addition to the SBE 56, the NCRMP Monitoring Station includes deployment of 3 ARMS units, 5 CAUs, and 5 BMUs; collection of 3 carbonate chemistry water samples (with associated CTD casts); acquisition of still photographic benthic imagery to document benthic cover and composition; and rugosity measurements of benthic topographic complexity.

A.1.1. Moored Instruments for Time-series Observations

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

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

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

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

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

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

A.1.2. Hydrographic Surveys

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

Shallow-water (Near-shore) Conductivity, Temperature, and Depth Casts: a CTD profiler deployed from a small boat provided water column data on temperature, conductivity (which is related to salinity) and pressure, which is related to depth (SBE 19*plus* SeaCAT Profiler). A transmissometer (C-Star, WET Labs, Philomath, 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 location where a water sample was collected. The CTD is lowered by hand, off a small boat at descent rates of ~ 0.5–0.75 m/s to depths up to 30 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 dissolved inorganic carbon (DIC), nutrients (N and P), salinity (S‰), and Total Alkalinity (TA) were collected at select locales concurrently with CTD casts.

A.1.3. Microbial Communities

The data collected by the microbial partner will provide added value to the assessment and monitoring of coral reefs by combining the microbial taxonomic and functional composition and the fluxes of matter and energy they facilitate with the data on benthic and pelagic macro-biota. This will allow for characterization of coral reef ecosystems from a molecular to an ecosystem scale across the entire US pacific.

We worked for about a year in 2015/2106 to improve our collection protocols for HARAMP based on criticisms we received from CRED. While we can see that this is still a work in progress, please note that we accomplished reducing seawater collections from about 100 L to 15 L and that we eliminated the task of delivering the microbial diver back to the ship early. We will continue to prioritize improvements to our protocols in order to strengthen the partnership between our team and CRED.

Collection of water chemistry using Minidon Niskin bottles

Primary goal: Collect water from reef benthos (light reef), reef matrix (dark reef), reef water column (5 m) and offshore water column (5 m) for DOC and inorganic nutrient concentrations, microbial abundances, and microbial DNA.

This provides (A) Most of the long term monitoring samples (water chemistry: organic carbon, inorganic nutrients; microbial activity: abundances and biomass, autotroph:heterotroph) and (B) On this round of cruises we have paired our sampling (reef, surface, offshore) with the OCC team's water samples for inorganic measurements (DIC/TA).

Procedural overview: The minidons will replace the standard 2-L Niskin water chemistry set. The minidons allow for filtration of seawater through filter apparatus into the analytical vials during the dive. At every reef site, samples will be collected from 1) the reef benthos, 2) the reef

matrix, and 3) the reef water column. Offshore samples will be collected opportunistically whenever the OCC team samples there. Each pair of minidons will produce the following analytes:

- DOC in a 60-ml plastic vial (via a 25-mm GF/F) (1)
- fDOM in a 20-ml plastic vial (via a 0.2-um polycarbonate filter) (1)
- inorganic nutrients in a 20-ml plastic vial (via a 0.2-um polycarbonate filter) (1)
- microbial sizes and abundances (epi-tubes with 1-ml fixed seawater) (2)
- flow cytometry (cryovials with seawater fixed in PFA or glutaraldehyde) (3)
- 0.2-um Sterivex filter for extraction of microbial DNA (1)

Two minidons will be deployed at each collection site (as listed above). When the paired minidons are taken apart for labeling and storage, each analyte will be pooled into one vial (detailed below).

Collection of water samples using Mega-Niskin (10-L water) for SPE-DOM (Solid Phase Eluted Dissolved Organic Matter) and benthic community sample (2-L water collected via bilge pump)

Primary goal: Isolation of DOM from seawater with low salt contamination for downstream analysis by HPLC, LCMS, NMR, or FTICRMS. These analyses will yield information concerning both the quality and quantity of DOM in benthic-associated seawater. Benthic associated samples will also be collected and processed to yield viromes via serial filtration and PEG precipitation. These should be collected along with the minidons as much as possible.

This provides (A) deeper characterization of the organic matter pool on reefs and (B) other long term monitoring samples (benthic microbiomes and viromes for metagenomic sequencing).

Procedural overview SPE-DOM: Large volumes of water (10 L) are collected in inert polycarbonate Niskin-type bottles and pressure-filtered through 0.2-um filter to remove particles. The water is acidified to pH 2 with concentrated HCl to increase extraction efficiency. The acidified water is passed over the PPL sorbent (pre-cleaned with methanol) using a peristaltic pump at a flow rate < 40 mL/min to bind SPE-DOM, requiring roughly 4 h. The cartridges are rinsed twice with 1 volume 0.01 M HCl made in low-DOC water to remove salts. The cartridges are dried with 5 min of airflow and immediately eluted with 1 volume methanol at a flow rate < 2 mL/min into borosilicate vials with crimp-seal teflon-lined silicone lids and stored –20°C.

Benthic metagenomes: This protocol is to replace the 80-L water collections in cubies and TFF concentration methods. Instead, 1 cubie will be filled about ¼ full with the bilge pump (vacuum the reef as usual benthic metagenome collection process). On surface, pour water from the cubie into a 2-L Niskin. Microbial metagenomes will be collected onto 0.45-um Sterivex filters. The 0.45-um filtrate will be collected into Nalgene bottles (600 mls, PEG precipitates) and onto 0.03-um PES filters (the remaining 1400 ml). PEG precipitates will be combined by island to generate "pooled viromes" via CsCl. Site level comparisons will be made using "total viral DNA" collected onto 0.03-um filters.

Collection of coral:algal interaction tissue biopsies
Primary goal: Microbiologist will collect 1 coral:algal biopsy transects across coral-algal interaction interfaces per site (goal: 2–4 punch transects per island depending on island size. Biopsies will be processed to yield coral and algal metagenomes, metatranscriptomes, viromes, and metabolomes. These samples are to be collected at reef sites, but do not need to be at NCRMP sites.

These collections (A) replace the collections of rubble and algae (i.e., smashed reef) that we have collected on previous cruises and (B) provide a spatial dataset for investigating mechanisms of coral resistance to algal competition at coral:algal interaction interfaces.

Procedural overview: Find a coral-algal interaction with enough surface area to take 11 punches. For coral species, we are aiming for *Porites lobata* or *Pocillopora meandrina*. Use underwater drill to collect 1 cm diameter "biopsies" from coral algal interactions. Once back on ship, remove samples from drill bit into their respective vials: (a) virome samples (n = 3) into cryovial, then into dewer; (b) metatranscriptome (n = 5) into cryovial with 1 ml RNA later (c) metabolome samples (n = 3) into 20-ml amber vials with 5 ml 70% methanol.

Measurement of coral geometry
Primary goal: Microbiologists will take high resolution images of single coral colonies to create 3D coral models, which will allow for the calculation of precise surface area, perimeter, and rugosity measurements.

Procedural overview: Once the coral to image has been chosen, lay a chain link on the coral interface and try to get the link as close to the perimeter as possible without blocking the camera's view of the interface. Start imaging the perimeter from about 25-cm working distance. Try to achieve a 90% overlap with each picture and keep the same camera orientation as you move around the coral. Make sure the chain link is in at least one of the images. Also, if there are other interactions within the colony, repeat the process for those interactions and include at least one chain link for calibration. The chain is carefully removed when the imaging is completed.

A.2. Biological Monitoring: Benthic Surveys

(Hatsue Bailey, Joao Garriques, Ashley Pugh, Brett Schumacher, and Dione Swanson)

A two-stage stratified random sampling design was employed to survey Rapid Ecological Assessment (REA) sites. The survey domain encompassed reef and hard bottom habitat, and was divided into strata based upon depth. Depth categories of shallow (0–6 m), mid (> 6–18m) and deep (> 18–30 m) were also incorporated into the stratification scheme. Allocation of sampling effort was proportional to strata area. Sites were randomly selected within each stratum.

A.2.1. Benthic composition and coral demographics

A two-stage stratified random sampling design was employed to survey the Rapid Ecological Assessment (REA) sites. The survey domain encompassed reef and hardbottom habitat, and was divided into strata based upon depth. Depth categories of shallow (0–6 m), mid (> 6–18 m) and

deep (> 18–30 m) were also incorporated into the stratification scheme. Allocation of sampling effort was proportional to strata area. Sites were randomly selected within each stratum.

Surveys at each site were conducted within two 18-m belt transects. Adult coral colonies (≥ 5 cm) were surveyed within four segments that were 1.0 m wide by 2.5 m long. Along the transect tape the segments were located at 0–2.5 m, 5.0–7.5 m, 10–12.5 m, and 15–17.5 m. All colonies whose center fell within 0.5 m on either side of each transect line were identified to lowest taxonomic level possible (species or genus), measured for size (maximum diameter to nearest cm), and morphology was noted. In addition, partial mortality and condition of each colony was assessed. Partial mortality was estimated as percent of the colony in terms of 'old dead' and 'recent dead' and the cause of recent mortality was identified if possible. The condition of each colony, including disease and bleaching, was noted along with the extent (percent of colony affected) and severity (range from moderate to acute).

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

Still photographs were collected to record the benthic community composition at predetermined points along the same 2 transect lines with a high-resolution digital camera mounted on a pole. Photographs were taken every 1 m from the 1-m to the 15-m mark. This work generated 30 photographs per site, which are later analyzed by CREP staff and partners using the computer program CoralNet. This analysis is the basis for estimating benthic cover and composition at each site (benthic habitat photographs at sites surveyed by the fish team are also analyzed using CoralNet).

A.3. Biological Monitoring: Surveys of Reef Fishes

(Louise Giuseffi, Kelvin Gorospe, Andrew Gray, Adel Heenan, Kaylyn McCoy, Andrew Purves, Kristin Raja and Emily Wallingford)

Divers conducted Fish REA surveys using the stationary-point-count (SPC) method at preselected REA sites. All fish REA sites visited were selected using a stratified random sampling design in shallow (0–6 m), mid (6–18 m), or deep (18–30 m) depth strata, in the forereef habitat 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.

Each fish REA site consists of a team of two divers conducting two adjacent and simultaneous SPC surveys. Once a transect line was deployed, the 2 divers moved to the 7.5-m and 22.5-m marks on this transect line to start their SPC surveys. Each of these marks or points, with 1 diver

at each, served as the center of a visually estimated cylindrical survey area with a radius of 7.5 m. During the first 5 min, divers created a list of all fish species found within their cylinder. Afterwards, divers went down their respective species lists, which were created from their work during the initial 5 min of a survey, sizing and counting all individuals within their cylinder, one species at a time. Cryptic species missed during the initial 5 min of a survey could still be counted, sized, and added to the original species list. Fish species observed at a REA site but not recorded during the SPCs were recorded for presence data.

After a survey was completed, divers recorded benthic habitat information within their respective cylindrical survey areas. Divers visually estimated habitat complexity, habitat type, and percentage of cover for hard corals, macroalgae, crustose coralline red algae, turf algae, and sand. Urchin densities were also estimated. Every meter along the transect line, still photographs were taken of the benthos to the right side of the line. This work generates 30 photographs per site, which analyzed later using CoralNet to estimate the benthic cover and composition at each site.

A.4. Biological Monitoring: Towed-Diver Surveys

(Hatsue Bailey, Joao Garriques, Andrew Gray, Kaylyn McCoy and Brett Schumacher)

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, 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 GPS Map 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.

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.

A.5. Biological Monitoring: Plankton Tows

A plankton net 50-cm diameter with an 80-μm mesh size having a 1-L cod end attached to net with flow meter will be trailing a few yards behind the stern of a small boat. Each tow will be assigned a unique station number with corresponding GPS coordinates, date & time recorded for start and finish of each tow. The tows will be just below the surface, for 5 min and the small boat will be going just fast enough for net to be tight and flow meter to run (1–2 kn). The net will be brought back onto the small boat and processed in the field. The outside of the plankton net will be washed down with seawater applied to outside collecting flora and fauna in the cod end. Plankton tows are conducted opportunistically, and depending on the number of days spent at each island, we expect to conduct 5–10 plankton tows per island. After using a hand net to separate taxa, all samples will be put into 50-mL Falcon tube(s) using 95% ethanol in squirt bottles to be fixed.

A.6. Benthic Habitat Mapping

Opportunistic multibeam mapping for Leg 3 of the HA-16-06 cruise was conducted primarily at night while the ship was not directly devoted to supporting small boat operations. If the ship did not have to run offshore to dump waste after the small boats came back in the evening, the ship would conduct a conductivity-temperature-depth (CTD) cast near the mapping site and then run track lines according to the planned areas of focus. Existing bathymetry was reviewed prior to the cruise and preliminary survey areas were identified. During the cruise, existing bathymetry gaps were further narrowed down and mapping plans were created to work within the cruise itinerary.

Multibeam mapping capability for Leg 3 included the ship's two multibeam echosounders (Kongsberg EM300 and EM3002D.) Table A.6-1 provides an overview of the two multibeam sonar systems and their capabilities.

Table A.6-1.--Sonar System Capabilities.

Sonar	Vessel	Freq. (kHz)	Depth Range (m)	Beam Size (deg)	Number of Beams
EM300	*Hi'ialakai*	30	30–3000	1½ × 1½	135
EM3002 D	*Hi'ialakai*	300	2–150	1 × 1	320–508

In addition to the multibeam sonar systems, the *Hi'ialakai* is equipped with an Applanix Position Orientation Sensor for Marine Vessels (POS/MV) vertical reference system. This system provides timing, position, velocity pitch, roll, heave, and heading information for correction of motion in the multibeam data. Conductivity-temperature-depth (CTD) sensors were used to provide sound velocity profiles (SVPs) that are critical for proper correction of sound velocity errors associated with multibeam data.

Since a helm display wasn't operational during the cruise and other technical limitations arose, the team created 30-m and 150-m boundary points around each survey area to help with planning. The boundary points were created using ArcGIS and in the process they were also layered on available multibeam (both processed and interpolated.) To help ship's command with navigation and planning during mapping efforts, the boundary points were also exported to GPX points for their bridge program "Coastal Explorer."

Kongsberg SIS interfaces for the EM300 and EM3002 were monitored by the ship's survey tech while mapping data was collected. The survey tech ensured SIS data, POS/MV, CTD cast and an acquisition log were all collected together and provided to the cruise data manager at the end of the cruise. The current plan for the collected multibeam data is for it to be processed after the ship returns from dry dock in 2017.

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APPENDIX B: FRENCH FRIGATE SHOALS

French Frigate Shoals, located at 23.064385° N, 166.173283° W, is the largest atoll in the Northwestern Hawaiian Islands (NWHI), Papahānaumokuākea Marine National Monument (PMNM). For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: "Methods."

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

Oceanographic operations during the cruise HA-16-06 entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), Autonomous Reef Monitoring Structures (ARMS), bioerosion monitoring units (BMUs), near-shore water sampling, and conductivity, temperature and depth (CTD) casts at select NCRMP sites.

Shallow-water CTD casts were performed at each location where water samples were collected, and these included sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Nineteen shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 16 STRs were retrieved and 14 STRs were deployed. Eight ARMS were recovered and processed for taxonomic analysis and 12 ARMS were deployed. Seventeen CAUs were retrieved and 25 deployed at 5 locations around the island as a part of the NCRMP monitoring stations. Sixteen collocated BMUs were retrieved and 20 were deployed. (Fig. B.1.1and Table B.1.1).

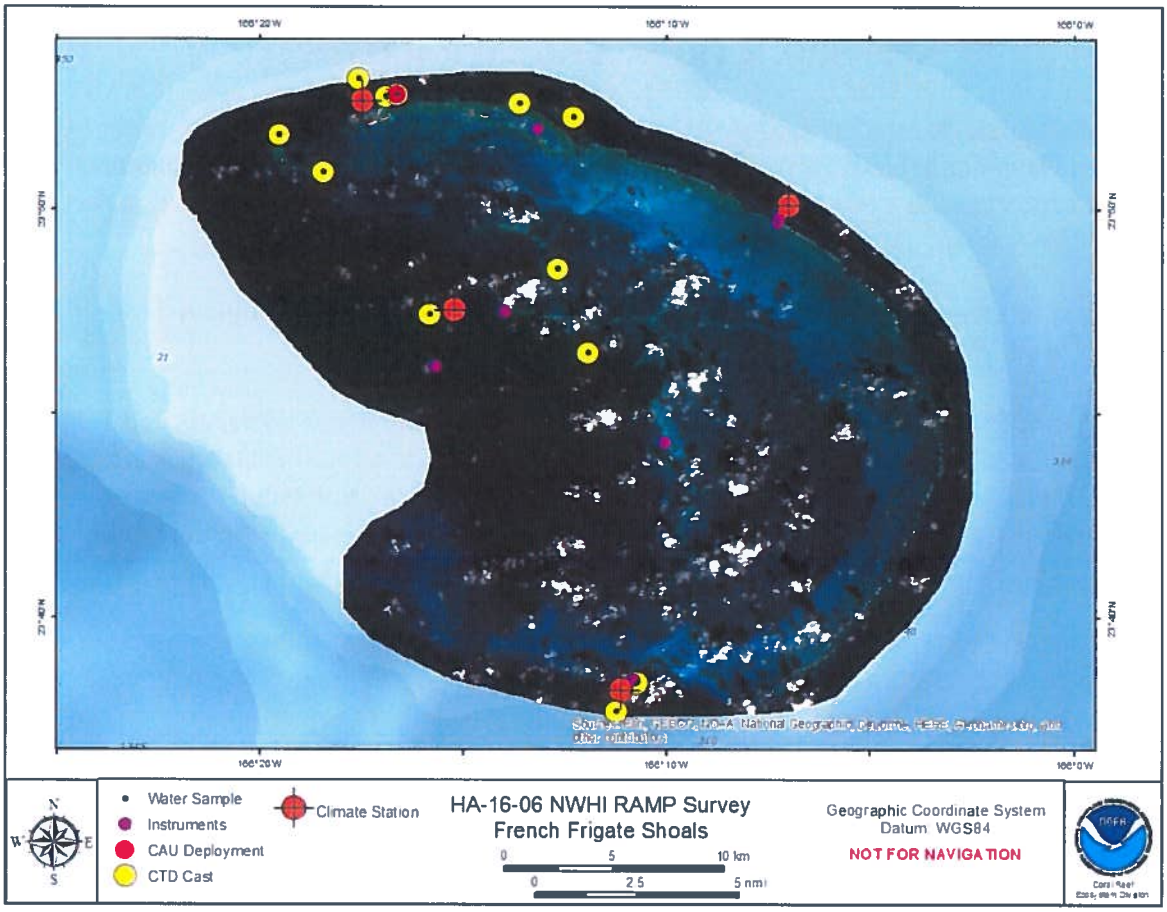

Figure B.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of near-shore CTD casts and water sampling performed at French Frigate Shoals during cruise HA-16-06.

Table B.1.1.--Geographic coordinates and depths of the moored oceanographic instruments (STR) and biological installations (CAU, ARMS, and BMUs), that were retrieved or deployed at French Frigate Shoals during cruise HA-16-06.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
FFS_OCEAN_011	01-Sep-16	STR	23.63498	-166.18556	24.1	1	–
FFS_OCEAN_011	01-Sep-16	STR	23.63498	-166.18556	24.1	–	1
FFS_OCEAN_015	01-Sep-16	STR	23.63690	-166.18527	14.3	1	–
FFS_OCEAN_015	01-Sep-16	STR	23.63690	-166.18527	14.3	–	1
FFS_OCEAN_016	01-Sep-16	STR	23.64106	-166.17977	6.4	1	–
FFS_OCEAN_016	01-Sep-16	STR	23.64106	-166.17977	6.4	–	1
FFS-40	01-Sep-16	ARMS	23.63686	-166.18515	14.3	3	3
FFS-40	01-Sep-16	BMU	23.63686	-166.18515	14.3	4	5
FFS-40	01-Sep-16	CAU	23.63686	-166.18515	14.3	5	5
FFS_OCEAN_005	02-Sep-16	STR	23.73813	-166.16750	2.7	1	–
FFS_OCEAN_005	02-Sep-16	STR	23.73813	-166.16750	2.7	–	1
FFS_OCEAN_018	02-Sep-16	STR	23.79240	-166.25379	12.5	1	–
FFS_OCEAN_018	02-Sep-16	STR	23.79240	-166.25379	12.5	–	1
FFS-41	02-Sep-16	BMU	23.79247	-166.25372	12.5	4	5
FFS-41	02-Sep-16	CAU	23.79247	-166.25372	12.5	5	5
FFS_OCEAN_002	03-Sep-16	STR	23.76894	-166.26134	4.6	1	–
FFS_OCEAN_002	03-Sep-16	STR	23.76894	-166.26134	4.6	–	1
FFS_OCEAN_003	03-Sep-16	STR	23.86608	-166.21969	2.7	1	–
FFS_OCEAN_003	03-Sep-16	STR	23.86608	-166.21969	2.7	–	1
FFS_OCEAN_017	03-Sep-16	STR	23.79184	-166.23322	4.6	1	–
FFS_OCEAN_017	03-Sep-16	STR	23.79184	-166.23322	4.6	–	1
FFS-41	03-Sep-16	ARMS	23.79247	-166.25372	12.5	3	3
FFS-41	03-Sep-16	CAU	23.79247	-166.25372	12.5	–	–
FFS_OCEAN_020	24-Sep-16	STR	23.83024	-166.12027	4.6	1	–
FFS_OCEAN_020	24-Sep-16	STR	23.83024	-166.12027	4.6	–	1
FFS_OCEAN_021	24-Sep-16	STR	23.83517	-166.11679	16.2	1	–
FFS_OCEAN_021	24-Sep-16	STR	23.83517	-166.11679	16.2	–	1
FFS_OCEAN_022	24-Sep-16	STR	23.83664	-166.11706	26.5	1	–
FFS_OCEAN_022	24-Sep-16	STR	23.83664	-166.11706	26.5	–	1
FFS-44	24-Sep-16	ARMS	23.83515	-166.11682	16.2	2	3
FFS-44	24-Sep-16	BMU	23.83515	-166.11682	16.2	2	5
FFS-44	24-Sep-16	CAU	23.83515	-166.11682	16.2	1	5
FFS_OCEAN_024	25-Sep-16	STR	23.87811	-166.29096	16.8	1	–
FFS_OCEAN_024	25-Sep-16	STR	23.87811	-166.29096	16.8	–	1
FFS_OCEAN_025	25-Sep-16	STR	23.87855	-166.29099	25.0	1	–
FFS_OCEAN_025	25-Sep-16	STR	23.87855	-166.29099	25.0	–	1
FFS-42	25-Sep-16	ARMS	23.87806	-166.29100	16.8	–	3
FFS-42	25-Sep-16	BMU	23.87806	-166.29100	16.8	4	5
FFS-42	25-Sep-16	CAU	23.87806	-166.29100	16.8	3	5
FFS-43	25-Sep-16	BMU	23.88021	-166.27707	16.8	2	–
FFS-43	25-Sep-16	CAU	23.88021	-166.27707	16.8	3	5
FFS_OCEAN_005	26-Sep-16	STR	23.73814	-166.16749	1.5	1	–
FFS_OCEAN_023	26-Sep-16	STR	23.87565	-166.29176	6.4	1	–
FFS_OCEAN_023	26-Sep-16	STR	23.87565	-166.29176	6.4	–	1
FFS_OCEAN_019	28-Sep-16	STR	23.82794	-166.12122	0.9	1	–

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

Belt-transect surveys were conducted and photographs were taken along transect lines at 26 REA sites around FFS to assess benthic composition, coral community structure, and coral and algal disease; water samples for microbial analyses were collected at 6 sites (Fig. B.2.1 and Table B.2.1). For more information about collections made at REA sites, see Table F.1.1 in Appendix F: "Biological Collections."

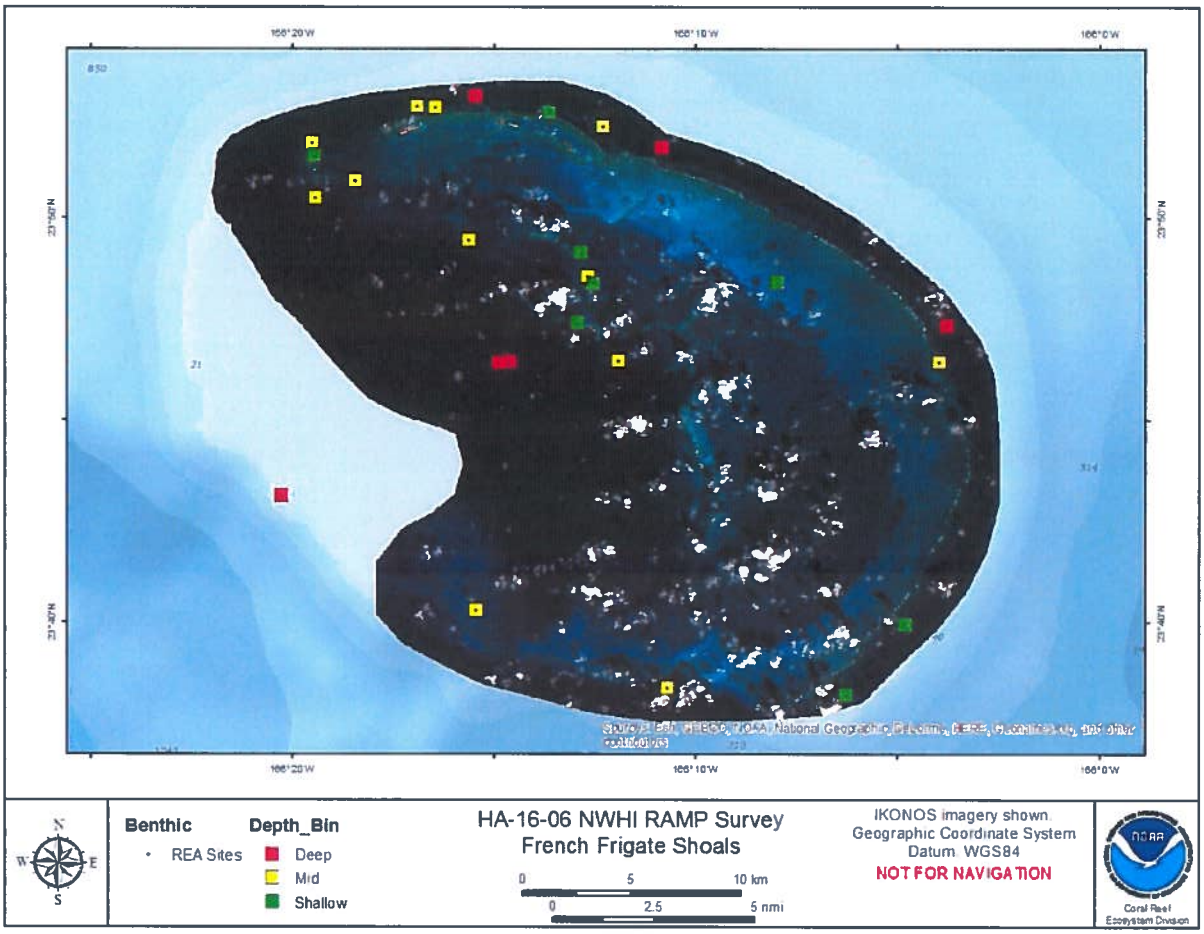

Figure B.2.1.--Locations of benthic REA sites surveyed at French Frigate Shoals during cruise HA-16-06. All of these REA sites were selected using a stratified random design.

Table B.2.1.--Summary of the Benthic REA surveys and microbial water collections performed at French Frigate Shoals during cruise HA-16-06.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude	Coral REA Survey	Microbial Samples
FFS-1301	31-Aug-16	Mid	Forereef	15.2	23.8416	-166.324	x	
FFS-40	01-Sep-16			14.5	23.6369	-166.1852		x
FFS-1266	01-Sep-16	Deep	Forereef	23.3	23.7189	-166.3379	x	
FFS-1284	01-Sep-16	Mid	Forereef	7.6	23.6399	-166.1786	x	
FFS-1302	01-Sep-16	Mid	Forereef	16.1	23.6718	-166.2575	x	
FFS-41	02-Sep-16			21.2	23.7925	-166.2537		x
FFS-1357	02-Sep-16	Mid	Lagoon	9.1	23.824	-166.2605	x	
FFS-1355	02-Sep-16	Mid	Lagoon	10.0	23.8487	-166.3072	x	
FFS-41	03-Sep-16			6.4	23.7925	-166.2537		x
FFS-1234	03-Sep-16	Deep	Forereef	19.4	23.7737	-166.2486	x	
FFS-1258	03-Sep-16	Deep	Forereef	20.0	23.774	-166.2437	x	
FFS-1350	03-Sep-16	Mid	Lagoon	9.7	23.8092	-166.2114	x	
FFS-1368	03-Sep-16	Shallow	Lagoon	5.8	23.8193	-166.2139	x	
FFS-1369	03-Sep-16	Shallow	Lagoon	4.5	23.8062	-166.2091	x	
FFS-1362	03-Sep-16	Shallow	Lagoon	5.2	23.7903	-166.2153	x	
FFS-1272	24-Sep-16	Deep	Forereef	22.4	23.7891	-166.0638	x	
FFS-1270	24-Sep-16	Mid	Forereef	8.2	23.7739	-166.0665	x	
FFS-1341	24-Sep-16	Shallow	Forereef	5.8	23.6659	-166.0801	x	
FFS-1336	24-Sep-16	Shallow	Forereef	4.2	23.6371	-166.1045	x	
FFS-42	25-Sep-16			16.7	23.8781	-166.291		x
FFS-1314	25-Sep-16	Deep	Forereef	22.4	23.8621	-166.181	x	
FFS-1288	25-Sep-16	Mid	Forereef	15.2	23.8711	-166.2048	x	
FFS-1317	25-Sep-16	Shallow	Forereef	3.9	23.8766	-166.2271	x	
FFS-1271	25-Sep-16	Mid	Forereef	7.3	23.8788	-166.2743	x	
FFS-42	26-Sep-16			15.2	23.8781	-166.291		x
FFS-1328	26-Sep-16	Deep	Forereef	20.6	23.8835	-166.258	x	
FFS-1309	26-Sep-16	Mid	Forereef	13.9	23.8794	-166.2815	x	
FFS-1279	26-Sep-16	Mid	Forereef	15.2	23.8638	-166.3252	x	
FFS-1338	26-Sep-16	Shallow	Forereef	4.5	23.8588	-166.3242	x	
FFS-1394	27-Sep-16	Mid	Lagoon	13.6	23.7746	-166.1987	x	x
FFS-1360	27-Sep-16	Shallow	Lagoon	4.2	23.8068	-166.1328	x	

Additionally, during the HA-16-06 cruise, 23 towed-diver surveys were completed around French Frigate Shoals, covering a total length of 52.8 km (an area of 52.8 ha) of the ocean floor (Fig. B.2.2).

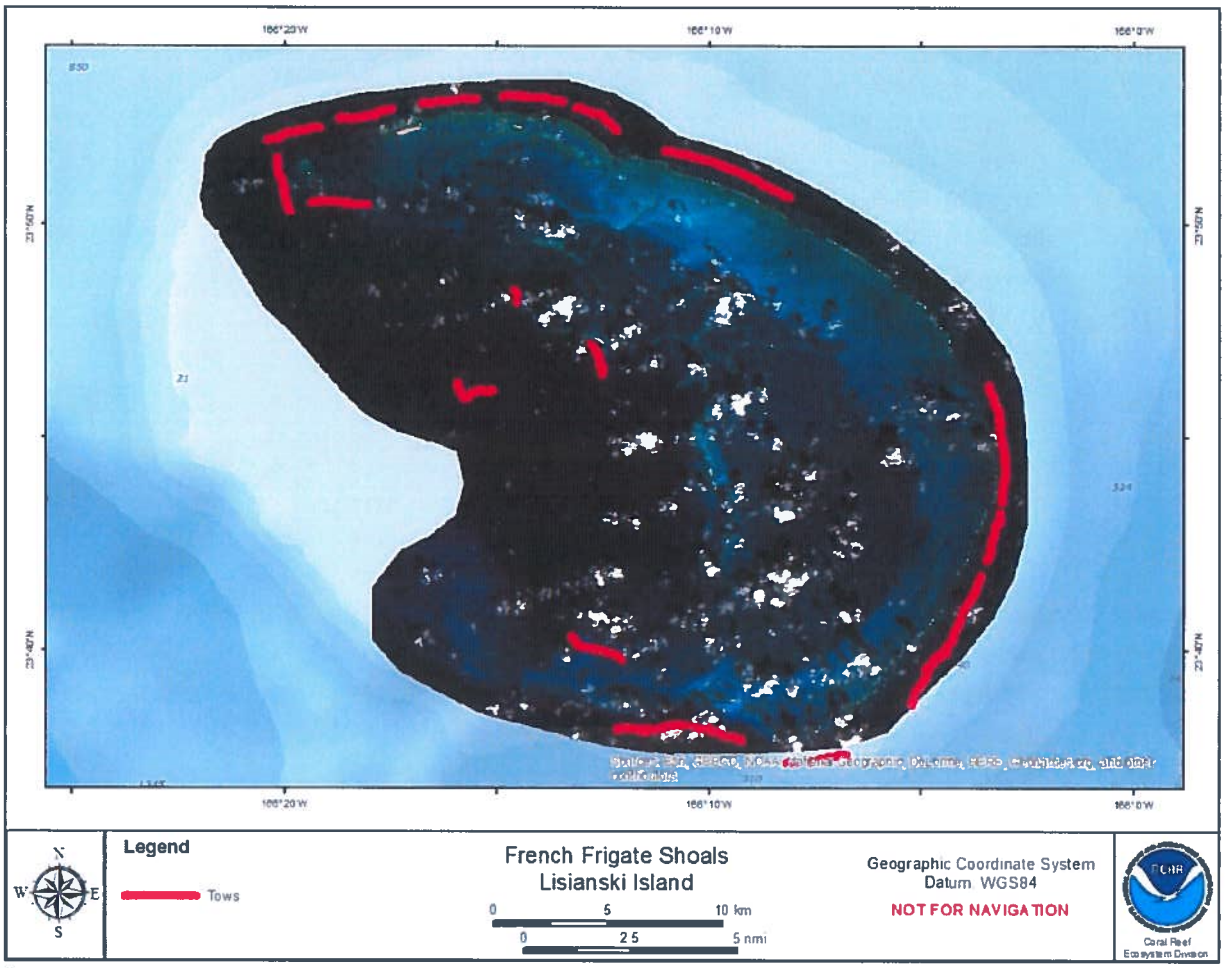

Figure B.2.2.--Track locations of towed-diver surveys conducted at French Frigate Shoals during the cruise HA-16-06.

B.3. Biological Monitoring: Reef Fish Community

Fish REA survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 47 REA sites at French Frigate Shoals over three different habitat depths: deep, mid, and shallow; and two different reef habitat zones: forereef and protected reef slope (Fig. B.3.1 and Table B.3.1). No fishes were collected during these surveys.

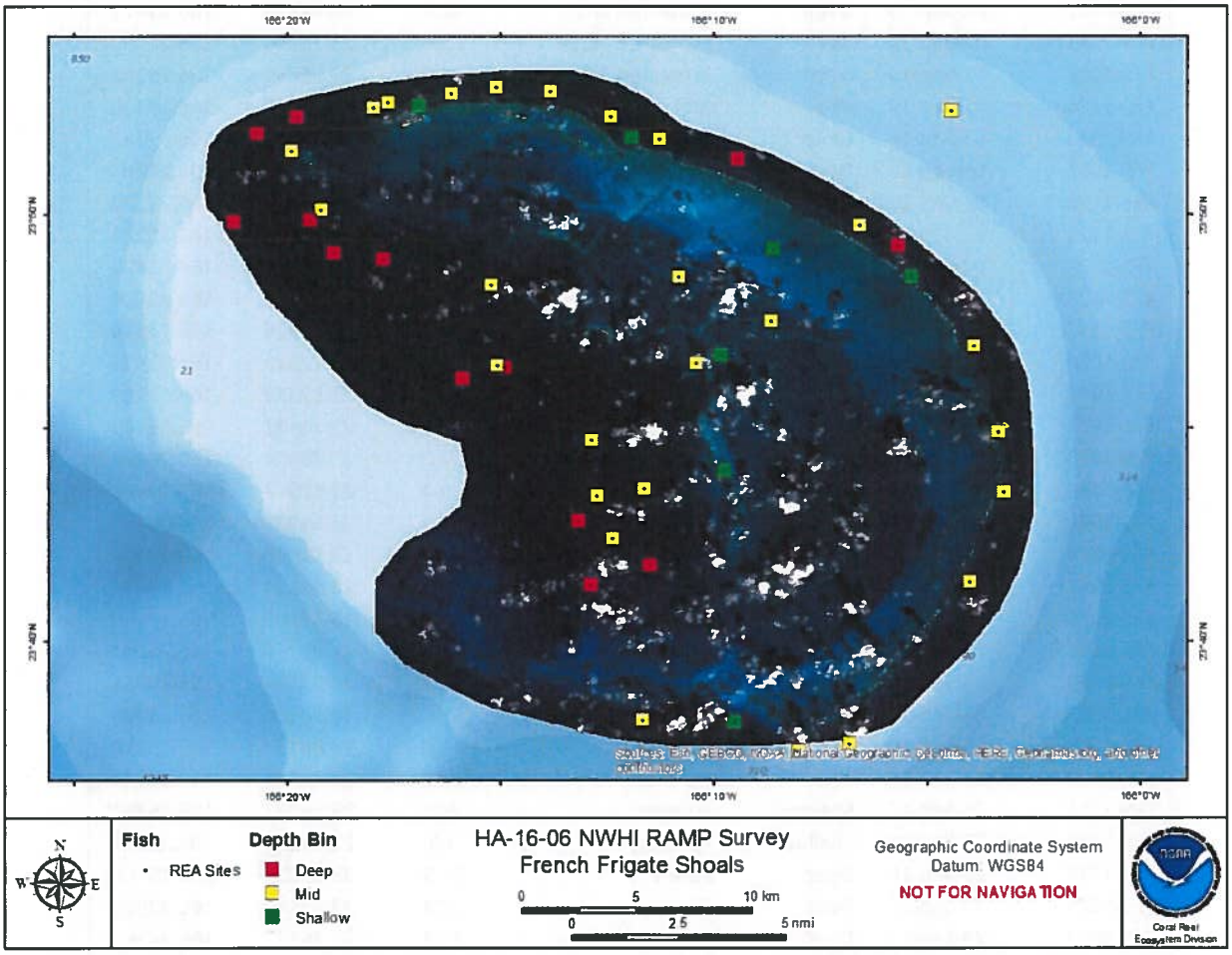

Figure B.3.1.--Locations of Fish REA sites surveyed at French Frigate Shoals during cruise HA-16-06. All of these REA sites were selected using a stratified random design.

Table B.3.1.--Summary of sites where Fish REA surveys were conducted at French Frigate Shoals during cruise HA-16-06.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
FFS-1091	01-Sep-16	Mid	Forereef	12.4	23.62682	-166.11394
FFS-1092	01-Sep-16	Mid	Forereef	12.1	23.62426	-166.13370
FFS-1094	01-Sep-16	Mid	Forereef	14.3	23.63595	-166.19473
FFS-1121	01-Sep-16	Shallow	Forereef	5.2	23.63536	-166.15904
FFS-1037	02-Sep-16	Deep	Protected Slope	20.4	23.68879	-166.21472
FFS-1041	02-Sep-16	Deep	Protected Slope	25.0	23.71366	-166.21953
FFS-1125	02-Sep-16	Deep	Protected Slope	20.0	23.69651	-166.19201
FFS-1126	02-Sep-16	Mid	Protected Slope	11.6	23.72628	-166.19436
FFS-1028	03-Sep-16	Deep	Protected Slope	23.5	23.83142	-166.32467
FFS-1061	03-Sep-16	Deep	Protected Slope	19.8	23.77375	-166.24863
FFS-1108	03-Sep-16	Mid	Protected Slope	8.8	23.80577	-166.25370
FFS-1123	03-Sep-16	Mid	Protected Slope	14.0	23.77439	-166.25149
FFS-1124	03-Sep-16	Mid	Protected Slope	17.0	23.74511	-166.21422
FFS-1127	03-Sep-16	Mid	Protected Slope	18.3	23.83546	-166.32024
FFS-1137	03-Sep-16	Deep	Protected Slope	19.1	23.76916	-166.26524
FFS-1064	24-Sep-16	Mid	Forereef	10.1	23.72520	-166.05353
FFS-1069	24-Sep-16	Mid	Forereef	14.0	23.87389	-166.07389
FFS-1071	24-Sep-16	Mid	Forereef	11.9	23.74832	-166.05549
FFS-1073	24-Sep-16	Mid	Forereef	12.2	23.78224	-166.06494
FFS-1088	24-Sep-16	Mid	Forereef	13.4	23.82942	-166.10960
FFS-1089	24-Sep-16	Mid	Forereef	10.4	23.69022	-166.06657
FFS-1114	24-Sep-16	Shallow	Forereef	5.7	23.80928	-166.08953
FFS-1132	24-Sep-16	Deep	Forereef	20.1	23.82114	-166.09477
FFS-1070	25-Sep-16	Mid	Forereef	12.8	23.87168	-166.20667
FFS-1086	25-Sep-16	Mid	Forereef	11.6	23.88094	-166.26904
FFS-1090	25-Sep-16	Mid	Forereef	13.7	23.87513	-166.29951
FFS-1093	25-Sep-16	Mid	Forereef	15.9	23.88324	-166.25169
FFS-1095	25-Sep-16	Mid	Forereef	11.0	23.88174	-166.23070
FFS-1097	25-Sep-16	Mid	Forereef	14.2	23.86321	-166.18819
FFS-1111	25-Sep-16	Shallow	Forereef	4.3	23.86353	-166.19891
FFS-1122	25-Sep-16	Shallow	Forereef	4.8	23.87612	-166.28187
FFS-1131	25-Sep-16	Deep	Forereef	22.5	23.85518	-166.15766
FFS-1025	26-Sep-16	Deep	Forereef	27.4	23.87140	-166.32988
FFS-1027	26-Sep-16	Deep	Protected Slope	23.7	23.86522	-166.34561
FFS-1035	26-Sep-16	Deep	Protected Slope	21.0	23.81578	-166.29598
FFS-1046	26-Sep-16	Deep	Protected Slope	28.8	23.81823	-166.31528
FFS-1048	26-Sep-16	Deep	Protected Slope	26.8	23.83030	-166.35473
FFS-1062	26-Sep-16	Mid	Forereef	11.6	23.85831	-166.33199
FFS-1119	26-Sep-16	Mid	Forereef	13.1	23.87696	-166.29397
FFS-1012	27-Sep-16	Shallow	Lagoon	3.0	23.77870	-166.16404
FFS-1015	27-Sep-16	Shallow	Lagoon	2.4	23.73342	-166.16307
FFS-1018	27-Sep-16	Shallow	Lagoon	4.0	23.82000	-166.14362
FFS-1034	27-Sep-16	Mid	Protected Slope	13.0	23.72361	-166.21222
FFS-1036	27-Sep-16	Mid	Protected Slope	13.7	23.70677	-166.20653
FFS-1076	27-Sep-16	Mid	Lagoon	8.8	23.79199	-166.14426
FFS-1104	27-Sep-16	Mid	Lagoon	9.7	23.80920	-166.18056
FFS-1107	27-Sep-16	Mid	Lagoon	8.5	23.77544	-166.17361

B.4. Benthic Habitat Mapping

Multibeam mapping surveys at French Frigate Shoals (FFS) were conducted using the *Hi'ialakai* EM3002D multibeam sonar. The ship conducted shallow water sonar mapping around FFS on September 24-25, 2016. The focused area of mapping was to fill gaps found from north to south on the east side of FFS. While conducting mapping it was noted that the STBD beam appears to be malfunctioning.

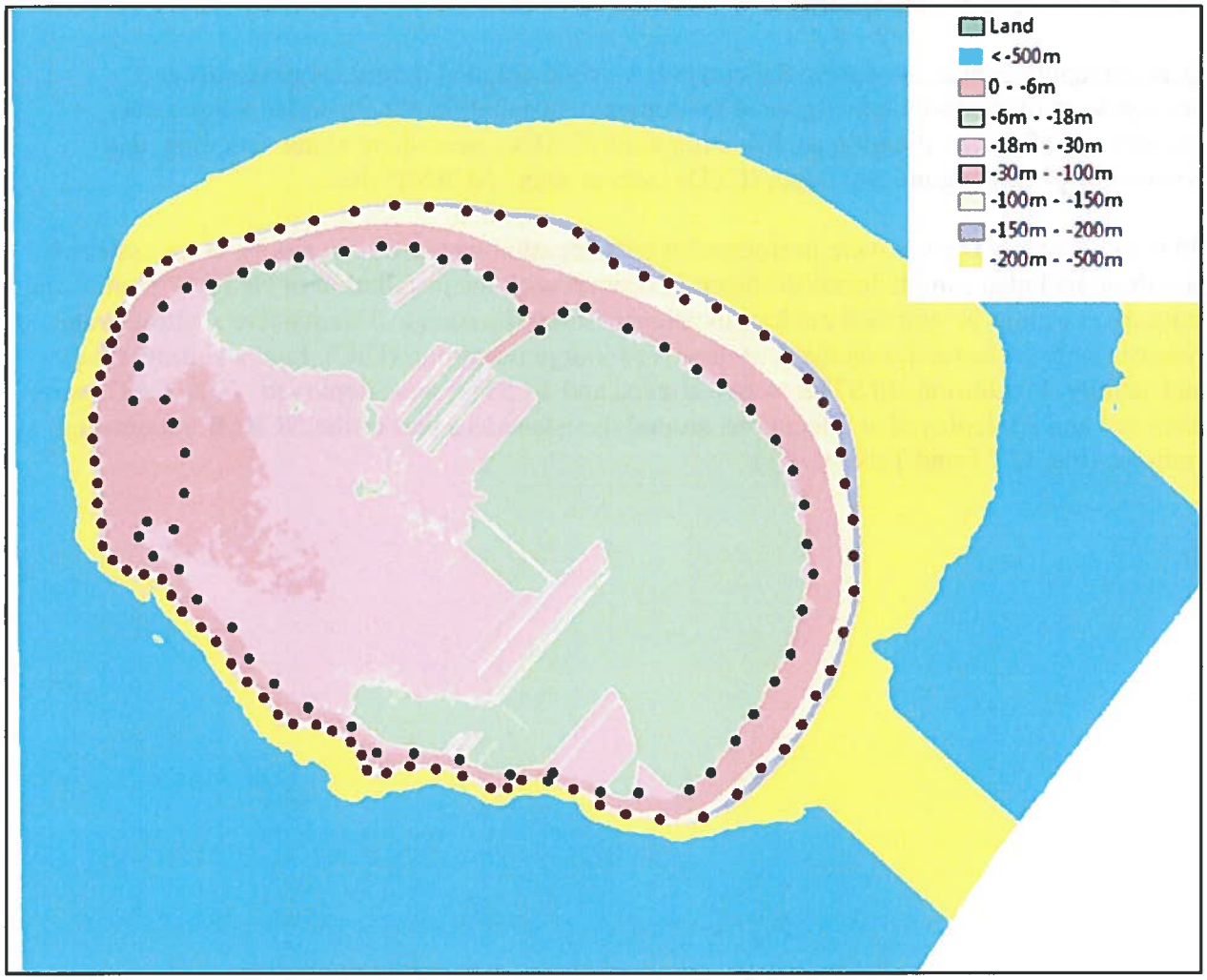

Figure B.4.1.--Image of multibeam planning map with 30-m and 150 m boundary points overlaid on depth bin separated interpolated multibeam for French Frigate Shoals.

APPENDIX C: KURE ATOLL

Kure Atoll, located at 28.418958° N, 178.326147° W, is the northernmost atoll in the world and is part of the Northwestern Hawaiian Islands (NWHI), Papahānaumokuākea Marine National Monument (PMNM). For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: "Methods."

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

Oceanographic operations during the cruise HA-16-06 entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), near-shore water sampling, and conductivity, temperature and depth (CTD) casts at select NCRMP sites.

Shallow-water CTD casts were performed at each location where water samples were collected, and these included sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Twenty-five shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 10 STRs were retrieved and 14 STRs were deployed. Nine CAUs were retrieved and 25 deployed at 5 locations around the island as a part of the NCRMP monitoring stations. (Fig. C.1.1 and Table C.1.1).

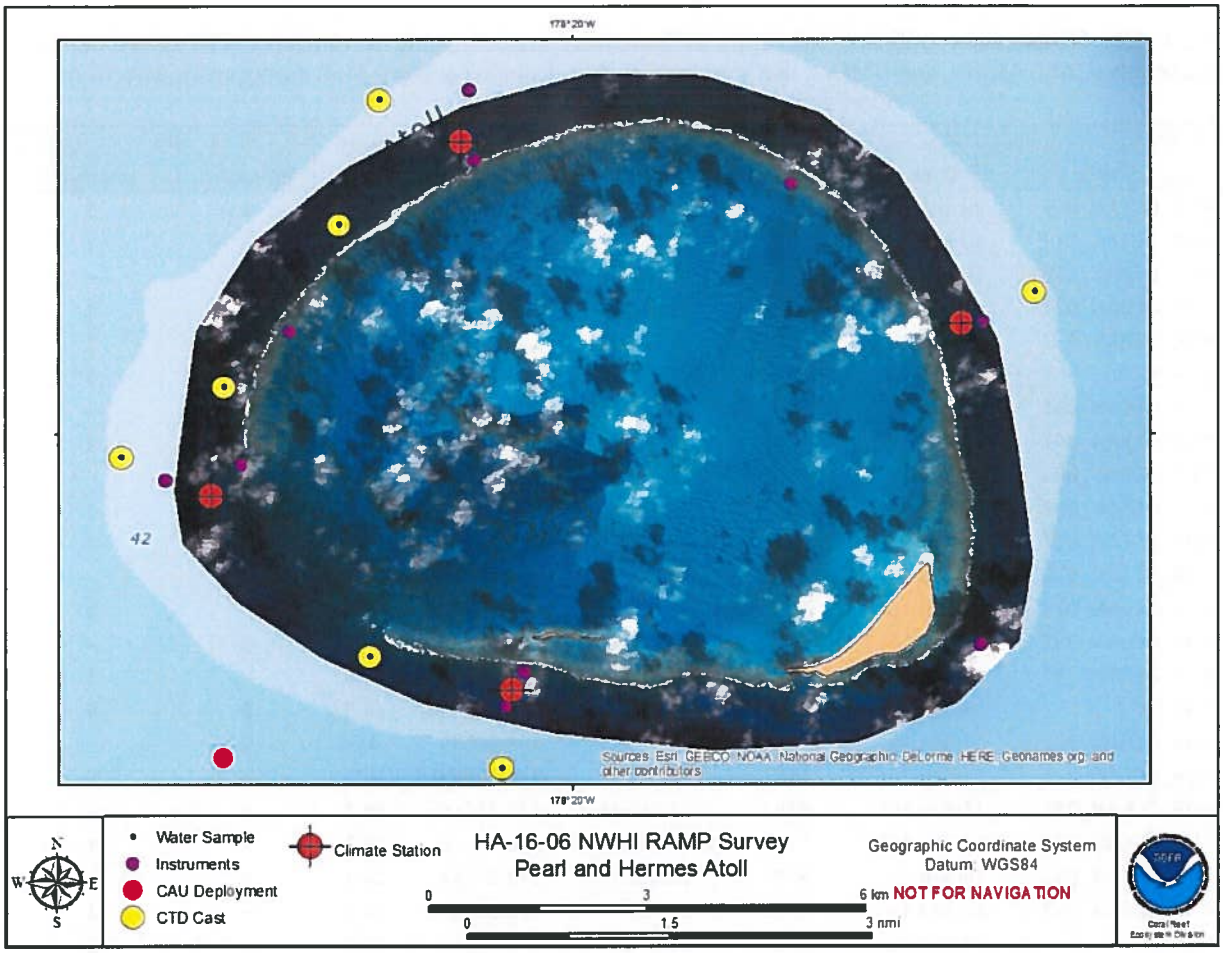

Figure C.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of near-shore CTD casts and water sampling performed at Kure Atoll during cruise HA-16-06.

Table C.1.1.--Geographic coordinates and depths of the moored oceanographic instruments (STR) and biological installations (CAU, ARMS, and BMUs), that were retrieved or deployed at Kure Atoll during cruise HA-16-06.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
KUR_OCEAN_009	12-Sep-16	STR	28.39062	-178.28271	18.6	1	1
KUR_OCEAN_019	12-Sep-16	STR	28.38721	-178.33932	4.9	–	1
KUR_OCEAN_020	12-Sep-16	STR	28.38298	-178.34158	24.7	1	–
KUR_OCEAN_020	12-Sep-16	STR	28.38298	-178.34158	24.7	–	1
KUR_OCEAN_052	12-Sep-16	STR	28.38505	-178.34088	14.3	–	1
KUR-52	12-Sep-16	CAU	28.38506	-178.34087	14.3	2	5
KUR_OCEAN_001	13-Sep-16	STR	28.42936	-178.36835	0.9	1	–
KUR_OCEAN_001	13-Sep-16	STR	28.42936	-178.36835	0.9	–	1
KUR_OCEAN_002	13-Sep-16	STR	28.44761	-178.30622	0.9	1	–
KUR_OCEAN_002	13-Sep-16	STR	28.44761	-178.30622	0.9	–	1
KUR_OCEAN_017	13-Sep-16	STR	28.41281	-178.37439	4.9	–	1
KUR_OCEAN_018	13-Sep-16	STR	28.41100	-178.38370	25.9	1	–
KUR_OCEAN_018	13-Sep-16	STR	28.41100	-178.38370	25.9	–	1
KUR_OCEAN_051	13-Sep-16	STR	28.40911	-178.37814	14.9	1	–
KUR_OCEAN_051	13-Sep-16	STR	28.40911	-178.37814	14.9	–	1
KUR-51	13-Sep-16	CAU	28.40908	-178.37808	14.9	2	5
KUR_OCEAN_021	14-Sep-16	STR	28.45055	-178.34543	4.6	1	–
KUR_OCEAN_021	14-Sep-16	STR	28.45055	-178.34543	4.6	–	1
KUR_OCEAN_022	14-Sep-16	STR	28.45923	-178.34616	26.2	1	–
KUR_OCEAN_022	14-Sep-16	STR	28.45923	-178.34616	26.2	–	1
KUR_OCEAN_053	14-Sep-16	STR	28.45297	-178.34717	14.3	1	–
KUR_OCEAN_053	14-Sep-16	STR	28.45297	-178.34717	14.3	–	1
KUR-50	14-Sep-16	CAU	28.37653	-178.37653	15.5	–	5
KUR-53	14-Sep-16	CAU	28.45290	-178.34706	14.3	2	5
KUR_OCEAN_024	15-Sep-16	STR	28.43043	-178.28252	25.3	–	1
KUR_OCEAN_054	15-Sep-16	STR	28.43037	-178.28523	14.3	1	–
KUR_OCEAN_054	15-Sep-16	STR	28.43037	-178.28523	14.3	–	1
KUR-54	15-Sep-16	CAU	28.43037	-178.28523	14.3	3	5

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

Belt-transect surveys were conducted and photographs were taken along transect lines at 19 REA sites around FFS to assess benthic composition, coral community structure, and coral and algal disease; water samples for microbial analyses were collected at 4 sites (Fig. C.2.1 and Table C.2.1). For more information about collections made at REA sites, see Table F.1.1 in Appendix F: "Biological Collections."

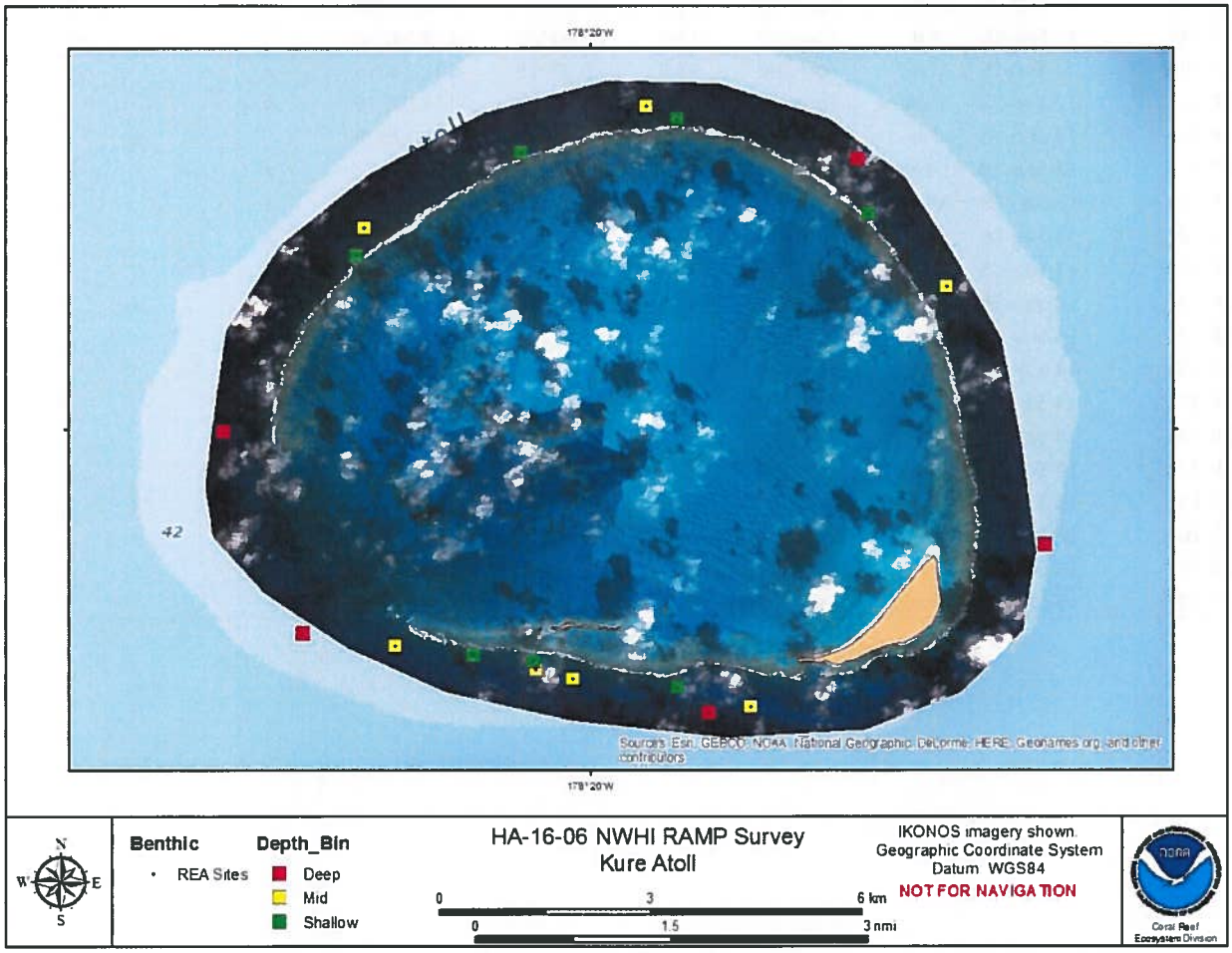

Figure C.2.1.--Locations of benthic REA sites surveyed at Kure Atoll during cruise HA-16-06. All of these REA sites were selected using a stratified random design.

Table C.2.1.--Summary of the Benthic REA surveys and microbial water collections performed at Kure Atoll during cruise HA-16-06.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude	Coral REA Survey	Microbial Samples
KUR-52	12-Sep-16	Mid	Forereef	15.8	28.38506	-178.34087		x
KUR-718	12-Sep-16	Deep	Forereef	26.1	28.39072	-178.37000	x	
KUR-714	12-Sep-16	Deep	Forereef	23.6	28.38061	-178.31826	x	
KUR-741	12-Sep-16	Mid	Forereef	14.8	28.38139	-178.31285	x	
KUR-736	12-Sep-16	Mid	Forereef	10.3	28.38916	-178.35833	x	
KUR-748	12-Sep-16	Mid	Forereef	13.6	28.38491	-178.33558	x	
KUR-746	12-Sep-16	Mid	Forereef	13.0	28.38619	-178.34033	x	
KUR-765	12-Sep-16	Shallow	Forereef	4.2	28.38802	-178.34826	x	
KUR-51	13-Sep-16	Mid	Forereef	15.2	28.40908	-178.37808		x
KUR-725	13-Sep-16	Deep	Forereef	21.2	28.41650	-178.38017	x	
KUR-754	13-Sep-16	Mid	Forereef	11.5	28.44253	-178.36224	x	
KUR-781	13-Sep-16	Shallow	Forereef	6.4	28.43898	-178.36309	x	
KUR-770	13-Sep-16	Shallow	Forereef	4.8	28.38718	-178.34053	x	
KUR-53	14-Sep-16	Mid	Forereef	17.3	28.45290	-178.34706		x
KUR-708	14-Sep-16	Deep	Forereef	21.2	28.45127	-178.29913	x	
KUR-734	14-Sep-16	Mid	Forereef	13.9	28.45797	-178.32618	x	
KUR-771	14-Sep-16	Shallow	Forereef	5.8	28.45206	-178.34215	x	
KUR-779	14-Sep-16	Shallow	Forereef	5.8	28.45638	-178.32226	x	
KUR-780	14-Sep-16	Shallow	Forereef	5.8	28.44431	-178.29776	x	
KUR-54	15-Sep-16	Mid	Forereef	18.5	28.43037	-178.28523		x
KUR-706	15-Sep-16	Deep	Forereef	26.1	28.40198	-178.27505	x	
KUR-753	15-Sep-16	Mid	Forereef	16.1	28.43506	-178.28772	x	
KUR-732	15-Sep-16	Shallow	Forereef	9.1	28.38394	-178.32214	x	

Additionally, during the HA-16-06 cruise, 13 towed-diver surveys were completed around Kure Atoll, covering a total length of 30.2 km (an area of 30.2 ha) of the ocean floor (Fig. C.2.2).

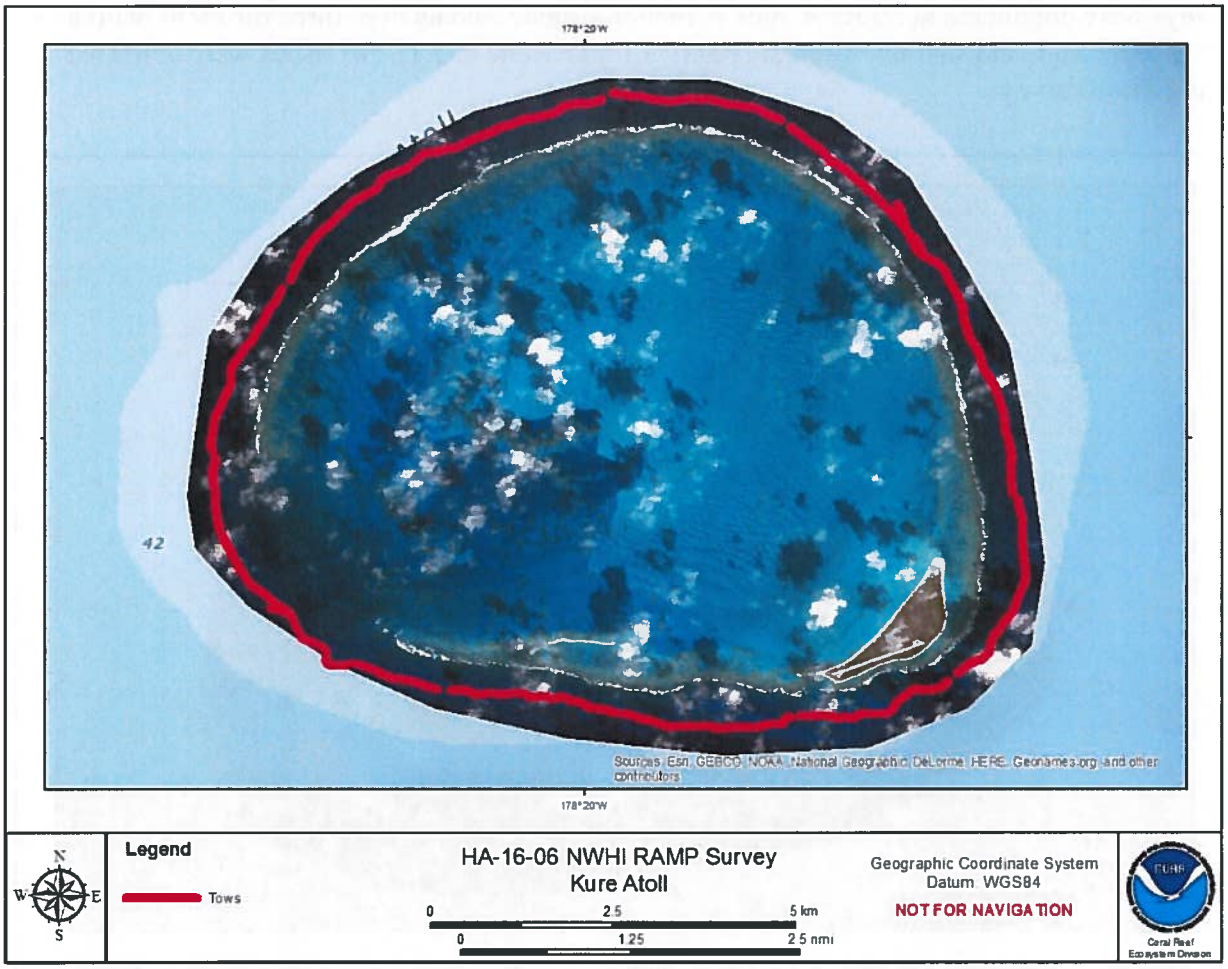

Figure C.2.2.--Track locations of towed-diver surveys conducted at Kure Atoll during the cruise HA-16-06.

C.3. Biological Monitoring: Reef Fish Community

Fish REA survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 39 REA sites at French Frigate Shoals over three different habitat strata: deep, mid, and shallow forereef (Fig.C.3.1 and Table C.3.1). No fishes were collected during these surveys.

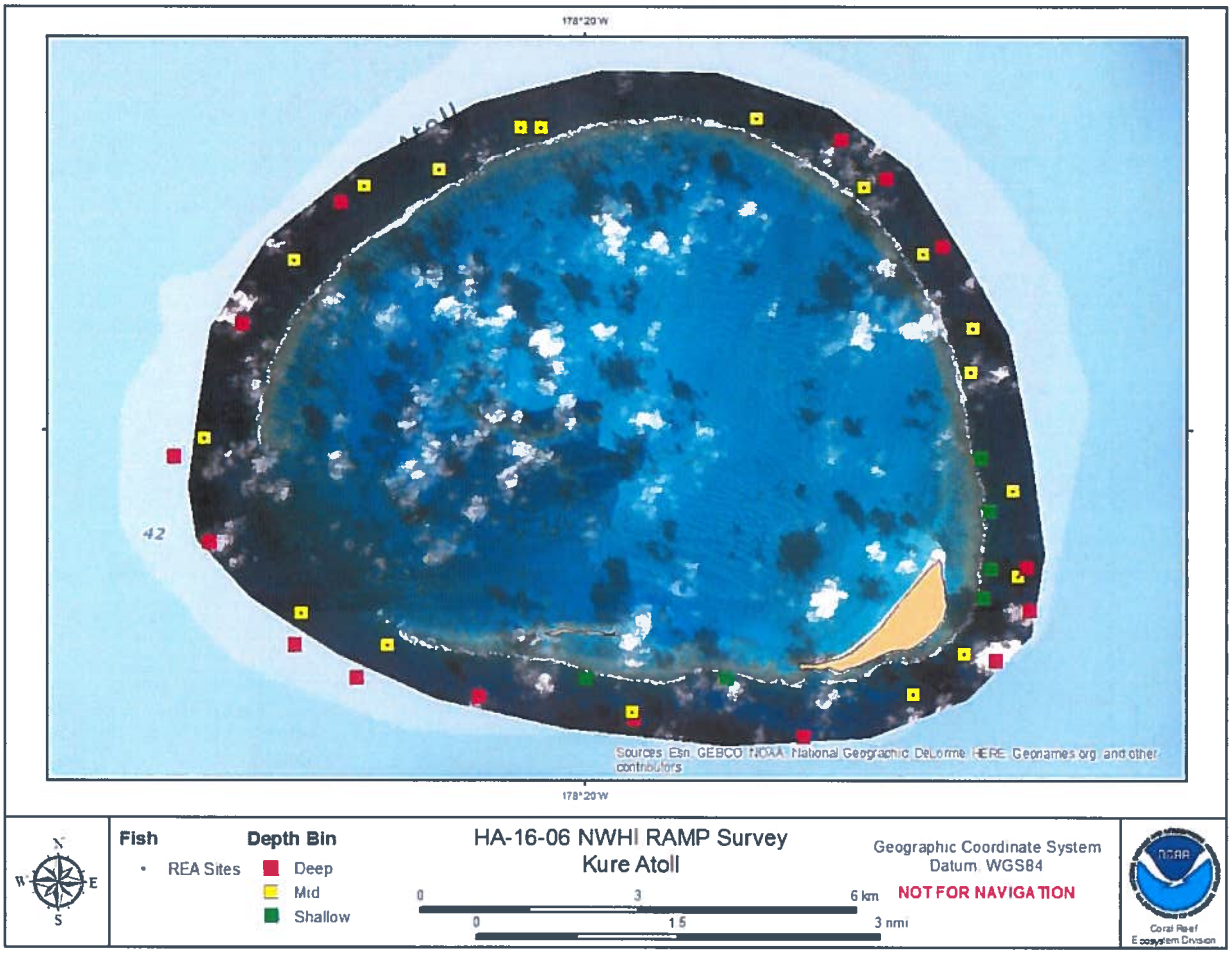

Figure C.3.1. --Locations of Fish REA sites surveyed at Kure Atoll during cruise HA-16-06. All of these REA sites were selected using a stratified random design.

Table C.3.1.--Summary of sites where Fish REA surveys were conducted at Kure Atoll during cruise HA-16-06.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
KUR-578	12-Sep-16	Deep	Forereef	19.5	28.38360	-178.34648
KUR-583	12-Sep-16	Deep	Forereef	25.5	28.38587	-178.36168
KUR-588	12-Sep-16	Deep	Forereef	23.8	28.38995	-178.36938
KUR-589	12-Sep-16	Deep	Forereef	21.5	28.38081	-178.32736
KUR-592	12-Sep-16	Deep	Forereef	21.2	28.37867	-178.30620
KUR-598	12-Sep-16	Shallow	Forereef	4.0	28.38593	-178.31576
KUR-611	12-Sep-16	Shallow	Forereef	5.2	28.38573	-178.33324
KUR-622	12-Sep-16	Mid	Forereef	16.1	28.39396	-178.36864
KUR-623	12-Sep-16	Mid	Forereef	12.2	28.38887	-178.28635
KUR-626	12-Sep-16	Mid	Forereef	7.5	28.39001	-178.35795
KUR-637	12-Sep-16	Mid	Forereef	14.2	28.38174	-178.32766
KUR-642	12-Sep-16	Mid	Forereef	17.9	28.38392	-178.29255
KUR-572	13-Sep-16	Deep	Forereef	21.5	28.40279	-178.37991
KUR-582	13-Sep-16	Deep	Forereef	22.4	28.44487	-178.36377
KUR-584	13-Sep-16	Deep	Forereef	21.6	28.42983	-178.37593
KUR-586	13-Sep-16	Deep	Forereef	25.5	28.41338	-178.38433
KUR-625	13-Sep-16	Mid	Forereef	11.8	28.45417	-178.33882
KUR-628	13-Sep-16	Mid	Forereef	10.1	28.44896	-178.35150
KUR-629	13-Sep-16	Mid	Forereef	15.5	28.44688	-178.36084
KUR-638	13-Sep-16	Mid	Forereef	11.8	28.45413	-178.34133
KUR-641	13-Sep-16	Mid	Forereef	18.2	28.41559	-178.38053
KUR-643	13-Sep-16	Mid	Forereef	13.3	28.43764	-178.36955
KUR-577	14-Sep-16	Deep	Forereef	22.0	28.44775	-178.29601
KUR-590	14-Sep-16	Deep	Forereef	22.0	28.43940	-178.28902
KUR-593	14-Sep-16	Deep	Forereef	22.3	28.45255	-178.30157
KUR-599	14-Sep-16	Shallow	Forereef	5.0	28.40657	-178.28298
KUR-619	14-Sep-16	Shallow	Forereef	5.8	28.41324	-178.28411
KUR-627	14-Sep-16	Mid	Forereef	11.5	28.45525	-178.31210
KUR-630	14-Sep-16	Mid	Forereef	14.5	28.42923	-178.28520
KUR-632	14-Sep-16	Mid	Forereef	10.3	28.44669	-178.29880
KUR-646	14-Sep-16	Mid	Forereef	11.2	28.43840	-178.29140
KUR-647	14-Sep-16	Mid	Forereef	11.6	28.42395	-178.28537
KUR-574	15-Sep-16	Deep	Forereef	26.4	28.38800	-178.28221
KUR-579	15-Sep-16	Deep	Forereef	21.1	28.39955	-178.27854
KUR-591	15-Sep-16	Deep	Forereef	26.8	28.39434	-178.27800
KUR-595	15-Sep-16	Shallow	Forereef	5.0	28.39583	-178.28371
KUR-612	15-Sep-16	Shallow	Forereef	4.3	28.39944	-178.28290
KUR-634	15-Sep-16	Mid	Forereef	15.8	28.39854	-178.27956
KUR-639	15-Sep-16	Mid	Forereef	14.3	28.40916	-178.28020

C.4. Benthic Habitat Mapping

Multibeam mapping surveys at Kure Atoll were conducted using the *Hi'ialakai* EM300 and EM3002D multibeam sonars. The ship conducted multibeam mapping around Kure Atoll on September 13-14, 2016. The focused area of mapping was to fill gaps around Kure Atoll.

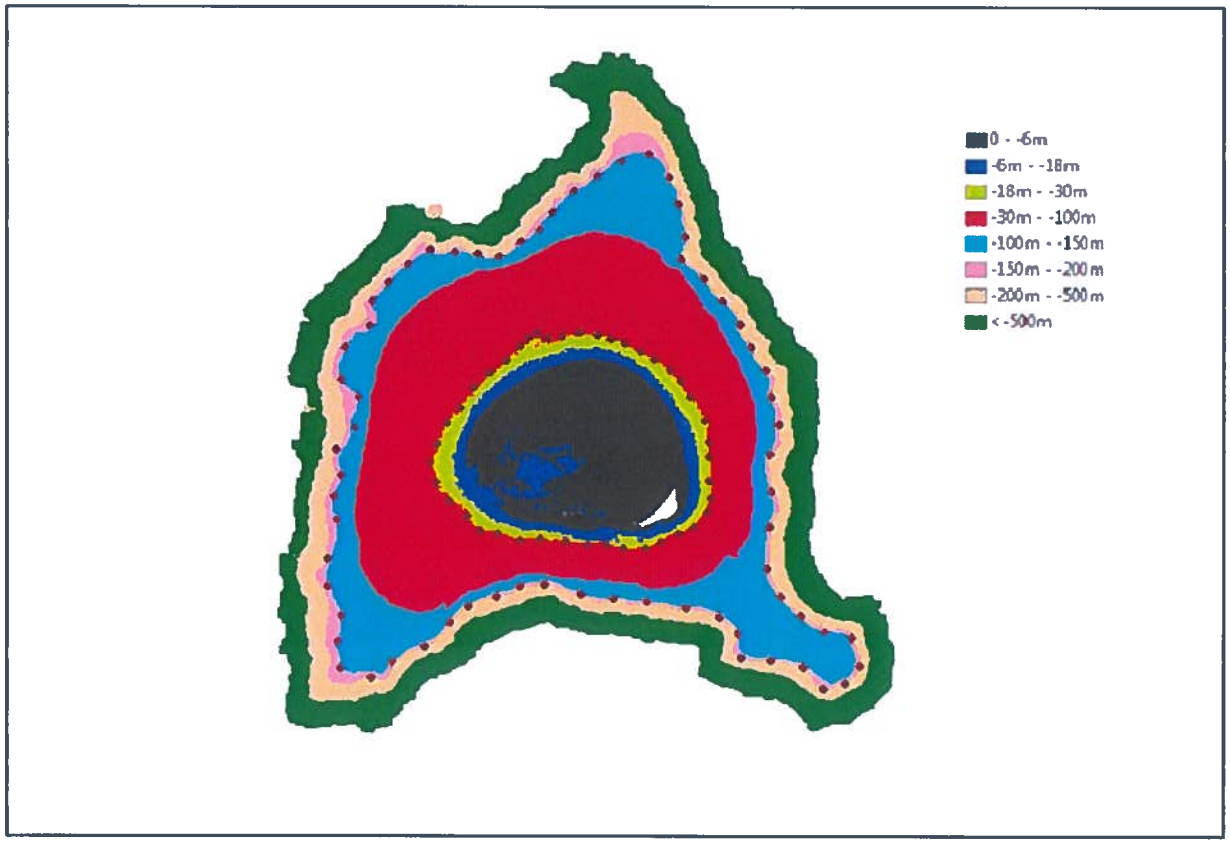

Figure C.4.1.--Image of multibeam planning map with 30-m and 150-m boundary points overlaid on depth bin separated interpolated multibeam for Kure Atoll.

APPENDIX D: LISIANSKI ISLAND

Lisianski Island and the surrounding atoll, Neva Shoal, are located at 26.064385° N, 173.965605° W and are part of the Northwestern Hawaiian Islands (NWHI), Papahānaumokuākea Marine National Monument (PMNM). For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: "Methods."

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

Oceanographic operations during the cruise HA-16-06 entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), bioerosion monitoring units (BMUs), near-shore water sampling, and conductivity, temperature and depth (CTD) casts at select NCRMP sites.

Shallow-water CTD casts were performed at each location where water samples were collected, and these included sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Thirty-three shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 15 STRs were retrieved and 14 STRs were deployed. Twenty-five CAUs were retrieved and 25 deployed at 5 locations around the island as a part of the NCRMP monitoring stations. (Fig. D.1.1and Table D.1.1).

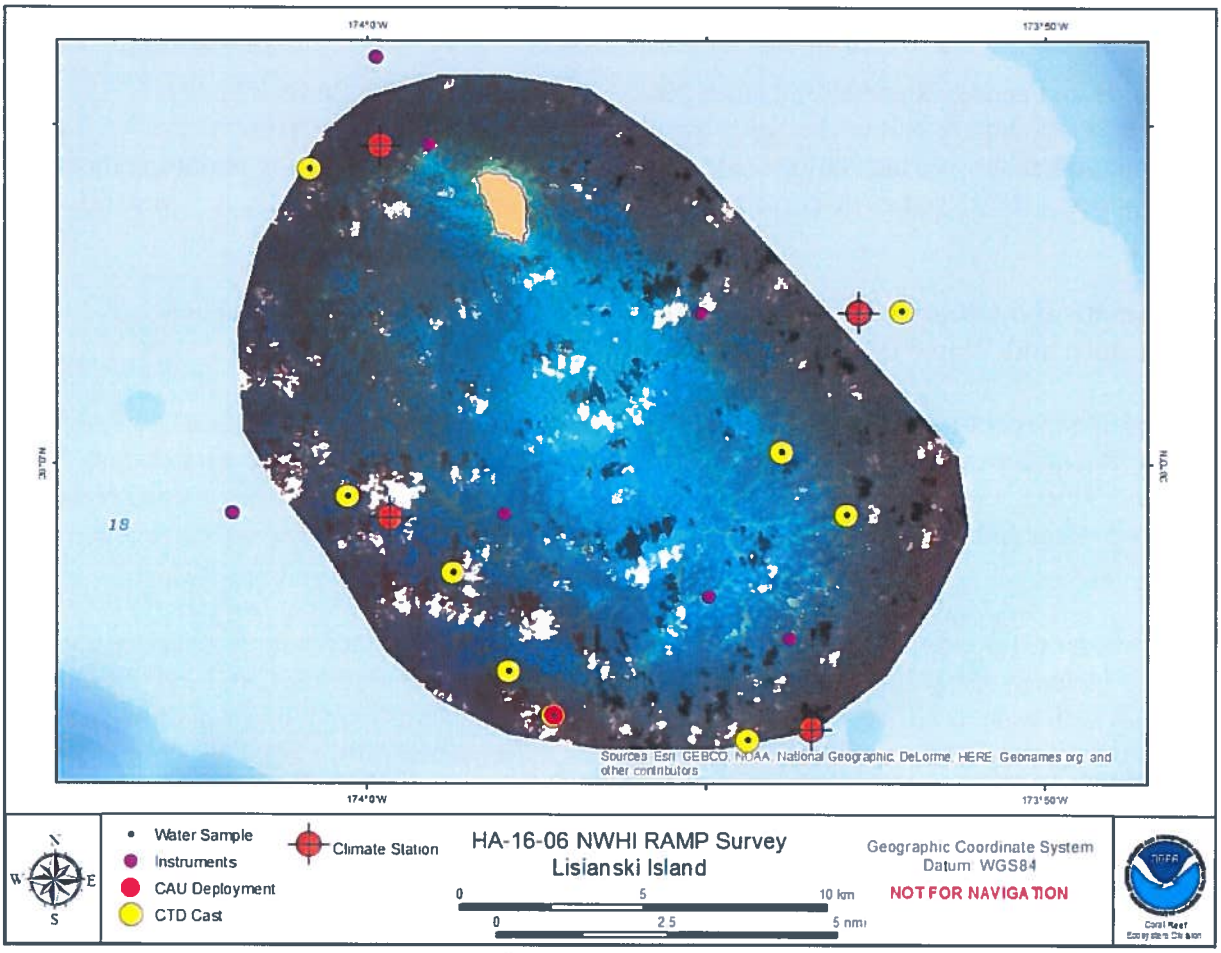

Figure D.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of near-shore CTD casts and water sampling performed at Lisianski during cruise HA-16-06.

Table D.1.1.--Geographic coordinates and depths of the moored oceanographic instruments (STR) and biological installations (CAU, ARMS), that were retrieved or deployed at Lisianski during cruise HA-16-06.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
LIS-52	17-Sep-16	CAU	25.93495	-173.89090	16.8	5	5
LIS-53	17-Sep-16	CAU	25.93831	-173.95396	16.8	5	5
LIS_OCEAN_001	17-Sep-16	STR	25.96765	-173.91585	0.9	1	–
LIS_OCEAN_005	17-Sep-16	STR	25.96765	-173.91585	10.1	1	1
LIS_OCEAN_010	17-Sep-16	STR	25.93467	-173.89125	26.2	1	–
LIS_OCEAN_011	17-Sep-16	STR	25.93504	-173.89104	16.8	1	–
LIS_OCEAN_001	17-Sep-16	STR	25.96765	-173.91585	0.9	–	1
LIS_OCEAN_010	17-Sep-16	STR	25.93467	-173.89125	26.2	–	1
LIS_OCEAN_011	17-Sep-16	STR	25.93504	-173.89104	16.8	–	1
LIS-50	18-Sep-16	CAU	26.03741	-173.87918	16.8	5	5
LIS_OCEAN_015	18-Sep-16	STR	26.03716	-173.91803	4.6	1	–
LIS_OCEAN_016	18-Sep-16	STR	26.03739	-173.87914	16.8	1	–
LIS_OCEAN_017	18-Sep-16	STR	26.03759	-173.87772	26.2	1	–
LIS_OCEAN_013	18-Sep-16	STR	25.98788	-173.96598	4.6	1	–
LIS_OCEAN_015	18-Sep-16	STR	26.03716	-173.91803	4.6	–	1
LIS_OCEAN_016	18-Sep-16	STR	26.03739	-173.87914	16.8	–	1
LIS_OCEAN_017	18-Sep-16	STR	26.03759	-173.87772	26.2	–	1
LIS_OCEAN_013	18-Sep-16	STR	25.98788	-173.96598	4.6	–	1
LIS-51	19-Sep-16	CAU	26.07842	-173.99699	14.6	5	5
LIS_OCEAN_004	19-Sep-16	STR	26.10018	-173.99801	23.5	1	–
LIS_OCEAN_009	19-Sep-16	STR	26.07838	-173.99701	14.6	1	–
LIS_OCEAN_019	19-Sep-16	STR	26.07870	-173.98476	4.3	1	–
LIS_OCEAN_004	19-Sep-16	STR	26.10018	-173.99801	23.5	–	1
LIS_OCEAN_009	19-Sep-16	STR	26.07838	-173.99701	14.6	–	1
LIS_OCEAN_019	19-Sep-16	STR	26.07870	-173.98476	4.3	–	1
LIS-54	20-Sep-16	CAU	25.98702	-173.99438	14.6	5	5
LIS_OCEAN_001	20-Sep-16	STR	25.96762	-173.91587	0.9	1	–
LIS_OCEAN_012	20-Sep-16	STR	25.95715	-173.89609	5.8	1	–
LIS_OCEAN_006	20-Sep-16	STR	25.98707	-173.99440	14.6	1	–
LIS_OCEAN_014	20-Sep-16	STR	25.98807	-174.03293	24.7	1	–
LIS_OCEAN_012	20-Sep-16	STR	25.95715	-173.89609	5.8	–	1
LIS_OCEAN_006	20-Sep-16	STR	25.98707	-173.99440	14.6	–	1
LIS_OCEAN_014	20-Sep-16	STR	25.98807	-174.03293	23.8	–	1

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

Belt-transect surveys were conducted and photographs were taken along transect lines at 19 REA sites around Lisianski to assess benthic composition, coral community structure, and coral and algal disease; water samples for microbial analyses were collected at 6 sites (Fig. D.2.1 and Table D.2.1). For more information about collections made at REA sites, see Table F.1.1 in Appendix F: "Biological Collections."

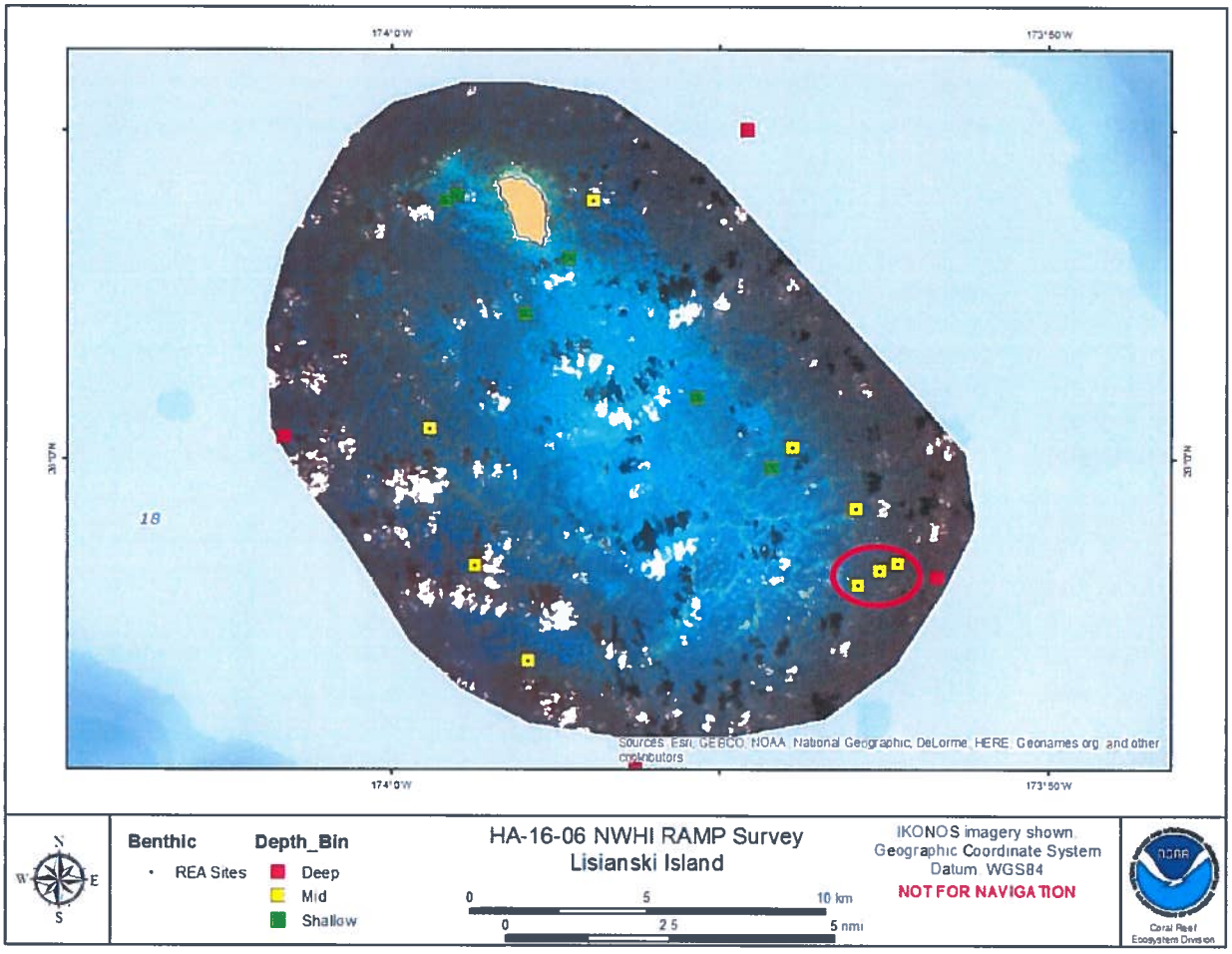

Figure D.2.1.--Locations of benthic REA sites surveyed at Lisianski during cruise HA-16-06. Most REA sites were selected using a stratified random design. Those that were surveyed to assess damage from the grounded buoy are circled in red. The shallow damage assessment site is obscured by one of the mid-depth sites.

Table D.2.1.--Summary of the Benthic REA surveys and microbial water collections performed at Lisianski during cruise HA-16-06. Sites marked with an asterisk were surveyed to assess damage from a NOAA National Weather Service Buoy, and were not selected through a stratified random process. At the site with the double asterisk (LIS-31), there was not enough time available to conduct an REA survey, so only site photos were taken.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude	Coral REA Survey	Microbial Samples
LIS-52	17-Sep-16		Forereef	18.2	25.93495	-173.89090		x
LIS-780	17-Sep-16	Deep	Forereef	18.8	25.92298	-173.93801	x	
LIS-804	17-Sep-16	Mid	Forereef	10.9	25.94903	-173.96504	x	
LIS-785	17-Sep-16	Mid	Forereef	17.6	25.97337	-173.97857	x	
LIS-805	17-Sep-16	Mid	Forereef	12.1	26.00798	-173.99034	x	
LIS-50	18-Sep-16		Forereef	18.2	26.03741	-173.87918		x
LIS-778	18-Sep-16	Deep	Forereef	22.1	25.97015	-173.86181	x	
LIS-783	18-Sep-16	Mid	Forereef	8.8	25.98768	-173.88223	x	
LIS-795	18-Sep-16	Mid	Forereef	7.0	26.00296	-173.89818	x	
LIS-810	18-Sep-16	Shallow	Forereef	3.3	25.99809	-173.90336	x	
LIS-50	19-Sep-16		Forereef	15.2	26.03741	-173.87918		x
LIS-54	20-Sep-16		Forereef	10.9	25.98702	-173.99438		x
LIS-755	20-Sep-16	Deep	Forereef	19.1	26.00600	-174.02712	x	
LIS-768	20-Sep-16	Deep	Forereef	22.7	26.08365	-173.90977	x	
LIS-834	20-Sep-16	Shallow	Forereef	4.5	26.05130	-173.95465	x	
LIS-823	20-Sep-16	Shallow	Forereef	5.5	26.03724	-173.96561	x	
LIS-802	20-Sep-16	Mid	Forereef	10.6	26.06563	-173.94885	x	
LIS-830	20-Sep-16	Shallow	Forereef	3.3	26.06712	-173.98336	x	
LIS-838	20-Sep-16	Shallow	Forereef	3.6	26.01569	-173.92223	x	
LIS-820	20-Sep-16	Shallow	Forereef	3.0	26.06578	-173.98597	x	
LIS-30*	21-Sep-16	Mid	Forereef	9.1	25.97202	-173.87626	x	
LIS-33*	21-Sep-16	Mid	Forereef	17.6	25.97374	-173.87198	x	
LIS-32*	21-Sep-16	Mid	Forereef	13.6	25.96848	-173.88195	x	
LIS-31**	21-Sep-16	Shallow	Forereef	8.2	25.96892	-173.88007	x	

Additionally, during the HA-16-06 cruise, 12 towed-diver surveys were completed around French Frigate Shoals, covering a total length of 29.2 km (an area of 29.2 ha) of the ocean floor (Fig. D.2.2).

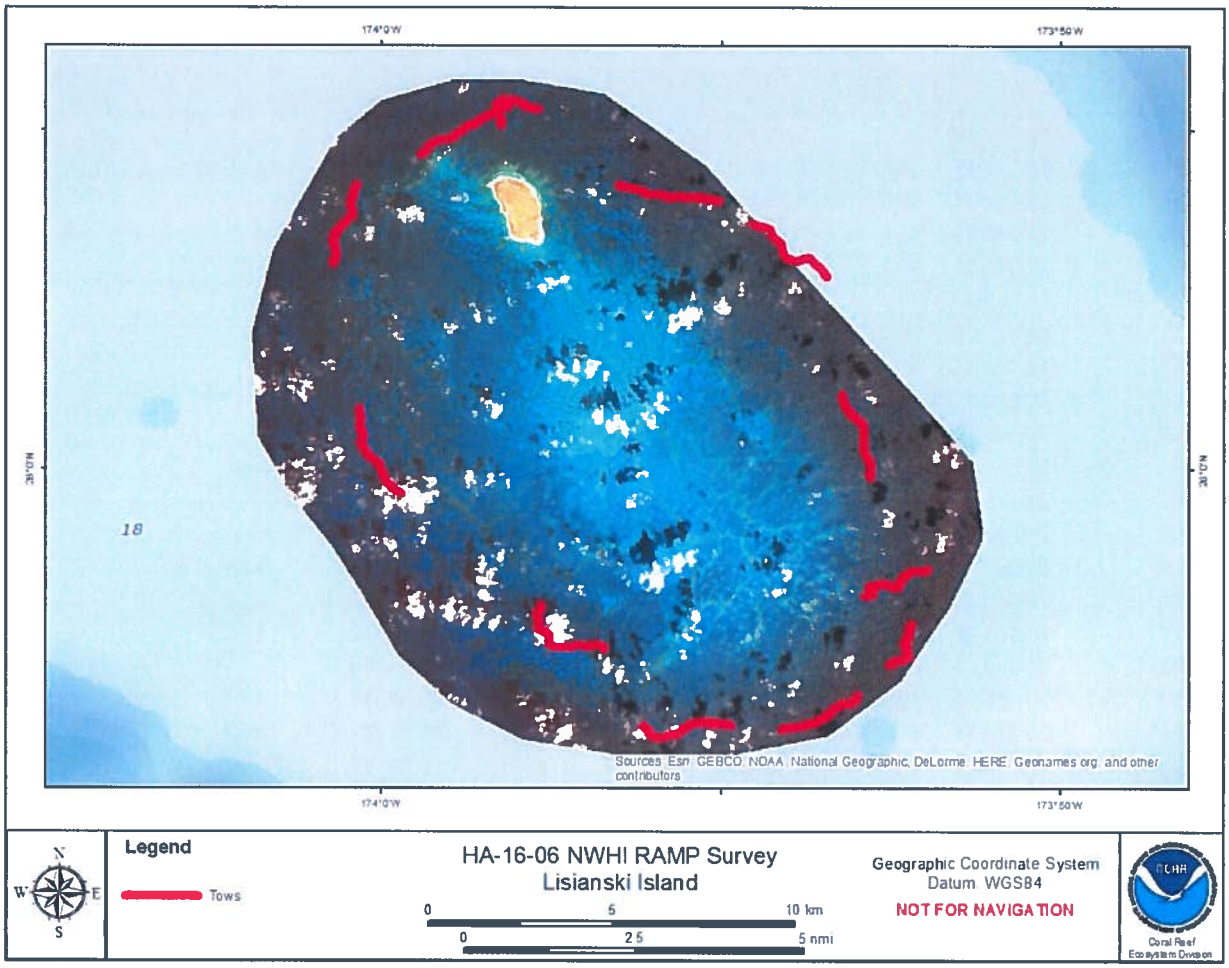

Figure D.2.2.--Track locations of towed-diver surveys conducted at Lisianski during the cruise HA-16-06.

D.3. Biological Monitoring: Reef Fish Community

Fish REA survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 40 REA sites at Lisianski over three different habitat strata: deep, mid, and shallow forereef (Fig. D.3.1 and Table D.3.1). No fishes were collected during these surveys.

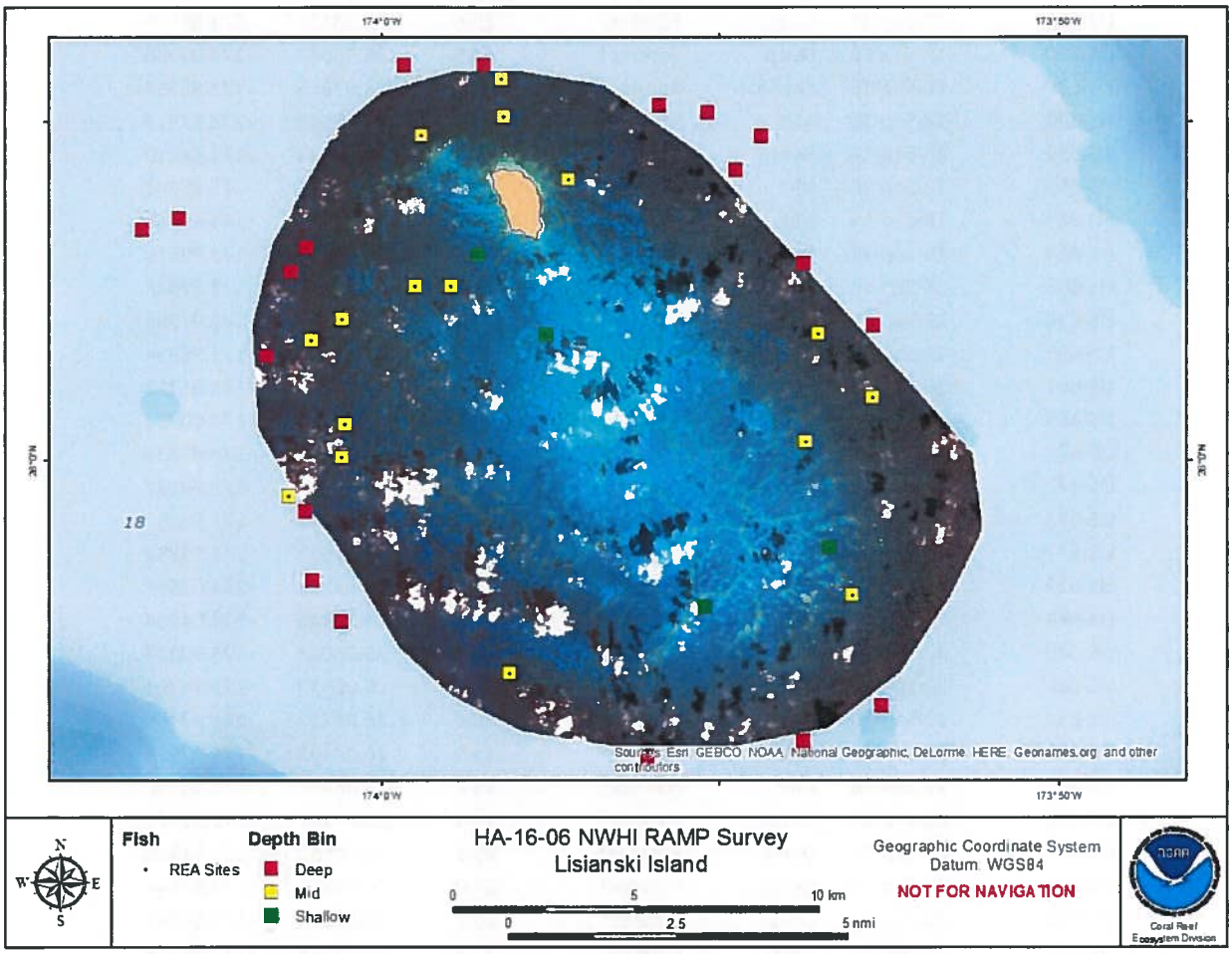

Figure D.3.1.--Locations of Fish REA sites surveyed at Lisianski during cruise HA-16-06. All of these REA sites were selected using a stratified random design.

Table D.3.1.--Summary of sites where Fish REA surveys were conducted at Lisianski during cruise HA-16-06.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
LIS-662	17-Sep-16	Mid	Forereef	10.4	25.94774	-173.96848
LIS-666	17-Sep-16	Mid	Forereef	12.1	26.00101	-174.00977
LIS-674	17-Sep-16	Deep	Forereef	21.2	25.97049	-174.01697
LIS-678	17-Sep-16	Deep	Forereef	18.6	25.92734	-173.93424
LIS-683	17-Sep-16	Mid	Forereef	15.2	25.99135	-174.02276
LIS-685	17-Sep-16	Deep	Forereef	25.6	25.93122	-173.89605
LIS-690	17-Sep-16	Deep	Forereef	24.5	25.96047	-174.00988
LIS-637	18-Sep-16	Shallow	Forereef	6.1	25.97855	-173.88987
LIS-648	18-Sep-16	Mid	Forereef	11.9	26.01544	-173.87918
LIS-652	18-Sep-16	Deep	Forereef	18.9	26.04834	-173.89610
LIS-655	18-Sep-16	Mid	Forereef	8.9	26.03115	-173.89243
LIS-663	18-Sep-16	Mid	Forereef	7.9	26.00473	-173.89566
LIS-664	18-Sep-16	Deep	Forereef	19.7	26.04834	-173.89610
LIS-668	18-Sep-16	Deep	Forereef	20.7	26.03326	-173.87888
LIS-633	19-Sep-16	Shallow	Forereef	4.2	26.05077	-173.97594
LIS-635	19-Sep-16	Shallow	Forereef	4.2	26.03086	-173.95924
LIS-661	19-Sep-16	Mid	Forereef	15.9	26.02969	-174.01712
LIS-669	19-Sep-16	Mid	Forereef	13.3	26.03486	-174.00993
LIS-671	19-Sep-16	Deep	Forereef	18.0	26.05236	-174.01834
LIS-672	19-Sep-16	Mid	Forereef	10.3	26.04294	-173.99152
LIS-673	19-Sep-16	Mid	Forereef	7.5	26.04296	-173.98294
LIS-677	19-Sep-16	Deep	Forereef	27.0	26.05667	-174.05890
LIS-679	19-Sep-16	Deep	Forereef	20.4	26.02568	-174.02835
LIS-682	19-Sep-16	Deep	Forereef	29.0	26.05946	-174.04964
LIS-649	20-Sep-16	Mid	Forereef	11.0	26.08003	-173.99007
LIS-656	20-Sep-16	Mid	Forereef	12.4	26.06910	-173.95391
LIS-659	20-Sep-16	Deep	Forereef	20.0	26.09727	-173.97458
LIS-665	20-Sep-16	Mid	Forereef	15.5	26.09355	-173.97029
LIS-667	20-Sep-16	Mid	Forereef	11.4	26.08457	-173.96996
LIS-675	20-Sep-16	Deep	Forereef	19.4	26.07147	-173.91270
LIS-681	20-Sep-16	Deep	Forereef	26.1	26.08552	-173.91958
LIS-687	20-Sep-16	Deep	Forereef	24.0	26.08721	-173.93144
LIS-688	20-Sep-16	Deep	Forereef	23.7	26.07974	-173.90644
LIS-693	20-Sep-16	Deep	Forereef	21.3	26.09726	-173.99438
LIS-638	21-Sep-16	Shallow	Forereef	4.6	25.96404	-173.92014
LIS-654	21-Sep-16	Mid	Forereef	12.4	25.96714	-173.88427
LIS-658	21-Sep-16	Mid	Forereef	9.7	26.00905	-174.00914
LIS-676	21-Sep-16	Deep	Forereef	19.8	26.04651	-174.02214
LIS-680	21-Sep-16	Deep	Forereef	21.9	25.98746	-174.01856
LIS-686	21-Sep-16	Deep	Forereef	20.9	25.93980	-173.87696

D.4. Benthic Habitat Mapping

Multibeam mapping surveys at Lisianski Island were conducted using the *Hi'ialakai* EM3002D multibeam sonar. The ship conducted shallow water sonar mapping around Lisianski on 18 September and 20 September 2016. While conducting mapping it was noted that the STBD beam appears to be malfunctioning.

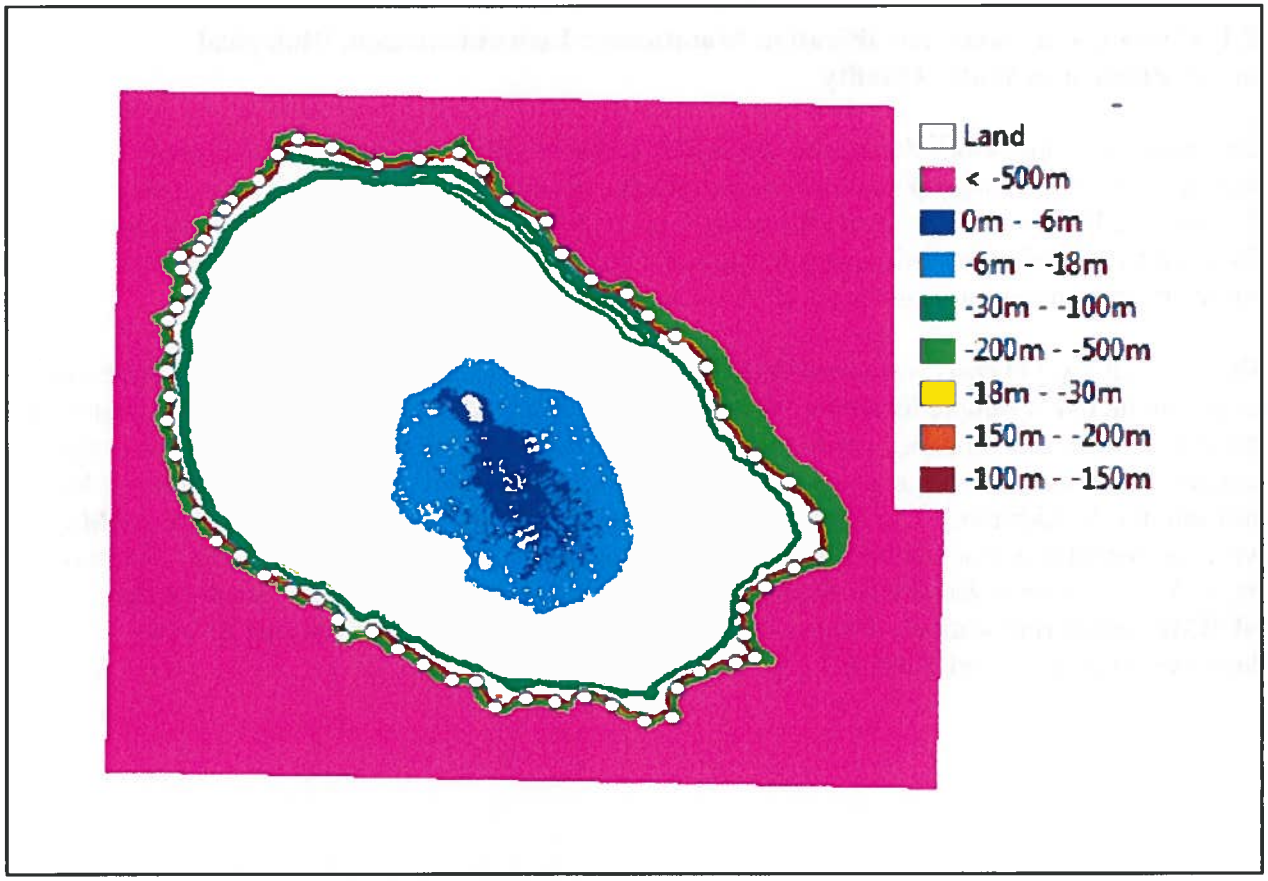

Figure D.4.1.--Image of multibeam planning map with 150-m boundary points overlaid on depth bin separated interpolated multibeam for Lisianski.

APPENDIX E: PEARL AND HERMES ATOLL

Pearl and Hermes Atoll, located at 27.856098° N, 175.847545° W, is a large atoll in the Northwestern Hawaiian Islands (NWHI), Papahānaumokuākea Marine National Monument (PMNM). For information about the methods used to perform the activities discussed in this appendix, please see Appendix A: "Methods."

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

Oceanographic operations during the cruise HA-16-06 entailed numerous retrievals and deployments of oceanographic moored instruments, installation of subsurface temperature recorders (STRs), calcification acidification units (CAUs), Autonomous Reef Monitoring Structures (ARMS), bioerosion monitoring units (BMUs), near-shore water sampling, and conductivity, temperature and depth (CTD) casts at select NCRMP sites.

Shallow-water CTD casts were performed at each location where water samples were collected, and these included sample locations taken in concert with the installation of NCRMP monitoring stations as well as at stratified random locations around the island. Twenty-two shallow-water samples were collected for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), and salinity. In addition, 17 STRs were retrieved and 16 STRs were deployed. Twelve ARMS were recovered and processed for taxonomic analysis and 12 ARMS were deployed. Twenty-one CAUs were retrieved and 25 deployed at 5 locations around the island as a part of the NCRMP monitoring stations. Twenty-one collocated BMUs were retrieved and 20 were deployed. (Fig. E.1.1and Table E.1.1).

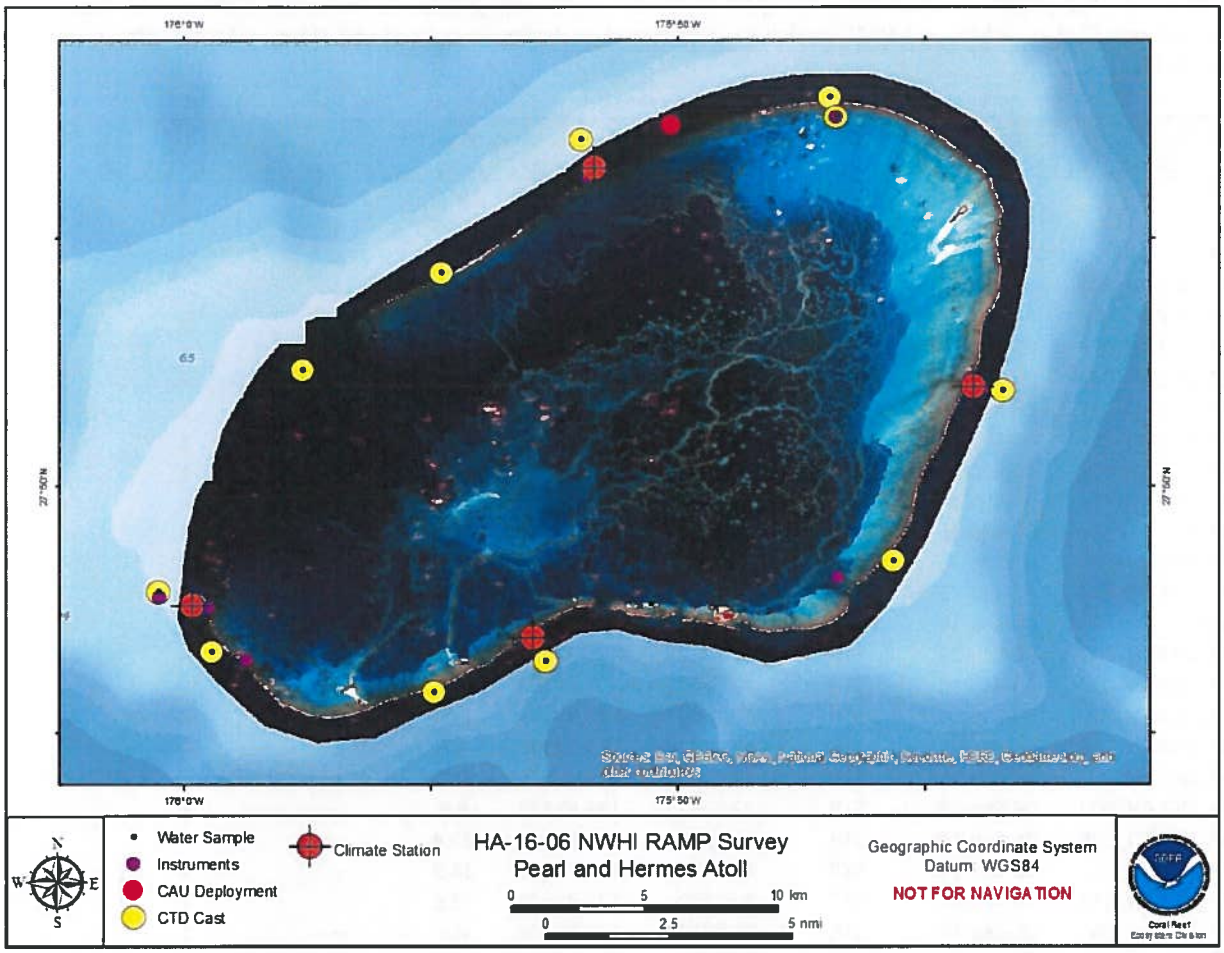

Figure E.1.1.--Mooring sites where oceanographic instruments and biological installations were retrieved or deployed and locations of near-shore CTD casts and water sampling performed at Pearl and Hermes Atoll during cruise HA-16-06.

Table E.1.1.--Geographic coordinates and depths of the moored oceanographic instruments (STR) and biological installations (CAU, ARMS, and BMUs), that were retrieved or deployed at Pearl and Hermes Atoll during cruise HA-16-06.

Site	Date	Instrument Type	Latitude	Longitude	Depth (m)	Retrieved	Deployed
PHR-52	06-Sep-16	ARMS	27.94055	-175.86165	14.3	3	3
PHR-52	06-Sep-16	BMU	27.94055	-175.86165	14.3	4	5
PHR-52	06-Sep-16	CAU	27.94055	-175.86165	14.3	5	5
PHR_OCEAN_023	06-Sep-16	STR	27.94050	-175.86173	16.5	1	–
PHR_OCEAN_016	06-Sep-16	STR	27.94243	-175.86346	23.5	1	–
PHR_OCEAN_023	06-Sep-16	STR	27.94050	-175.86173	14.3	1	–
PHR_OCEAN_032	06-Sep-16	STR	27.93765	-175.86349	6.1	1	–
PHR_OCEAN_016	06-Sep-16	STR	27.94243	-175.86346	23.5	–	1
PHR_OCEAN_023	06-Sep-16	STR	27.94050	-175.86173	14.3	–	1
PHR_OCEAN_032	06-Sep-16	STR	27.93765	-175.86349	6.1	–	1
PHR-53	07-Sep-16	BMU	27.95493	-175.83582	14.3	3	–
PHR-53	07-Sep-16	CAU	27.95493	-175.83582	14.3	3	5
PHR_OCEAN_004	07-Sep-16	STR	27.95763	-175.78021	0.9	1	–
PHR_OCEAN_004	07-Sep-16	STR	27.95763	-175.78021	0.9	–	1
PHR-50	08-Sep-16	ARMS	27.78237	-175.88194	14.3	3	3
PHR_OCEAN_009	08-Sep-16	STR	27.78175	-175.88087	38.4	1	–
PHR_OCEAN_010	08-Sep-16	STR	27.78202	-175.88103	23.5	1	–
PHR_OCEAN_012	08-Sep-16	STR	27.78243	-175.88193	14.3	1	–
PHR_OCEAN_053	08-Sep-16	STR	27.78334	-175.88306	4.6	1	–
PHR_OCEAN_002	08-Sep-16	STR	27.77474	-175.97870	0.9	1	–
PHR_OCEAN_002	08-Sep-16	STR	27.77474	-175.97870	0.9	–	1
PHR_OCEAN_009	08-Sep-16	STR	27.78175	-175.88087	38.4	–	1
PHR_OCEAN_012	08-Sep-16	STR	27.78243	-175.88193	14.3	–	1
PHR_OCEAN_014	08-Sep-16	STR	27.78202	-175.88103	23.5	–	1
PHR_OCEAN_053	08-Sep-16	STR	27.78334	-175.88306	4.6	–	1
PHR-50	09-Sep-16	BMU	27.78237	-175.88195	14.3	5	5
PHR-50	09-Sep-16	CAU	27.78237	-175.88195	14.3	5	5
PHR_OCEAN_005	09-Sep-16	STR	27.80265	-175.77950	1.5	1	–
PHR_OCEAN_031	09-Sep-16	STR	27.86892	-175.73491	4.6	1	–
PHR_OCEAN_005	09-Sep-16	STR	27.80265	-175.77950	1.5	–	1
PHR_OCEAN_031	09-Sep-16	STR	27.86892	-175.73491	4.6	–	1
PHR-51	10-Sep-16	ARMS	27.86679	-175.73358	14.3	3	3
PHR-51	10-Sep-16	BMU	27.86679	-175.73358	14.3	5	5
PHR-51	10-Sep-16	CAU	27.86679	-175.73358	14.3	5	5
PHR_OCEAN_029	10-Sep-16	STR	27.86587	-175.73026	24.7	1	–
PHR_OCEAN_030	10-Sep-16	STR	27.86691	-175.73350	14.3	1	–
PHR_OCEAN_029	10-Sep-16	STR	27.86587	-175.73026	24.7	–	1
PHR_OCEAN_030	10-Sep-16	STR	27.86691	-175.73350	14.3	–	1
PHR-54	11-Sep-16	ARMS	27.79316	-175.99722	14.3	3	3
PHR-54	11-Sep-16	BMU	27.79316	-175.99722	14.3	4	5
PHR-54	11-Sep-16	CAU	27.79316	-175.99722	14.3	4	5
PHR_OCEAN_027	11-Sep-16	STR	27.79317	-175.99710	14.3	1	–
PHR_OCEAN_028	11-Sep-16	STR	27.79585	-176.00852	24.7	1	–
PHR_OCEAN_054	11-Sep-16	STR	27.79233	-175.99158	4.9	1	–
PHR_OCEAN_027	11-Sep-16	STR	27.79317	-175.99710	14.3	–	1
PHR_OCEAN_028	11-Sep-16	STR	27.79585	-176.00852	24.7	–	1
PHR_OCEAN_054	11-Sep-16	STR	27.79233	-175.99158	4.9	–	1

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

Belt-transect surveys were conducted and photographs were taken along transect lines at 20 REA sites around Pearl and Hermes Atoll to assess benthic composition, coral community structure, and coral and algal disease; water samples for microbial analyses were collected at 4 sites (Fig. E.2.1 and Table E.2.1). For more information about collections made at REA sites, see Table F.1.1 in Appendix F: "Biological Collections."

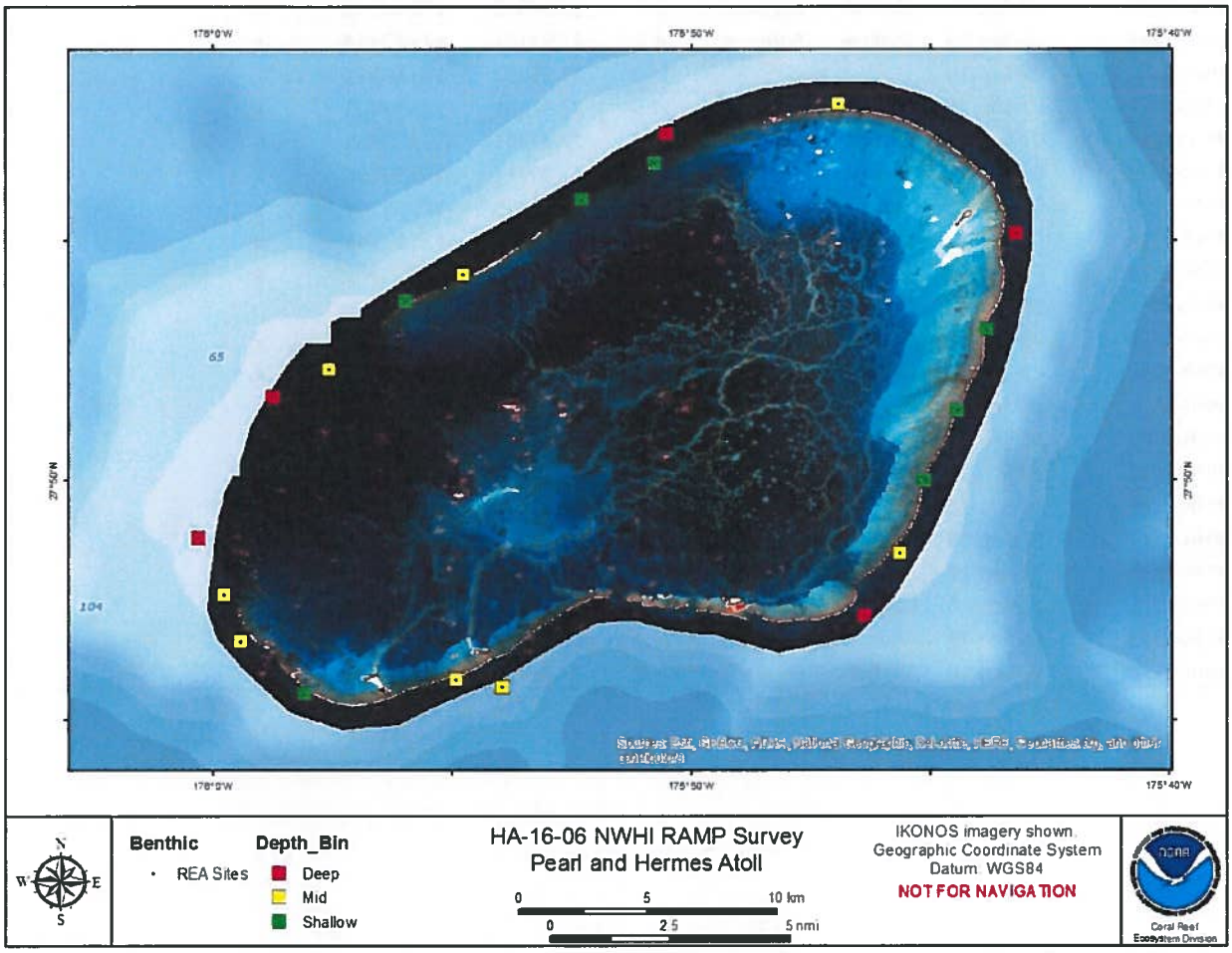

Figure E.2.1.--Locations of benthic REA sites surveyed at Pearl and Hermes Atoll during cruise HA-16-06. All of these REA sites were selected using a stratified random design.

Table E.2.1.--Summary of the Benthic REA surveys and microbial water collections performed at Pearl and Hermes Atoll during cruise HA-16-06.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude	Coral REA Survey	Microbial Samples
PHR-52	06-Sep-16		Forereef	13.9	27.94055	-175.86165		x
PHR-1024	06-Sep-16	Deep	Forereef	24.2	27.95412	-175.84234	x	
PHR-1066	06-Sep-16	Mid	Forereef	12.1	27.96440	-175.78211	x	
PHR-1121	06-Sep-16	Shallow	Forereef	5.2	27.94385	-175.84631	x	
PHR-1129	06-Sep-16	Shallow	Forereef	4.5	27.93137	-175.87164	x	
PHR-53	07-Sep-16			15.2	27.95493	-175.83582		x
PHR-1022	07-Sep-16	Deep	Forereef	27.3	27.86261	-175.97905	x	
PHR-1064	07-Sep-16	Mid	Forereef	14.5	27.87231	-175.95955	x	
PHR-1139	07-Sep-16	Shallow	Forereef	4.5	27.89574	-175.93296	x	
PHR-1071	07-Sep-16	Mid	Forereef	10.9	27.90525	-175.91299	x	
PHR-1095	08-Sep-16	Mid	Forereef	9.7	27.76398	-175.91548	x	
PHR-1075	08-Sep-16	Mid	Forereef	16.1	27.76140	-175.89942	x	
PHR-50	09-Sep-16		Forereef	15.2	27.78237	-175.88195		x
PHR-1020	09-Sep-16	Deep	Forereef	22.7	27.78606	-175.77295	x	
PHR-1097	09-Sep-16	Mid	Forereef	15.2	27.80817	-175.76072	x	
PHR-51	10-Sep-16		Forereef	14.8	27.86679	-175.73358		x
PHR-1045	10-Sep-16	Deep	Forereef	20.6	27.91951	-175.72029	x	
PHR-1122	10-Sep-16	Shallow	Forereef	4.8	27.88620	-175.73035	x	
PHR-1124	10-Sep-16	Shallow	Forereef	4.2	27.85766	-175.74054	x	
PHR-1117	10-Sep-16	Shallow	Forereef	4.8	27.83360	-175.75197	x	
PHR-1033	11-Sep-16	Deep	Forereef	19.7	27.81351	-176.00518	x	
PHR-1076	11-Sep-16	Mid	Forereef	12.7	27.79347	-175.99641	x	
PHR-1093	11-Sep-16	Mid	Forereef	12.7	27.77751	-175.99067	x	
PHR-1138	11-Sep-16	Shallow	Forereef	4.8	27.75924	-175.96786	x	

Additionally, during the HA-16-06 cruise, 31 towed-diver surveys were completed around Pearl and Hermes Reef, covering a total length of 74.8 km (an area of 74.8 ha) of the ocean floor (Fig. E.2.2).

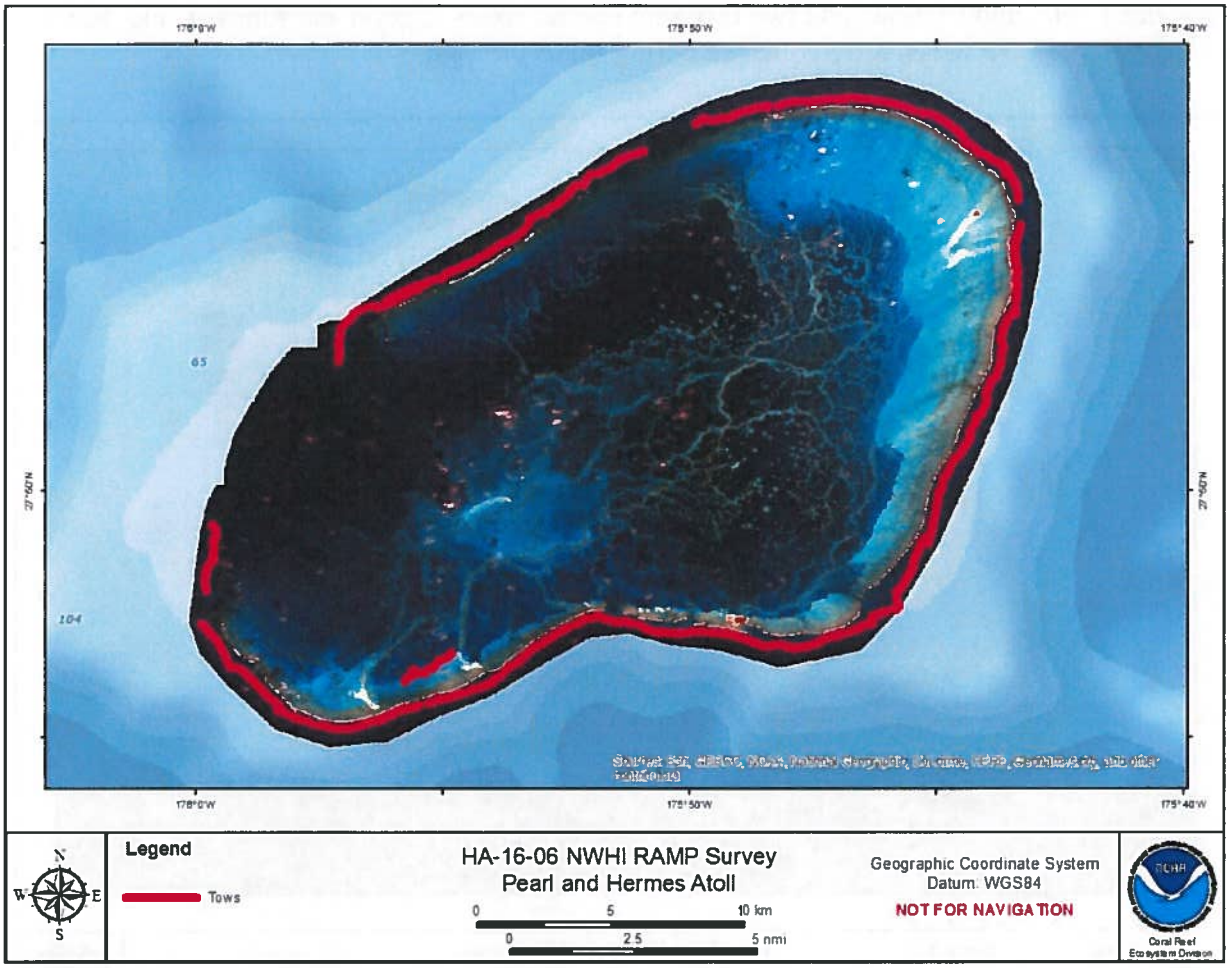

Figure E.2.2.--Track locations of towed-diver surveys conducted at Lisianski during the cruise HA-16-06.

E.3. Biological Monitoring: Reef Fish Community

Fish REA survey sites were chosen using a stratified random design. Stationary-point-count surveys were conducted at 56 REA sites at French Frigate Shoals over three different depth strata: deep, mid, and shallow; and two different habitat zones: lagoon and forereef (Fig. E.3.1 and Table E.3.1). No fishes were collected during these surveys.

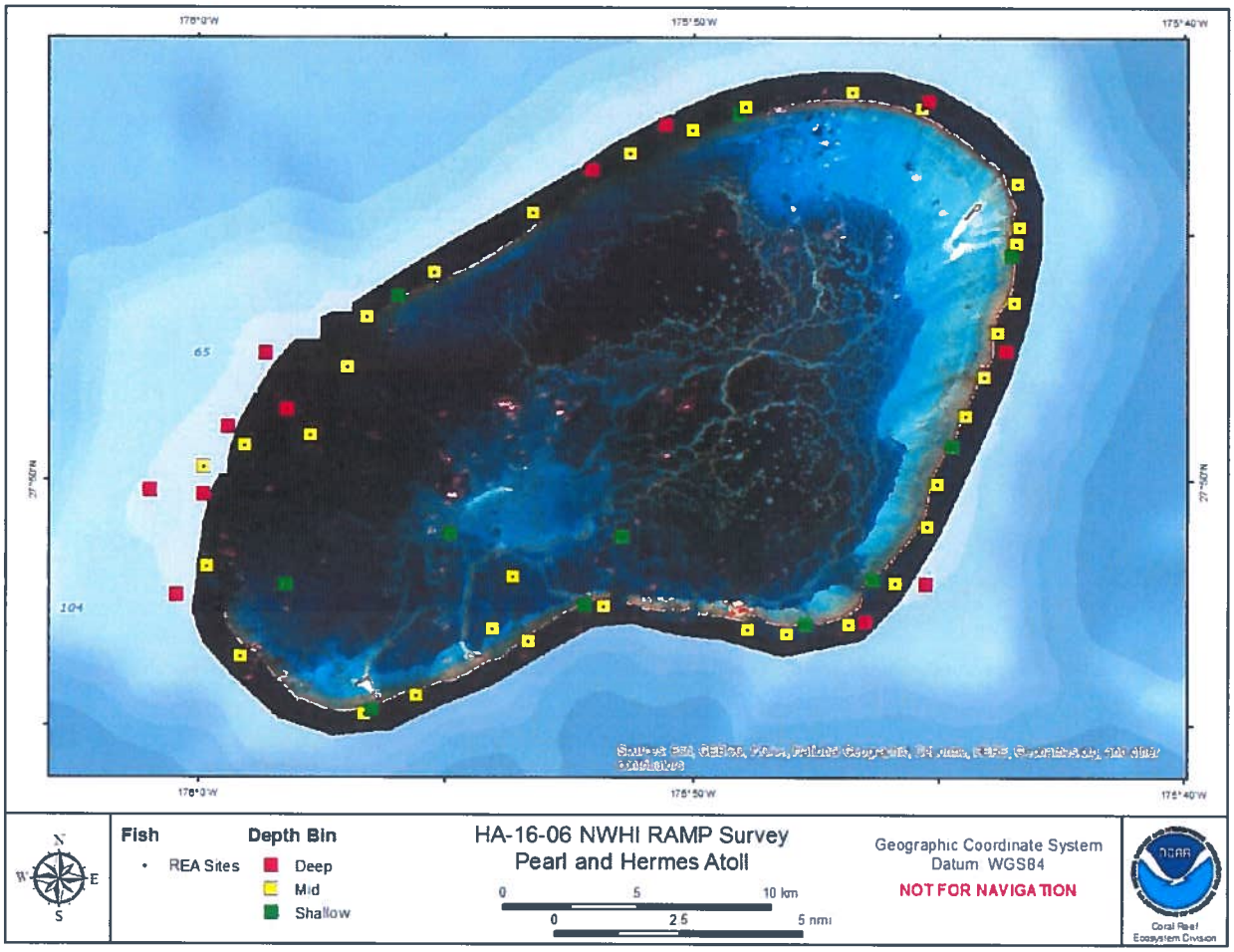

Figure E.3.1.--Locations of Fish REA sites surveyed at Pearl and Hermes Atoll during cruise HA-16-06. All of these REA sites were selected using a stratified random design.

Table E.3.1.--Summary of sites where Fish REA surveys were conducted at Pearl and Hermes during cruise HA-16-06.

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
PHR-773	06-Sep-16	Deep	Forereef	22.4	27.93865	-175.86769
PHR-779	06-Sep-16	Deep	Forereef	23.5	27.95400	-175.84285
PHR-783	06-Sep-16	Deep	Forereef	18.3	27.96185	-175.75382
PHR-823	06-Sep-16	Mid	Forereef	12.8	27.95937	-175.75585
PHR-827	06-Sep-16	Mid	Forereef	9.1	27.95214	-175.83367
PHR-828	06-Sep-16	Mid	Forereef	14.3	27.96513	-175.77922
PHR-829	06-Sep-16	Mid	Forereef	15.5	27.95998	-175.81595
PHR-834	06-Sep-16	Mid	Forereef	12.7	27.94434	-175.85492
PHR-862	06-Sep-16	Shallow	Forereef	4.8	27.95736	-175.81747
PHR-790	07-Sep-16	Deep	Forereef	25.7	27.87657	-175.97706
PHR-792	07-Sep-16	Deep	Forereef	25.0	27.85142	-175.98996
PHR-804	07-Sep-16	Mid	Forereef	15.2	27.92392	-175.88703
PHR-814	07-Sep-16	Mid	Forereef	15.9	27.90384	-175.92040
PHR-817	07-Sep-16	Mid	Forereef	8.5	27.87193	-175.94978
PHR-818	07-Sep-16	Mid	Forereef	9.5	27.88844	-175.94330
PHR-848	07-Sep-16	Deep	Forereef	20.0	27.85747	-175.97017
PHR-850	07-Sep-16	Mid	Forereef	17.8	27.84867	-175.96213
PHR-875	07-Sep-16	Shallow	Forereef	4.2	27.89601	-175.93276
PHR-803	08-Sep-16	Mid	Forereef	15.9	27.75398	-175.94428
PHR-811	08-Sep-16	Mid	Lagoon	8.7	27.78285	-175.90045
PHR-841	08-Sep-16	Mid	Forereef	12.8	27.76034	-175.92652
PHR-843	08-Sep-16	Mid	Forereef	15.9	27.79049	-175.86345
PHR-849	08-Sep-16	Mid	Forereef	11.5	27.77881	-175.88856
PHR-857	08-Sep-16	Shallow	Lagoon	4.3	27.81427	-175.85710
PHR-858	08-Sep-16	Mid	Lagoon	7.0	27.80081	-175.89359
PHR-868	08-Sep-16	Shallow	Forereef	6.3	27.75563	-175.94168
PHR-880	08-Sep-16	Shallow	Forereef	3.2	27.79086	-175.86969
PHR-781	09-Sep-16	Deep	Forereef	22.4	27.78536	-175.77484
PHR-786	09-Sep-16	Deep	Forereef	20.5	27.79821	-175.75444
PHR-795	09-Sep-16	Mid	Forereef	17.0	27.78465	-175.78034
PHR-801	09-Sep-16	Mid	Forereef	13.7	27.81768	-175.75404
PHR-809	09-Sep-16	Mid	Forereef	14.2	27.79866	-175.76492
PHR-831	09-Sep-16	Mid	Forereef	8.5	27.78142	-175.80128
PHR-838	09-Sep-16	Mid	Forereef	14.8	27.78290	-175.81435
PHR-873	09-Sep-16	Shallow	Forereef	4.6	27.79977	-175.77216
PHR-876	09-Sep-16	Mid	Forereef	8.7	27.83189	-175.75062
PHR-878	09-Sep-16	Shallow	Forereef	5.2	27.78422	-175.79513
PHR-774	10-Sep-16	Deep	Forereef	23.9	27.87710	-175.72717
PHR-806	10-Sep-16	Mid	Forereef	12.5	27.93377	-175.72330
PHR-807	10-Sep-16	Mid	Forereef	12.8	27.91910	-175.72289
PHR-822	10-Sep-16	Mid	Forereef	13.6	27.89393	-175.72457
PHR-836	10-Sep-16	Mid	Forereef	10.4	27.85516	-175.74086
PHR-852	10-Sep-16	Mid	Forereef	15.2	27.91346	-175.72389
PHR-867	10-Sep-16	Shallow	Forereef	4.6	27.90962	-175.72498
PHR-869	10-Sep-16	Mid	Forereef	10.4	27.88370	-175.73011

REA Site	Date	Depth Bin	Reef Zone	Depth (m)	Latitude	Longitude
PHR-872	10-Sep-16	Shallow	Forereef	4.8	27.84469	-175.74541
PHR-877	10-Sep-16	Mid	Forereef	8.8	27.86840	-175.73458
PHR-775	11-Sep-16	Deep	Forereef	19.5	27.82833	-175.99821
PHR-780	11-Sep-16	Deep	Forereef	26.1	27.79424	-176.00722
PHR-791	11-Sep-16	Deep	Forereef	26.4	27.82971	-176.01623
PHR-819	11-Sep-16	Mid	Forereef	14.6	27.77364	-175.98567
PHR-821	11-Sep-16	Mid	Forereef	9.8	27.84516	-175.98438
PHR-833	11-Sep-16	Shallow	Lagoon	5.9	27.81521	-175.91483
PHR-837	11-Sep-16	Mid	Forereef	14.1	27.80417	-175.99738
PHR-846	11-Sep-16	Shallow	Lagoon	5.1	27.79773	-175.97060
PHR-851	11-Sep-16	Mid	Forereef	17.4	27.83794	-175.99836

E.1. Benthic Habitat Mapping

Multibeam mapping surveys at Pearl and Hermes Atoll were conducted using the *Hi'ialakai* EM300 and EM3002D multibeam sonars. The ship conducted multibeam mapping around Pearl and Hermes Atoll on 6 September, 8 September, and 10 September 2016. Deep sonar multibeam mapping was conducted on September 6, 2016 on the north side of Pearl and Hermes. Shallow sonar multibeam crossline mapping was conducted on 8 September 2016, inside of the survey planned area. Then on 10 September 2016, deep sonar crossline mapping was conducted on the west side of Pearl and Hermes from north to south during a transit.

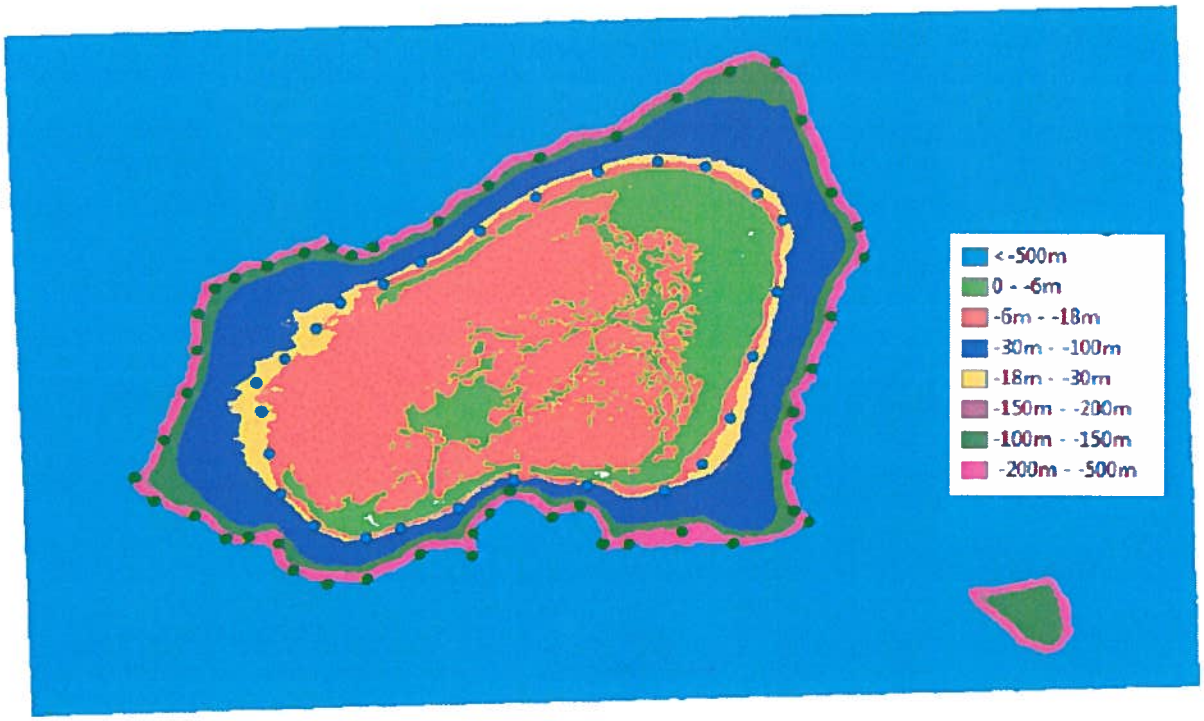

Figure E.4.1.--Image of multibeam planning map with 30-m and 150-m boundary points overlaid on depth bin separated interpolated multibeam for Pearl and Hermes Atoll.

APPENDIX F: BIOLOGICAL COLLECTIONS

Biological samples were collected at French Frigate Shoals, Pearl and Hermes Atoll, Kure Atoll, and Lisianski Island, and their surrounding waters for multiple research purposes. A complete listing of these collections is presented here in Table F.1.1.

Table F.1.--Biological samples collected at French Frigate Shoals (FFS), Pearl and Hermes Atoll (PHR), Kure Atoll (KUR), and Lisianski Island and Neva Shoal (LIS) during cruise HA-16-06.

Site	Date	Latitude	Longitude	Sample Collected	Number of Samples	Depth (m)
Microbial Collections: Water Samples						
FFS-40	01-Sep-16	23.63686	-166.18515	2 L	2	14.6
FFS-41	02-Sep-16	23.79247	-166.25372	2 L	3	21.3
FFS-42	25-Sep-16	23.87806	-166.29100	2 L	3	16.8
FFS-1394	27-Sep-16	23.77460	-166.19873	2 L	3	10.7
KUR-52	12-Sep-16	28.38506	-178.34087	2 L	3	15.8
KUR-52	12-Sep-16	28.38506	-178.34087	20 L	0.5	15.8
KUR-51	13-Sep-16	28.40908	-178.37808	2 L	3	15.2
KUR-51	13-Sep-16	28.40908	-178.37808	20 L	0.5	15.2
KUR-53	14-Sep-16	28.45290	-178.34706	2 L	3	17.4
KUR-53	14-Sep-16	28.45290	-178.34706	20 L	0.5	17.4
KUR-54	15-Sep-16	28.43037	-178.28523	2 L	3	18.6
KUR-54	15-Sep-16	28.43037	-178.28523	20 L	0.5	18.6
LIS-52	17-Sep-16	25.93495	-173.89090	2 L	3	18.3
LIS-52	17-Sep-16	25.93495	-173.89090	20 L	0.5	18.3
LIS-50	18-Sep-16	26.03741	-173.87918	2 L	3	18.3
LIS-50	18-Sep-16	26.03741	-173.87918	20 L	0.5	18.3
LIS-50	19-Sep-16	26.03741	-173.87918	2 L	3	15.2
LIS-50	19-Sep-16	26.03741	-173.87918	20 L	0.5	15.2
LIS-54	20-Sep-16	25.98702	-173.99438	2 L	2.5	11.0
LIS-54	20-Sep-16	25.98702	-173.99438	20 L	0.5	11.0
PHR-52	06-Sep-16	27.94055	-175.86165	2 L	3	14.0
PHR-52	06-Sep-16	27.94055	-175.86165	20 L	0.5	14.0
PHR-50	09-Sep-16	27.78237	-175.88195	2 L	3	14.6
PHR-50	09-Sep-16	27.78237	-175.88195	20 L	0.5	14.6
PHR-51	10-Sep-16	27.86679	-175.73358	2 L	3	14.9
PHR-51	10-Sep-16	27.86679	-175.73358	20 L	0.5	14.9
Coral Collections: Microbial Coral/Algal Biopsies						
FFS-41	03-Sep-16	23.79247	-166.25372	Cubic Centimeter	1	6.4
FFS-42	25-Sep-16	23.87806	-166.29100	Cubic Centimeter	1	15.2
KUR-51	13-Sep-16	28.40908	-178.37808	Cubic Centimeter	1	15.2
KUR-53	14-Sep-16	28.45290	-178.34706	Cubic Centimeter	1	17.4
KUR-54	15-Sep-16	28.43037	-178.28523	Cubic Centimeter	1	18.6
LIS-52	17-Sep-16	25.93495	-173.89090	Cubic Centimeter	1	18.3
LIS-50	18-Sep-16	26.03741	-173.87918	Cubic Centimeter	1	18.3
LIS-50	19-Sep-16	26.03741	-173.87918	Cubic Centimeter	1	18.3

Site	Date	Latitude	Longitude	Sample Collected	Number of Samples	Depth (m)
LIS-54	20-Sep-16	25.98702	-173.99438	Cubic Centimeter	1	11.0
PHR-52	06-Sep-16	27.94055	-175.86165	Cubic Centimeter	1	14.0
PHR-53	07-Sep-16	27.95493	-175.83582	Cubic Centimeter	1	15.2
PHR-50	09-Sep-16	27.78237	-175.88195	Cubic Centimeter	1	14.6
PHR-51	10-Sep-16	27.86679	-175.73358	Cubic Centimeter	1	14.9
Algal Collections: Ocean Acidification						
FFS-40	01-Sep-16	23.63686	-166.18515	BMU UNIT	4	14.3
FFS-40	01-Sep-16	23.63686	-166.18515	CAU UNIT	5	14.3
FFS-41	02-Sep-16	23.79247	-166.25372	BMU UNIT	4	12.5
FFS-41	02-Sep-16	23.79247	-166.25372	CAU UNIT	5	12.5
PHR-52	06-Sep-16	27.94055	-175.86165	BMU UNIT	4	14.3
PHR-52	06-Sep-16	27.94055	-175.86165	CAU UNIT	5	14.3
PHR-53	07-Sep-16	27.95493	-175.83582	BMU UNIT	3	14.3
PHR-53	07-Sep-16	27.95493	-175.83582	CAU UNIT	3	14.3
PHR-50	09-Sep-16	27.78237	-175.88195	BMU UNIT	5	14.3
PHR-50	09-Sep-16	27.78237	-175.88195	CAU UNIT	5	14.3
PHR-51	10-Sep-16	27.86679	-175.73358	BMU UNIT	5	14.3
PHR-51	10-Sep-16	27.86679	-175.73358	CAU UNIT	5	14.3
PHR-54	11-Sep-16	27.79316	-175.99722	BMU UNIT	4	14.3
PHR-54	11-Sep-16	27.79316	-175.99722	CAU UNIT	4	14.3
KUR-52	12-Sep-16	28.38506	-178.34087	CAU UNIT	2	14.3
KUR-51	13-Sep-16	28.40908	-178.37808	CAU UNIT	2	14.9
KUR-53	14-Sep-16	28.45290	-178.34706	CAU UNIT	2	14.3
KUR-54	15-Sep-16	28.43037	-178.28523	CAU UNIT	3	14.3
LIS-52	17-Sep-16	25.93495	-173.89090	CAU UNIT	5	16.8
LIS-53	17-Sep-16	25.93831	-173.95396	CAU UNIT	5	16.8
LIS-50	18-Sep-16	26.03741	-173.87918	CAU UNIT	5	16.8
LIS-51	19-Sep-16	26.07842	-173.99699	CAU UNIT	5	14.6
LIS-54	20-Sep-16	25.98702	-173.99438	CAU UNIT	5	14.6
FFS-44	24-Sep-16	23.83515	-166.11682	BMU UNIT	2	16.2
FFS-44	24-Sep-16	23.83515	-166.11682	CAU UNIT	1	16.2
FFS-42	25-Sep-16	23.87806	-166.29100	BMU UNIT	4	16.8
FFS-43	25-Sep-16	23.88021	-166.27707	BMU UNIT	2	16.8
FFS-42	25-Sep-16	23.87806	-166.29100	CAU UNIT	3	16.8
FFS-43	25-Sep-16	23.88021	-166.27707	CAU UNIT	3	16.8
Cryptofauna collections: Autonomous Reef Monitoring Structures						
PHR-52	06-Sep-16	27.94055	-175.86165	ARMS	3	14.3
PHR-50	08-Sep-16	27.78237	-175.88194	ARMS	3	14.3
PHR-51	10-Sep-16	27.86679	-175.73358	ARMS	3	14.3
PHR-54	11-Sep-16	27.79316	-175.99722	ARMS	3	14.3
FFS-40	01-Sep-16	23.63686	-166.18515	ARMS	3	14.3
FFS-41	03-Sep-16	23.79247	-166.25372	ARMS	3	12.5
FFS-44	24-Sep-16	23.83515	-166.11682	ARMS	2	16.2
FFS-42	25-Sep-16	23.87806	-166.29100	ARMS	–	16.8