CRUISE REPORT[1]

VESSEL: *Hi`ialakai*, Cruise 06-04 (Fig. 1)
CRUISE

PERIOD: 15 March-8 April 2006

AREA OF OPERATION: Jarvis Island, Palmyra Atoll, and Kingman Reef National Wildlife Refuges

TYPE OF OPERATION: Personnel from the Coral Reef Ecosystem Division, Pacific Island Fisheries Science Center (PIFSC), National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), plus one each from the U.S. Fish and Wildlife Service (USFWS) and NOAA dive center conducted reef assessment/monitoring and mapping studies in waters surrounding the U.S. Line Islands of Jarvis Island, Palmyra Atoll, and Kingman Reef.

ITINERARY:

15 March

Start of cruise. Embarked Craig Musburger (fish), Todd Wass (fish), Paula Ayotte (fish), Jim Maragos (coral, USFWS), Bernardo Vargas Angel (coral disease), Scott Godwin (invertebrates), Aline Tribollet (algae), Bonnie DeJoseph (algae), Amy Hall (towed-diver survey/fish), Edmund Coccagna (towed-diver survey /fish), Molly Timmers (towed-diver survey /habitat), Eric Dobbs (towed-diver survey /habitat), Kyle Hogrefe (oceanography), Daniel Merritt (oceanography), Charles Young (oceanography), Kevin Lino (oceanography), Scott Ferguson (mapping), Jeremy Jones (mapping), Emily Lundblad (mapping), Jonathan Weiss (mapping), Stephane Charette (divemaster) and Jim Bostick (chamber operator, NDC). Departed Pago Pago at 0930, en route for Jarvis Island. An introductory meeting was held for all scientific personnel and new crew members at 1300. During a fire drill, Third Assistant Engineer Ric Gabona was injured, losing a portion of his thumb. At 1430 the ship diverted back to Pago Pago. At 1800 the scientific party conducted a planning meeting to discuss operations at Jarvis Island. At 1845 Gabona

[1] PIFSC Cruise Report CR-06-020
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was transferred ashore in a small boat, along with Executive Officer LT Matt Wingate and Medical Officer LT Mike Futch. The ship stood by outside the entrance buoy. Ric Gabona was treated and sent to Honolulu for further care. At 2230 the small boat was recovered and the vessel departed for Jarvis Island.

16 March — Transit day. At 1000 conducted dive safety meeting. Conducted man-overboard drill. At 1800 the scientific party conducted a planning meeting to discuss operations at Palmyra Atoll. Acoustic Doppler current profiler (ADCP) data are being collected during the transits between islands.

17 March — Transit day.

18 March — Transit day. At 1800 the scientific party conducted a planning meeting to discuss operations at Kingman Reef.

19 March — Transit day.

20 March — Arrived at Jarvis Island at 0500 to begin field operations. The REA teams occupied three established sites on the north side of the island (JAR-9, JAR-8, and JAR-1). The towed-diver survey team completed six tows, circumnavigating the island. The oceanography team recovered and replaced one ocean data platform (ODP), recovered and replaced two subsurface temperature recorders (STRs) and deployed two new STRs and deployed a new sea surface temperature (SST) at the site of the one deployed in 2004 that later went adrift. The Acoustic Habitat Investigator (*AHI)* mapped 10- to 300-m depths around the island. Shipboard mapping began after all small boats were onboard, working in depths from about 400 m to 2700 m.

21 March — Continued working at Jarvis. The rapid ecological assessment (REA) teams occupied three established sites on the south side of the island (JAR-10, JAR-4P, and JAR-2). The last site was cut short when a large manta ray cut the line to the surface float; only one transect was completed before the dive was terminated. The towed-diver survey team completed four tows and conducted one invertebrate collection dive. The oceanography team recovered and replaced two STRs and deployed two new STRs, conducted two 30-m conductivity-temperature-depth (CTD) casts and two 200-m CTD casts and performed one water quality profile at a 30-m cast site during which eight water samples were taken to be later analyzed for chlorophyll (four samples) and nutrient (four samples) content. The *AHI* completed mapping the east bank and thereafter supported the oceanography team. Shipboard mapping

was conducted during the day to cover areas close to the island which were deeper than the *AHI* can map. During the night the ship conducted two 300-m and six 500-m CTD/water quality casts during which ninety-six water samples were taken to be later analyzed for chlorophyll (48 samples) and nutrient (48 samples) content.

22 March — Continued working at Jarvis. The REA teams established one new site (JAR-12) on the south side and occupied two established sites on the northwestern side of the island (JAR-7P and JAR-11P). The towed-diver survey team conducted two tows and conducted one dive for invertebrate collection and two dives to assist in coral assessment surveys. The oceanography team conducted 35 30-m CTD casts with 17 water quality profiles being conducted during which 142 water samples were taken to be later analyzed for nutrient (71 samples) and chlorophyll (71 samples) content. The *AHI* conducted eight 30-m and eight 200-m CTDs. The ship departed for Palmyra after all small boats were recovered.

23 March — Transit day. Conducted collision and abandon ship drills. ADCP data are being collected during the transits between islands.

24 March — Arrived at Palmyra Atoll at 0500 to begin field operations. The REA teams occupied three established sites on the south side of the island (PAL-25, PAL-10P and PAL-19). The towed-diver survey team completed six tows around the edge of the western bank and south of the island. The oceanography team installed a 2-MHz inverted ADCP in the channel to the west lagoon at a depth of 8 m. A string of temperature recorders was deployed nearby with recorders positioned at depths of 1, 3, and 6 m. One STR was recovered and replaced in the same location. An SST was deployed in the east lagoon along with three STRs located nearby at 5, 16 and 26 m. The STRs are attached to the SST anchor by a long line because of poor visibility at the site. Twelve 30-m CTD casts were taken with four water quality profiles conducted during which 32 water samples were taken to be later analyzed for chrlorophyll (16 samples) and nutrient (16 samples) content. The *AHI* mapped the reef along the southern shore in depths between 10 and 300 m. At night the ship mapped the deeper banks around the atoll.

25 March — Continued working at Palmyra Atoll. The REA teams occupied three established sites on the west side of the island (PAL-26, PAL-11 and PAL-5). The towed-diver survey team completed six tows in the lagoon and along the north side of the island. The oceanography team recovered an existing Coral Reef Early

Warning System (CREWS) buoy and replaced it with a refurbished unit replacing both the 540 kg anchor and recruitment plate array. In addition one STR was installed on the CREWS buoy anchor and two 8-m CTD casts were conducted near the buoy to gauge temperature and salinity drift in the buoy's sensors. The *AHI* mapped the reef along the northern shore in depths between 10 and 300 m. At night the ship mapped the deeper banks around the atoll.

26 March — Continued working at Palmyra Atoll. Bad weather delayed the start of operations until 1030. The REA teams occupied two established sites on the south side of the island (PAL-9 and PAL-1). The towed-diver survey team completed three tows around the south of the island. The oceanography team recovered two STRs and replaced them with two new ones. Ten 30-m CTD casts were conducted during which two water quality profiles were performed collecting 16 water samples for later analysis of chlorophyll (8 samples) and nutrient (8 samples) content. The *AHI* mapped the western portion of Palmyra Lagoon. At night the ship ran an 87-km ADCP box transect around the atoll. Four 500-m CTD/water quality casts were conducted during which 48 water samples were taken for later analysis of chlorophyll (24 samples) and nutrient (24 samples) content.

27 March — Continued working at Palmyra Atoll. The REA teams occupied established sites on the north side of the atoll (PAL-20, PAL-12 and PAL-21). The towed-diver survey team completed three tows around the north side of the island but ran into problems when the habitat camera housing flooded on the third tow destroying the photographic record for all tows. After the cameras were removed the housings were tested to ensure they were not leaking. Oceanography recovered and replaced one STR and deployed one new STR. Twenty-five 30-m CTD casts were conducted during which four water quality profiles were performed collecting 32 water samples for later analysis of chlorophyll (16 samples) and nutrient (16 samples) content. The *AHI* mapped the middle lagoon and started mapping the western bank. At night the ship mapped the deeper banks around the atoll.

28 March — Continued working at Palmyra Atoll. The REA teams occupied two established sites on the west and east sides of the atoll (PAL-16P and PAL-15P) and snorkeled at the longliner wreck, site PAL-6. The towed- diver survey team completed three tows around the western side of the island. Oceanography conducted fourteen 30-m CTD casts, during which two water quality profiles were performed collecting 16 water samples for later analysis of

chlorophyll (8 samples) and nutrient (8 samples) content. They also retrieved the inverted ADCP and the string of temperature recorders from in the channel. The *AHI* mapped portions of the western bank. Five 500-m CTD/water quality casts were conducted from the ship along an east/west transect to the west of the atoll at a 1.8-km interval, from which 60 water samples were taken for later analysis of chlorophyll (30 samples) and nutrient (30 samples) content. Departed for Kingman Reef.

29 March — Arrived at Kingman Reef at 0530 to begin field operations. The REA teams occupied established sites on the southern outer reef (KIN-11, KIN-17 and KIN-13). The towed-diver survey team completed five tows on the northeastern forereef and conducted one invertebrate collection dive. The oceanography team recovered and replaced one SST buoy, four STRs, and one recruitment plate array which was/is installed on the CREWS anchor that remains near the SST site. Additionally they installed a 2-MHz inverted ADCP in the La Paloma channel. The *AHI* mapped along the south inner and outer reef. At night the ship mapped the deeper banks around the reef.

30 March — Continued operations at Kingman Reef. The REA teams occupied established sites on the northeast outer and inner reef (KIN-4, KIN-10 and KIN-8). The towed-diver survey team completed five tows on the south forereef and backreef and one conducted one invertebrate collection dive. The oceanography team recovered and replaced one STR and installed a second STR in a new location. They also conducted twenty-one 30-m CTD casts during which 4 water quality profiles were performed collecting 32 water samples to be later analyzed for chlorophyll (16 samples) and nutrient (16 samples) content. They also conducted one invertebrate collection dive. The *AHI* mapped along the outside of the southern and western reefs. At night the ship mapped the deeper banks around the reef.

31 March — Continued operations at Kingman Reef. The REA teams occupied established sites on the southern backreef and lagoon interior (KIN-7, KIN-19 and KIN-12). The towed-diver survey team completed five tows on the northeast backreef and conducted one invertebrate collection dive. The oceanography team conducted thirty 30-m CTD casts during which 6 water quality profiles were performed collecting 48 water samples to be later analyzed for chlorophyll (24 samples) and nutrient (24 samples) content. The *AHI* mapped along the outside of the northeastern forereef and northwestern reef crest. At night the ship ran a 74-km ADCP box transect around the reef and conducted four 500-m CTD/water

	quality casts during which 48 water samples were taken to be later analyzed for chlorophyll (24 samples) and nutrient (24 samples) content.
1 April	Continued operations at Kingman Reef. The weather was calm at first but built during morning. At 1115 the ship recalled all the boats for the day. Before that time the REA teams occupied one established site on a patch reef in the lagoon (KIN-15). The towed-diver survey team completed three tows along the south backreef. The oceanography team conducted nine 30-m CTD casts during which two water quality profiles were performed collecting 16 water samples for later analysis of chlorophyll (8 samples) and nutrient (8 samples) content. The *AHI* mapped along the outside of the northwestern reef crest and western interior. After the boats were recovered the ship mapped the deeper banks around the reef.
2 April	Continued operations at Kingman Reef. The REA teams occupied established sites in the southeast portion of the lagoon (KIN-3, KIN-5P and KIN-16P). The towed-diver survey team completed four tows along the southeastern backreef and in the lagoon pool. The team also conducted two invertebrate collection dives. The oceanography team installed one new STR and conducted thirteen 30-m CTD casts during which two water quality profiles were performed collecting 16 water samples for later analysis of chlorophyll (8 samples) and nutrient (8 samples) content. The *AHI* mapped along the northwestern backreef and completed several survey lines across the central lagoon. After the boats were recovered the ship mapped the deeper banks around the reef.
3 April	Continued operations at Kingman Reef. The weather was marginal with winds in excess of 20 knots. The REA teams occupied existing station (KIN-21) and two new stations (KIN-22 and KIN23); the latter two dives were qualitative species inventory dives. The towed-diver survey team conducted four invertebrate collection dives. The oceanography team recovered the ADCP deployed on 29 March and conducted two invertebrate collection dives. The *AHI* was not deployed becaue of concerns that the weather would deteriorate further making recovery dangerous. At 1630 the ship began transiting to Hawaii.
4 – 6 April	Transit days. Cruise reported development, data analysis, and equator crossing ceremonies.
7 April	Arrived at Penguin Bank at 1445 to begin ship-based mapping operations. Mapping continued through the night to define the 100-m isobath of the western portion of the bank.

8 April — Continued operations at Penguin Bank. At 1130 the ship began transiting to Honolulu. Arrived Honolulu. Disembarked Musburger, Wass, Ayotte, Maragos, Vargas Angel, Godwin, Tribollet, DeJoseph, Hall, Coccagna, Timmers, Dobbs, Hogrefe, Merritt, Young, Lino, Ferguson, Jones, Lundblad, Weiss, Charette, and Bostick

Table 1: Cruise statistics for Jarvis Island and the U.S. Line Islands.

	Jarvis Island	Palmyra Atoll	Kingman Reef
Towed-Diver Habitat/Fish Surveys	12	18	22
Combined tow lengths (km)	24.24	42.40	52.35
Fish Rapid Ecological Assessments	9	13	16
Benthic Rapid Ecological Assessments	9	13	16
Ocean Data Platforms (ODP) Recovered	1	-	-
Ocean Data Platforms (ODP) Deployed	1	-	-
SST buoys recovered	-	-	1
SST buoys deployed	1	1	1
STRs recovered	4	4	5
STRs deployed	8	9	7
CREWS buoys recovered	-	1	-
CREWS buoys deployed	-	1	-
Small vessel CTDs (33-m max)	45	63	73
Small vessel CTDs (200-m max)	12	6	5
Small vessel water quality profiles (30-m max) taken - 1 profile consists of chlorophyll and nutrient samples at 1 to 4 depths as depth allows.	18	12	14
Shipboard CTDs (500-m max)	10	12	7
Shipboard water quality profiles (1 profile consists of chlorophyll and nutrient samples at 6 depths.)	8	9	4
Nutrient Samples – total	123	102	80
Cholorophyll Samples – total	123	102	80
ADCP lines run, km	-	87	74
Multibeam mapping (sq. km)	316	1082	926
Scuba dives	120	175	217

MISSIONS AND RESULTS:

A. Conduct ecosystem monitoring of the species composition, abundance, percent cover, size distribution, and general health of the fish, corals, other invertebrates, and algae of the shallow water (<35 m) coral reef ecosystems of Jarvis Island, Palmyra Atoll, and Kingman Reef.

1. Continued the monitoring of coral reef habitats of Jarvis, Palmyra, and Kingman during this cruise. The process included the selection of long-term monitoring sites based on a rigorous coverage of the range of habitats present and their representative fish, coral, invertebrates and algae faunas, and the high probability of year-round access to the site. A list of sites was selected and refined during the course of the cruise. Both the fish and benthic survey teams participated in this monitoring effort occupying 52 stations. At each site a complete fish and benthic survey was conducted on the same 25-m transect lines. The fish surveys were conducted along three transect lines, while the benthic survey used two. The benthic survey covers three components of the reef habitat: coral, non-coral invertebrates, and algae. The methodology used to survey those sites is documented in Appendix A.3. Survey summaries and Descriptions of sites visited at Jarvis Island, Palmyra Atoll, and Kingman Reef are included within the Benthic Environment and Fish sections of Appendices B, C, and D, respectively.

2. Towed-diver survey methods were used to provide a general description of reef habitat, invertebrates, and reef fishes over a large spatial scale. This method, described in Appendix A.4, allows monitoring large-scale disturbances and general distribution and abundance patterns of corals, macroinvertebrates, and reef fishes over 50 cm total length. The initial summaries of these data are integrated into the Benthic Environment and Fish sections.

B. Conduct benthic habitat mapping of the reefs and submerged banks surrounding the Jarvis Island, Palmyra Atoll, and Kingman Reef using ship-based and launch-based multibeam echosounders and underwater towed cameras.

1. Mapping from the *Hi'ialakai* and the survey launch R/V *AHI* resulted in the collection of high resolution multibeam bathymetry and backscatter imagery in each of the work areas. The survey methods used are described in Appendix A.1. The waters surrounding Jarvis Island were completely mapped in depths ranging from 4 to 3500 m. Preliminary maps are included in Appendix B.1. At Palmyra Atoll, all of the shelf and slopes ranging from 20 to 3500 m were surveyed. Preliminary maps are included in Appendix C.1. In addition, the western and central lagoon waters deeper than 3 m were surveyed. The eastern lagoon was not accessible and therefore not surveyed. Outside the atoll some areas of the western and eastern banks less than 20 m deep but accessible to the survey launch were not surveyed. At

Kingman Reef all of the seabed slopes from 20 m to 3500 m were surveyed. Preliminary maps are included in Appendix D.1. Approximately 20% of the western reef crest and interior reef was also surveyed but large areas remain to be surveyed.

2. Towed-diver survey methods were used to record video data that will provide data to ground-truth the high-resolution bathymetry and imagery data collected in depths less than 30 m.

C. Deploy an array of CREWS buoys, SST buoys, subsurface Ocean Data Platforms, subsurface wave and tide recorders, and subsurface temperature recorders to allow remote long-term monitoring of oceanographic and environmental conditions affecting coral reef ecosystems of Jarvis Island, Palmyra Atoll, and Kingman Reef.

1. A total of one CREWS Buoy, four Sea Surface Temperature (SST) buoys, one Ocean Data Platform (ODP), 24 Subsurface Temperature Recorders (STR), and one Recruitment Plate Array were deployed during the cruise. In addition to these standard instrument deployments, one Nortec Aquadop ADCP was tested during temporary deployments in the channel at Palmyra Atoll and in the reef pass at the southeast corner of Kingman Atoll and one vertical string of three STRs was also deployed near the ADCP in the Palmyra channel to augment its temperature data. Refer to See Appendix A.2 for a description of methodologies and to Appendices B.2, C.2, and D.2 for summaries of the work conducted at each site. Unless otherwise noted in the itinerary and the appendices, most deployments were replacements of existing instrumentation to assure the continuity of data for the assessment of oceanographic conditions.

2. In addition to these standard deployments an investigation was undertaken using an inverted ADCP to provide an initial understanding of the water volume that is transported in and out of the dredged channel at Palmyra Atoll and La Paloma Channel at Kingman Reef.

D. Collect water samples for analysis of nutrient and chlorophyll levels.

1. Water quality profiles were conducted as a subset of these casts at 44 sites resulting in the collection of 179 nutrient and 179 chlorophyll samples.

E. Conduct shipboard CTDs to a depth of 500 m, shallow water CTDs from small boats to a depth of ~30 m, and shipboard ADCP surveys around reef ecosystems to examine physical and biological linkages supporting and maintaining these island and atoll ecosystems.

1. Throughout the cruise, “small vessel” conductivity, temperature and depth (CTD) casts to a maximum depth of 33 meters, including turbidity

measurements, were performed at 181 sites out of a 6-m SAFE boat. Small vessel CTD casts were made to a maximum depth of 200 meters at 23 sites throughout the cruise with 8 of these casts focused on the effort to study the upwelling at Jarvis Island (ref. below).

2. Shipboard CTD casts/water quality profiles, including dissolved oxygen and chlorophyll concentration measurements, were performed along ADCP transects around Palmyra and Kingman Atolls for a total of two ADCP transects, 19 CTD casts and 13 water quality profiles with a total of 78 chlorophyll and 78 nutrient samples being collected. Additional shipboard CTD casts were performed from the vessel to provide sound velocity profiles to support the mapping effort. These casts will also be analyzed as part of the oceanographic data set.

3. At Jarvis Island, a series of CTD casts were conducted to 1) elucidate the nature of the high frequency (semidiurnal) temperature variability caused by the Equatorial undercurrent impinging on the western side of the island, 2) characterize the nutrient input from this cold-water upwelling into the surface mixed layer, and 3) measure the nearshore nutrient and chlorophyll gradient around the island. This work included a 26-hour high-resolution CTD time-series conducted 2 kilometers off the western side of the island.

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

1. During this cruise, initiated the monitoring of coral and coralline algal diseases in reef habitats of Jarvis, Palmyra, and Kingman. Surveys were conducted in conjunction with the continued long-term monitoring of fish, coral, invertebrates, and algae. The coral disease team participated in this effort occupying 9 sites at Jarvis Island, 13 at Palmyra Atoll, and 16 at Kingman Reef. At each site, quantitative surveys were conducted along the first two transect lines deployed by the fish team. The methodology used is documented in Appendix A.3. Survey summaries and Descriptions of sites visited are included within the Benthic Environment sections of Appendices B, C, and D, respectively.

G. Collect ADCP data during all transits. The ADCP unit shall be configured to collect narrow-band data in 16 meter bins (deepwater mode).

1. ADCP data were collected during all transits, totaling 4430 km of ADCP deepwater transect data.

SCIENTIFIC PERSONNEL:

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Jim Bostick, Chamber Operator, National Oceanic and Atmospheric Administration Dive Center

DATA COLLECTED:

- Quantitative surveys of reef fishes (larger than 25 cm TL) to species level from REA team Stationary Point Counts
- Quantitative surveys of all reef fishes to species level from REA team Belt Transects
- Reef fish species presence records from REA team roving diver surveys
- Digital images of diseased coral
- Quantitative data surveys for coral size class distribution, abundance, and diversity
- Quantitative data surveys for benthic cover, including live coral, dead coral, pavement, sand, macroalgae, crustose coralline algae, and other sessile invertebrates
- Field notes on signs of coral bleaching or disease
- Samples of diseased coral for histopathological analysis
- Digital images from algal photoquadrats
- Algal voucher specimens
- Algal field notes of species diversity and relative abundance
- Acoustic Doppler current profile (ADCP) data
- Conductivity, temperature and depth data including turbidity from small vessel casts Conductivity, temperature and depth data including dissolved oxygen and chlorophyll concentration from on shipboard casts
- Water samples for nutrient analysis – frozen water stored for post-cruise processing.
- Water samples for chlorophyll analysis − filtered with frozen filter stored for post-cruise processing
- Oceanographic data downloaded from previously deployed instrumentation
- Digital images of the benthic habitat from towboard surveys
- Macroinvertebrate counts from towboard surveys
- Quantitative surveys of reef fishes (larger than 50 cm TL) to species level from towboards
- Habitat lineation from towboard surveys
- Benthic composition estimations from towboard surveys

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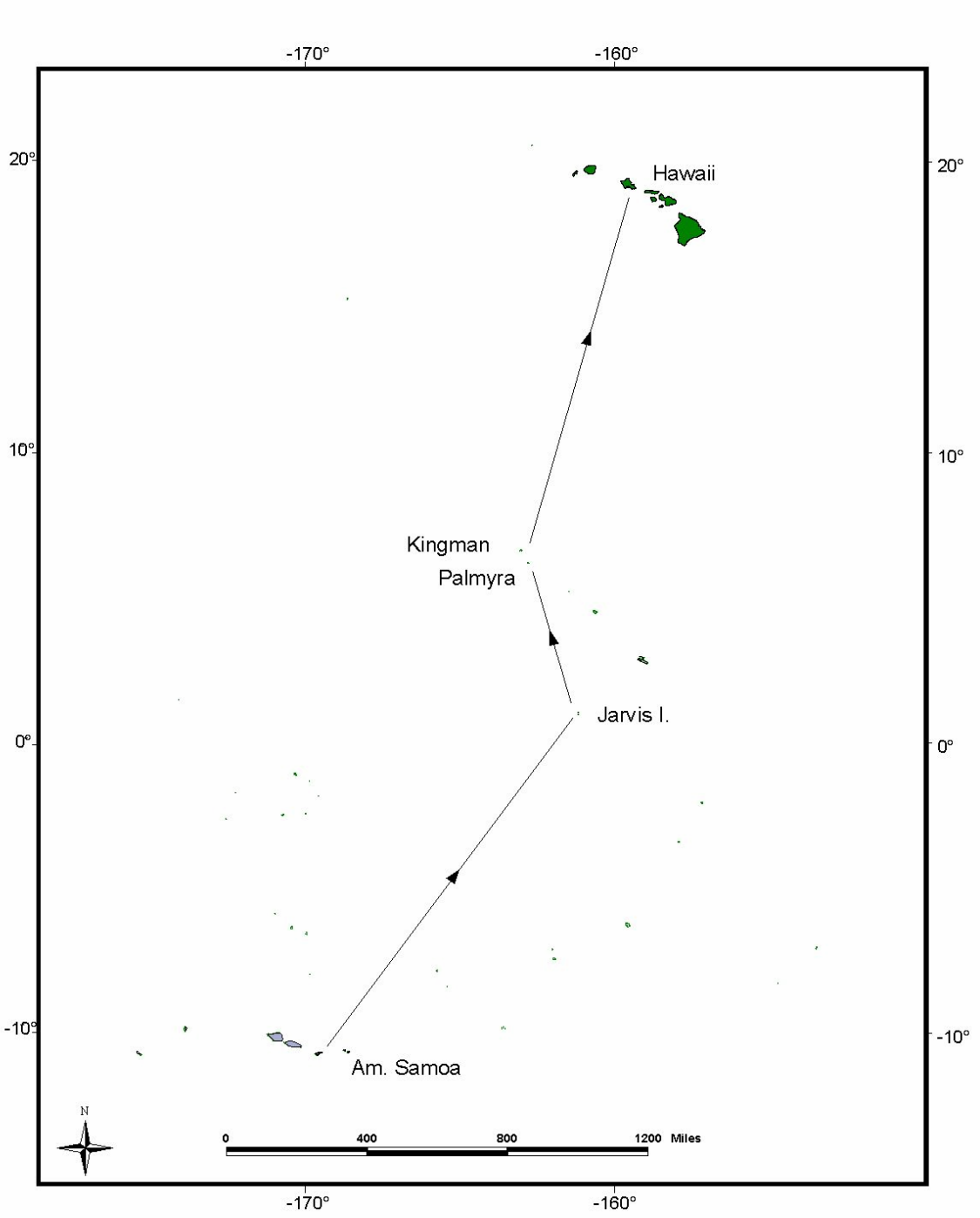


Figure 1. Track of the *Hi`ialakai* HI-06-04, March 15 – April 8, 2006.

Appendix A: Methods

A.1. Benthic Habitat Mapping Methods

(Emily Lundblad, Jeremey Jones, Jonathan Weiss, and Scott Ferguson)

System Descriptions

Multibeam mapping capability for cruise HI0604 included two shipboard multibeam echosounders (Kongsberg EM300 and EM3002D) and the Reson 8101ER multibeam aboard the 8-m launch R/V *Acoustic Habitat Investigator* (*AHI)*. Table A-1 provides an overview of the three multibeam sonars and their capabilities.

Table A-1. HI0501 Sonar Capabilities.

Sonar	Vessel	Freq. (kHz)	Depth Range (m)	Beam Size (deg)	Number of Beams
EM300	*Hi'ialakai*	30	30-3000	1 ½ x 1 ½	135
EM3002D	*Hi'ialakai*	300	2-150	1 x 1	320-508
Reson 8101ER	*AHI*	240	2-250	1 ½ x 1 ½	101

In addition to the multibeam sonars, each vessel was equipped with an Applanix Position Orientation Sensor for Marine Vessels (POS/MV) vertical reference system, which provides timing, position, velocity pitch, roll, heave, and heading information for correction of motion in the multibeam data. Three different 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.

All sensors on both vessels were interfaced to the SAIC ISS-2000 data acquisition and survey control system, which includes survey planning, data acquisition, and data processing capabilities.

Methods for acquisition and post processing

Prior to the HI0604, data were assembled to provide a baseline for acquisition of multibeam data. These data included (1) grids of multibeam bathymetry data from previous cruises to Jarvis, Palmyra and Kingman; (2) IKONOS imagery; (3) predicted tides for stations 1612340 Honolulu and 1617760 Hilo; (4) tide zones corrections (provided by NOAA Center for Operational Oceanographic Products and Services); and (5) preliminary survey plans. These data were integrated into the ISS-2000 software either before or during the first part of the cruise. In addition, existing grids, and tow location data from 2001 to 2004 cruises were assembled and integrated into the Arc 9 Geographic Information System (GIS).

The ISS-2000 survey system is used on both the ship and the launch, enabling seamless sharing of data between the two vessels. The Generic Sensor Format (GSF), which is implemented in the ISS-2000 system, allows logging of multibeam data from a variety of multibeam sonars into a single, standardized format; the GSF also provides integrated

metadata within the real-time multibeam files. In addition, the ISS-2000 creates digital message logs that allow full traceability of software and real-time events.

During system configuration, all vessel offsets are entered into either the POS/MV, the sonar, or into the ISS-2000. In addition, predicted tides are calculated for all tide zones to be surveyed and then recorded into the data in real time. Survey plans can be loaded into the real-time system on both vessels; coverage grids that are generated in real time during data acquisition can be viewed during planning, acquisition, and processing phases.

SVPs are taken at the beginning of each 12-hour period of surveying on the ship and each 8-hour day of surveying on the *AHI*. Standardized survey procedures, including a 2-minute warm up on deck and a 2-minute surface equilibration, are used on every cast. After the sound velocity cast is done, the data are downloaded with VelocWin software on the ship and with the SeaBird software on the launch. Sound velocity profiles are loaded using the ISS-2000 download utility; the downloaded profiles are sent to the two Kongsberg sonars on the ship and to the Reson sonar on the *AHI*, and the sound velocity information is logged as a part of the GSF. A real-time probe is used on the ship to monitor the surface sound velocity (SSV); if a difference between the SSV and the SVP at the surface is greater than 3 m/sec, an alarm is generated. The sonar on the *AHI* is less susceptible to SSV errors, and the daily casts are generally sufficient to correct for sound velocity. In all cases, the data are carefully monitored for sound velocity artifacts using the real-time displays.

During real-time operations, the ISS-2000 operator starts the ISS-2000 software, making sure to load the appropriate system configuration file. The System Control and Message windows are loaded at that time. The operator creates a dataset for the entire cruise that is named with the corresponding cruise delineator; *Hi'ialakai* and *AHI* data were logged into separate datasets (HI0604 and AHI0604) for file management purposes. After the dataset is created and all configurations are checked, "Start Survey" is selected and the Navigation Manager, Multibeam Manager, and Helm Display windows are opened. Text icons for all programs appear in the System Control window; the icons can be colored white, yellow, red, or green. White means that the program is selected but not activated; yellow means the program is activated but not logging; red means that there is a problem with the program; and green means that the program is operating and data are being logged. Files are automatically created for all multibeam sensors, for navigation inputs, for the POS/MV vertical reference, and for the messages generated by the system. Predicted tide files that can be used throughout 2006 were prepared before the cruise and were applied to the multibeam data in real time. (Note, real-time tides were implemented during the entire cruise with the exception of 4 days of data collected on the *AHI* at Kingman. The data collected on the *AHI* during those days were corrected for tides in post-processing.)

After the ISS-2000 Navigation Manager is started, a survey plan created is chosen and one or more surveys is selected for execution. Tide zones, existing coverage grids, and navigational charts can be loaded into the display, if desired. The navigated ship icon

appears on the screen. Survey lines are then selected from the survey file or made in real time and loaded into a Survey Schedule; lines can be selected in any order and their azimuth can be reversed; these lines appear on the screen when loaded into the schedule. When survey lines are being run in Survey Mode, the multibeam data is almost always logged (if logging is activated), but may be flagged as either "online" or "off-line." During transits, survey can be done in the "Underway Mode," but a flag must be set to not flag the off-line data during transits. If a coverage grid is loaded using the Coverage Monitor program and enabled for real-time logging, multibeam data is added to the coverage grid in real-time.

The Helm Display is also activated when the survey is started. This Helm Display appears both on the survey lab screens and on a screen on the bridge, and screen display parameters can be manipulated at either location. The same coverage grids, navigation charts, and survey lines selected in the Navigation Manager interface appear on the Helm Display as well; however, the display of these grids, charts, and lines can be turned on and off in the Helm Display independently of the Navigation Manager. The Helm Display can also be changed to different scales and color schemes than what is displayed on the Navigation Manager. The ISS-2000 feature, display of the coverage grids on the Helm Manager, enabled the bridge to steer lines in underway mode based upon existing coverage rather than always needing to create a formal survey line for the bridge to follow.

The Multibeam Manager is used to monitor the status of data files, to view and apply SVPs, and to view the multibeam bathymetry and backscatter data in real time. Many problems with the data can be detected immediately using feedback from these real-time displays. The Kongsberg SIS interfaces for the EM300 and the EM3002 are mounted above the two ISS-2000 screens, and other multibeam displays that provide different views of the data are available through SIS. Backscatter displays for all systems showed distinct and intriguing bottom types, but the ultimate quality of the data from the different sonars cannot be evaluated until data processing is complete.

During HI0604 aboard ship, multibeam data were collected during night operations and when data gaps existed closer to shoals than 1.8 km during the daytime. The EM300 was used for depths between 100 m and 3500 m, where the mapping limits of data acquisition are reached.

The *AHI* was deployed for 2 days at Jarvis, 4 days at Palmyra and 5 days at Kingman. The *AHI* was operated from 0800 to 1630, and data collection was concentrated in depths between 10 and 250 m.

HI0604 data were logged to two disks simultaneously in real time. The ISS-2000 AutoArchive program, which copies the data to a third permanent archive disk was run as needed during post processing. The AHI0604 dataset was logged on the real-time computer in the launch, and a second copy of the data was manually made on a portable disk; the disk was then moved to the ship and connected to the shipboard computers, and the data were read to the permanent archive disk. A final copy of all data was made to

the PIBHMC network disks, and data processing was done on only this copy of the data. The SABER data processing package, which provides full multibeam processing capability, was primarily used to manually edit the multibeam data in GSF, to plot tracklines, to update SVPs and tide data when necessary, and to create gridded data sets using the Pure File Magic (PFM) format that enables editing the integrated data set within the grid as well as reading any edits made in the grid back to the GSF multibeam files. Tape backups of all processed data were made one to two times per bank visited. The gridded data sets were converted to ASCII files for conversion to Arc raster grids. Map products were made as grids were created and added to the GIS product archive.

Backscatter data are logged as part of the GSF multibeam file and will be processed at PIBHMC after return to Honolulu.

A.2. Oceanography & Water Quality Methods

(Kyle Hogrefe, Charles Young, Danny Merritt, and Kevin Lino)

Since 2002, the Coral Reef Ecosystem Division has been conducting multidisciplinary research around Jarvis Island, Palmyra Atoll, and Kingman Atoll. Considering that the oceanographic component of this research has been well established, the recovery/redeployment of instrument platforms and the continuation of oceanographic measurements represent an ongoing effort of monitoring and assessment. During HI0604, the oceanography team utilized both well established and new methods to monitor long-term trends and assess oceanographic conditions.

While logistical constraints dictate that each site be visited for only a short period every 2 years, long-term oceanographic monitoring and assessment were accomplished by deployment and retrieval of a variety of internally recording and near real-time telemetered instrument platforms. These instruments include:

- Coral Reef Early Warning System (CREWS) buoys: Surface buoys which measure solar radiation, air temperature, wind speed and direction, sea surface temperature, salinity, turbidity, and (on enhanced models) photosynethtically active chlorophyll. CREWS buoys telemeter a portion of their collected data in near real time.
- Sea Surface Temperature (SST) buoys: Surface buoys which measure high resolution water temperature and telemeter their data in near real time.
- Wave and Tide Recorders (WTR): Moored instruments which measure spectral wave energy, precision tidal elevation, and subsurface water temperature.
- Ocean Data Platforms (ODP): Moored instruments which measure subsurface temperature, salinity, directional spectral wave energy, precision tidal elevation, and current profiles.
- Subsurface Temperature Recorders (STR): Moored instruments which measure high resolution subsurface temperatures.
- Surface Velocity Program (SVP) Drifters: Free floating, drogued (Lagrangian) devices which provide surface layer circulation and water temperature data. Satellite drifters telemeter their data in near real time.

- Recruitment Plate Arrays (RPA): An arrangement of ceramic tiles embedded in a PVC framework and affixed to both CREWS buoy and ODP anchors. These arrays support studies throughout the region to monitor the recruitment patterns of coral species.

While at each site, more discrete data and physical samples were collected to study oceanographic phenomena and water quality. Sampling was intended to provide a focused analysis of vertical profiles concerning water properties to provide indications for water mass movement, local seawater chemistry changes, and chlorophyll concentration. These activities included:

- Small vessel water sampling: Conductivity, temperature and depth (CTD) casts, including turbidity measurements, were performed to a maximum depth of 30 meters from a 6-m launch using an SBE 19+ at regularly spaced intervals around each island/atoll. Water quality profiles were conducted as a subset of the CTD casts using a hand deployed Niskin bottle string at depths of 30 m, 20 m, 10 m and 1 m as allowed by the depth at each cast site. Water samples were collected for nutrient and chlorophyll concentration at each depth.
- Shipboard water sampling: Conductivity, temperature and depth (CTD) casts, including chlorophyll concentration and dissolved oxygen measurements, were performed to a maximum depth of 500 meters from the *Hi'ialakai* using an SBE911. These casts were performed along ADCP (below) transects or independently depending on the focus of study. Water samples were collected from the majority of casts at 150 m, 125 m, 100 m, 80 m, 30 m and 3 m using Niskin bottles affixed to the CTD rosette. Water samples were collected for nutrient and chlorophyll concentration at each depth.
- Acoustic Doppler Current Profiler (ADCP) data provide information on oceanographic current structure from the surface to 600 m. ADCP box transects were conducted in conjunction with deepwater CTDs around each island/atoll as well as during transits and most other vessel activity.
- Continuous recording of surface and subsurface water temperatures as a function of depth were recorded during all towed-diver operations, providing a broad and diverse spatial and thermal sampling method.

A.3. Rapid Ecological Assessment Methods

(Fish: Craig Musburger, Paula Ayotte, Todd Wass; Coral team: Bernardo Vargas Angel, Ph.D., James Maragos, Ph.D.; Invertebrates: Scott Godwin; Algae: Aline Tribollet, Ph.D., and Bonnie DeJoseph)

The survey methodology used during HI0604 is the same as previously used during REA surveys conducted in 2004, when long-term monitoring sites were selected and surveyed by the full REA team (fish, corals, algae, and other invertebrates). At each REA site, three 25-m transect lines were laid out by the fish team, separated from each other by approximately 2–3 m. At most sites, transects were laid out at 13–15 m depth, except for a few shallow locations (4–11 m). REA methods for each specific discipline are as follows.

A.3.1. Fish

The REA Fish Team conducted three types of surveys at REA sites: Belt Transects (BLT), Stationary Point Counts (SPC), and Roving Diver Rapid Ecological Assessments (REA). BLTs were performed along three consecutive 25-m lines set along a single depth contour. As each line was set, two observers swam about 5 m apart along either side of the line, identifying to the lowest possible taxon, counting, and recording size classes for all fishes >20 cm total length (TL) within an area 4 m wide and 4 m high. At the end of each 25-m line, the divers turned around and returned along their respective sides of the line identifying, counting and recording size classes of all fishes <20 cm TL within 2 m of their side of the line and 4 m off the bottom. The third fish team diver simultaneously conducted four SPCs at each REA site, generally ~15 m from the transect line. SPCs consist of the diver identifying, counting, and recording the size classes for all fishes >25 cm total length observed in a cylindrical volume 10 m in radius during a 5-minute period. Following and opportunistically during the BLT and SPC surveys, all three fish team divers recorded the presence of all fish species seen outside the transect area and outside the SPC counts. The fish REA team's species presence records are combined with fish species observed by other divers (benthic team, tow team, or mooring team) to develop an island-wide record of all fishes observed. No collection efforts were made by the fish REA team during HI0604.

A.3.2. Algae

Macroalgae were identified to genus in the field, and ranked abundance of algal genera was collected from 12 quadrats (0.18 m^2) at each site (1 being the most abundant, 2 being the next most abundant, etc., with 10 being the maximum number of genera found in a single quadrat). Six quadrats were located at random points along the first two transects (three per transect), and six quadrats were located at points 3 m perpendicular from each random point in the direction of shallower water. Additionally, samples of macroalgae present within each quadrat were collected as voucher specimens (Preskitt et al., 2004). A random swim at the end of each dive augmented macroalgal collections attained from quadrats and allowed cryptic species that predominantly occurred in shaded areas to be qualitatively recorded. Because of difficulties with identification in the field, algae that fell within the functional groups of turf, cyanophytes, branched coralline algae, and crustose coralline algae were lumped into their respective categories. All ranked data were collected by the same individual to minimize the effects of observer bias.

A.3.3. Corals

Since 2004, the general coral specialist (Maragos) has conducted censuses of coral populations along both of the benthic REA transects. At each site, the first two transect lines are laid by the fish team, which serve as the focal point for coral quantitative studies. Each coral whose center fell within one half meter of either side of the transect line was assigned to a genus and one of seven size classes: 1-5 cm, 6-10 cm, 11-20 cm, 21-40 cm, 41-80 cm, 81-160 cm, and >160 cm based upon a visual estimate of the identification and long diameter of each coral. For all but a few sites, corals were completely censused along both lines, but in some cases, time was not sufficient to complete the census. In these latter cases, the length of the lines actually censused was recorded and used to establish corrections to allow for comparisons with coral census data from other sites. The above data were used to compile generic richness, determine frequency of corals (no. per m^2) and mean diameter (cm), and plot the size distribution of

corals at each site. Using the formula for an ellipse, the coral census data were also used to compute coral cover data in terms of coverage of coral per transect. However, these are not directly comparable to the percent coral cover estimated by the line intercept method because of several factors. In any case, it is beyond the time needed and scope of this report to calculate and present the coral cover estimates generated from the population data.

A.3.3.1. Coral populations over time at permanently marked transects.

Between 2000 and 2002, the general coral specialist (Maragos) had established three permanently marked transects at each of the three island/atolls at REA sites. The same type of generic diversity and population data of the type described above has been collected for corals at these sites. At each new site, the coral specialist would drive in and cement 1- to 3-foot tall stainless steel pins at 5-meter intervals along a 50 m long section of the benthic transects using a short-handled 3-kg sledge hammer and underwater epoxy. All permanently marked transects were established at depths of 9-11 m to insure that installation or relocation/repair and resurvey of each transect could be accomplished during one REA dive. A 50 m long graduated surveyor's tape was laid at sites where the REA transects were placed in deeper water or to connect the gap between the first and second benthic transects where the REA and permanent transects lines were laid at the same place and depth. In cases where the REA and permanent sites coincided, the coral specialist would census the corals in situ, in the same manner as during the non-marked REA sites. In cases where the permanent and REA sites were too far apart, the coral specialist gratefully acknowledges the help provided by divers from CRED tow and oceanography teams. In these cases, a photoquadrat frame measuring one m^2 was centered by a CRED diver over each 1-meter increment of the 50 m long transect while the coral scientist hovered above and took digital photographs of each quadrat placement. The photoquadrats themselves were then later censused via a computer screen, generating the same data within the same total area (50 m^2) as within REA sites. The photoquadrats also provided a permanent record from which the census was based.

A.3.3.2. Coral sample collection

As time permitted, the coral team also collected coral samples needed by other investigators at the University of Hawaii. The coral specialist (Maragos) collected 18 samples of *Acropora cytherea* and 29 samples of *Fungia scutaria* from Kingman Reef National Wildlife Refuge (NWR) and 22 samples of *Fungia scutaria* from Jarvis Island NWR for genetic connectivity analyses to be accomplished by Dr. Iliana Baums of the Hawaii Institute of Marine Biology.

A.3.3.3. Coral health and disease assessment

Only the first two 25-m transect lines, previously laid out by the fish team, were surveyed for percent live coral cover and coral diseases. Vargas Angel (CRED) used the line intercept method at 50-cm intervals along the first two transects to calculate the percent live cover of the different benthic components. In addition, Vargas Angel also surveyed an area of 4–5 m (depending on bottom time) of each side of the transect lines (approx. 400–500 m^2) to document incidence of coral bleaching and/or disease. Within this survey area, each diseased coral colony was identified to the lowest taxonomic level possible, and the following information was recorded: (1) colony size, (2) type of affliction (bleaching, tissue loss, tumor, growth anomaly, necrosis, discoloration, parasites, other),

(3) area affected (percent live/dead), (4) severity of the affliction (mild, moderate, marked, severe, acute), and (5) procurement of photographic records and tissue samples as needed. Tissue samples were catalogued and fixed in buffered zinc-formalin solution for further histopathological analyses. The disease data will be used to estimate disease incidence, prevalence; samples and photographs will be used to aid in further disease characterization.

A.3.4. Macroinvertebrates

Quantitative counts for specific target marine invertebrates are conducted along two separate 10- by 25-m belt transects. Additionally, ten 0.25 m^2 quadrats are enumerated along each transect line to determine the average percent cover of certain sessile target species or for subsampling large populations of semimobile species (e.g., boring urchins).

Based on data from previous rapid ecological assessments, a group of target species is chosen for quantitative counts. The species in this list were chosen because they have been shown to be common components of the reef habitats of the central and southern Pacific, and they are species that are generally visible (i.e., non-cryptic) and easily enumerated during the course of a single 50-60-minute scuba survey.

These target species are:

- PORIFERA - sponges
- CNIDARIA
    - Zoanthids – rubber corals
    - Actiniaria – anemones
    - Hydroidea – hydroids etc.
    - Octocorallia – soft corals
- ECHINODERMS
    - Echinoids – sea urchins
    - Holothuroids – sea cucumbers
    - Asteroids – sea star
    - Crinoids – feather star
- MOLLUSCA
    - Bivalves – spondylid oysters, tridacnid clams and pearl oysters
    - Nudibranchs – sea slugs
    - Gastropods – snails
    - Cephalopods - octopus
- CRUSTACEA
    - Hermit crabs, lobsters and large crabs

Collections of species that cannot be identified in the field, and samples of coral rubble are brought back to the laboratory on the research vessel. The cryptic organisms found in the rubble are picked out and preserved, and the sand samples are dried and bagged so they can be examined for micromollusks and foraminifera at a later date. The marine invertebrate species recorded and identified during the course of the field operations for HI-06-04 represent the non-cryptic fauna of the reef habitat and should not be considered the only species present at each site. There is an abundance of other organisms, both cryptic and non-cryptic, that dwells in these habitats that are not included in the rapid assessment scheme, which will be included in a final species inventory at a later date.

A.4. Towed-diver Survey Methods

(Molly Timmers, Eric Dobbs, Amy Hall, Stephane Charette, and Edmund Coccagna)

Towed-diver surveys were conducted in shallow water habitats using a pair of diver-observers on towboards equipped with a downward-looking high resolution digital still camera with dual strobes (benthic towboard) and a forward-looking digital video camera (fish towboard) to quantify habitat composition and complexity and abundance and distribution of ecologically and economically important fish and macroinvertebrate taxa. The downward-looking camera was maintained ~1 m of the bottom and was programmed to photograph the benthic substrate every 15 seconds. The diver-observer on the benthic towboard observed and recorded habitat composition and characteristics (substrate percentages), and tallied conspicuous macroinvertebrates (Crown-of-thorns, urchins, sea cucumbers, giant clams) over 5-minute ensembles. The fish towboard, outfitted with a forward-looking digital video camera, recorded fish distribution and habitat complexity. The diver-observer on the fish towboard recorded fish greater than 50 cm total length within limits of visibility for 1 minute followed by all fish within a 10-m swath for 4 minutes. These 5-minute segments corresponded with the same 5-minute ensembles used by the benthic observer. Both towboards were instrumented with precision temperature and depth recorders (Seabird SBE39). Each towboard was equipped with a SBE 39 which recorded temperature and depth every 5 seconds along each transect. A Garmin GPS76Map GPS was used to record position at 5-second intervals along each tow track to geo-reference the collected data. The data was downloaded and presented in Arc View GIS and overlaid on high resolution IKONOS imagery.

A.5. Terrestrial Survey Methods

Terrestrial surveys were not conducted during HI-06-04.

Appendix B: Jarvis Island
Work was conducted at Jarvis Island from March 20 to March 22, 2006.

B.1. Benthic Habitat Mapping

The seabed surrounding Jarvis Island was completely mapped in shallow and intermediate water depths of less than 10 m to as deep as 3500 m (Fig. B-1). The *Hi'ialakai* arrived at Jarvis at around 0500 on March 20. The Acoustic Habitat Investigator (*AHI)* launched the morning of March 20 and finished three laps around Jarvis to get nearly complete multibeam coverage from 10 m to 300 m depth. That night, shipboard mapping began data acquisition. The ship completed three laps around Jarvis, overlapping the unedited *AHI* data and covering depths down to 3500 m depth.

During the night of March 20, mapping was briefly delayed when the 260-meter conductivity-temperature-depth (CTD) cast began returning erroneous spikes in the data. During the recovery of the CTD, the cast continued to deliver false readings. Three bad data records were noted in Velocowin, but in the ASVP file, none of the bad data were found. The 260-meter cast was used with historical data added to 12000 m. Mapping resumed by 1900 that night.

During the morning of March 21, the *AHI* completed coverage on the inside of the Eastern Bank of Jarvis. After the mapping completion, the *AHI* supported the Oceanography team for the rest of the day. While daytime work continued, the ship maneuvered safely around the island to map the gap that was left between the edited *AHI* coverage and the ship coverage from the night before. Overall, the *AHI* collected about 10 km^2 of multibeam bathymetry while shipboard mapping covered about 306 km^2.

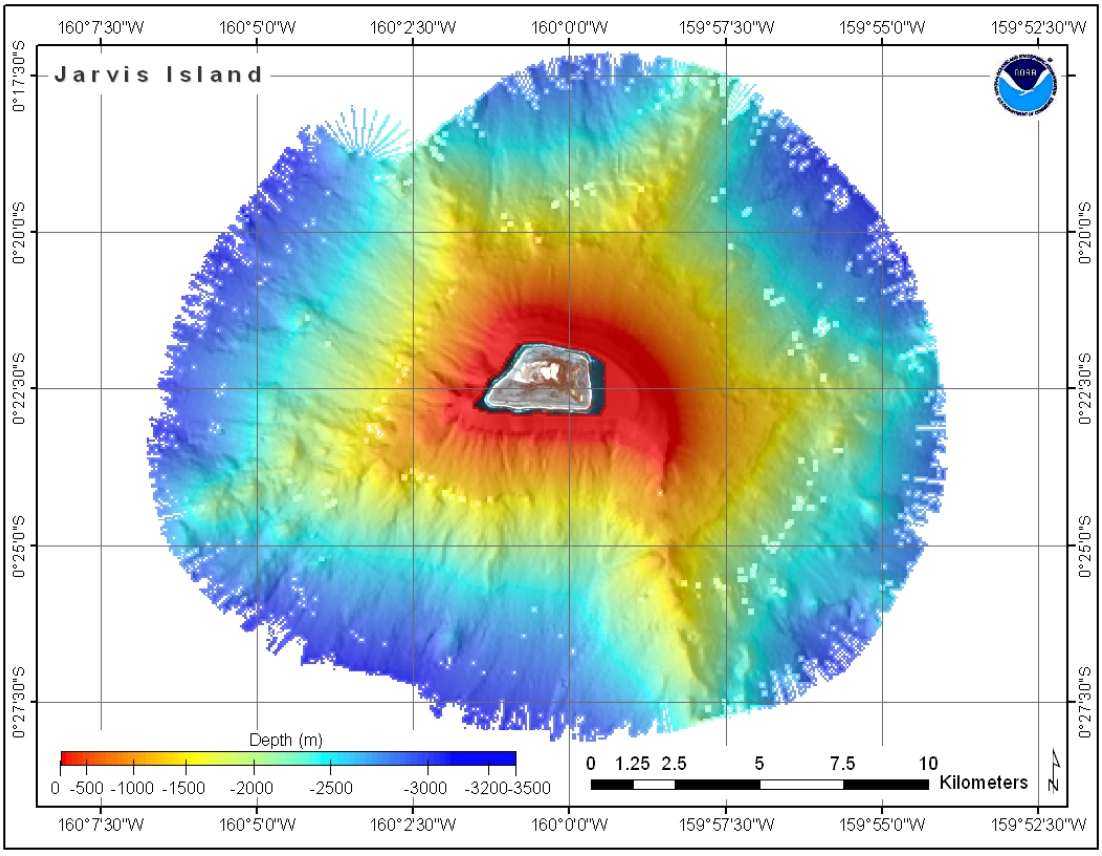


Figure B-1: High resolution multibeam coverage at Jarvis Island, March 2006

Jarvis drops steeply on the western (leeward), north and south shores. The windward eastern bank extends about 1.5 km from the shoreline and then drops steeply as well. The geomorphology at Jarvis appeared to be very similar to Baker Island, the equatorial island located about 16° -17° west of Jarvis.

The initial survey planning for Jarvis brought to light a minor problem with the ISS2000 data acquisition software. The coverage grid for Jarvis, made in survey planning, defaulted to UTM North while the plan and coverage were defined as UTM South. Therefore, a short report was sent to SAIC, the software vendor. They promptly noted the error and provided a solution that allowed us to write to the coverage. A patch is being written to correct the problem with working so close to the equator. The coverage needed to use bounding coordinates north of 00° 01' and south of 00° 01'. In the meantime, we also found that a coverage made with MB-System with one false sounding would also work as needed in survey planning and for real time data acquisition. In the end, the coverage made with the false sounding was used for data acquisition, and the survey operation was conducted without further problem.

B.2. Oceanography & Water Quality

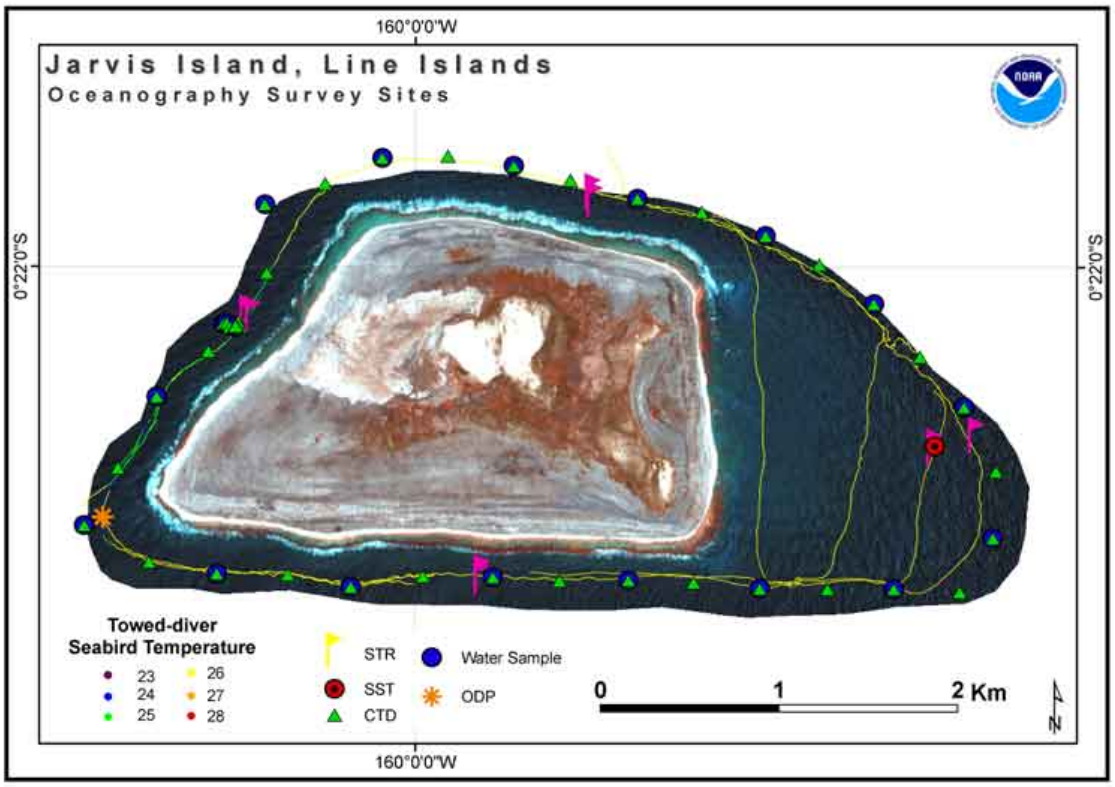


Figure B.2-1: Oceanography sites at Jarvis Island

B.2.1. CTD Casts and Water Samples

Thirty-five CTD casts to 33 meters were conducted around the periphery of the island at a .4-km interval in as close to 35 meters of depth as possible considering the slope of the island and surf conditions. Water quality profiles were conducted at every other CTD site for a total 17 profiles from which 71 chlorophyll and 71 nutrient samples (including replicates) were collected. In concert with this circumferential sampling of the island, eight 30-meter and eight 200-meter CTDs were conducted alternating between two sites. The shallow site was the same as the initial circumferential site while the deep site was the same as the repetitive site sampled during night operations (see below). This simultaneous effort was made possible by the cooperation of the mapping team with the R/V *AHI* being coxswained by Jeremey Jones. Two casts were also conducted at the repetitive sites during the previous day with one water quality profile being conducted at the shallow site and four chlorophyll and four nutrient samples being collected.

Eight deepwater CTD/water quality profile casts were conducted off of the *Hi'ialakai* during night operations. These casts were conducted at the same site at a 90-minute interval with 48 chlorophyll and 48 nutrient samples collected. The purpose of these repetitive casts was to gather data concerning the upwelling of the equatorial counter current and its subsequent effects on water chemistry and nutrient cycling around the

periphery of Jarvis Island. It is hoped that such information will further the understanding of variable species distributions around the island. Two CTD casts were conducted from the *AHI* to 200 m, and 2 CTD casts were conducted to 500 meters in support of the mapping effort.

B.2.2. Oceanographic Instrumentation Deployments

One Ocean Data Platform (ODP) was recovered and replaced. One sea surface temperature (SST) was installed at the established site but the old SST was no longer present; it was known to have gone adrift over a year ago. The SST clump anchor was located on its side about a meter from the edge of the sand patch in which it was deployed with about 2 m of the mooring line still attached, indicating that the instrument was most likely dragged by high surf conditions to the edge of the patch allowing the line to be severed by abrasion by the reef edge. To avoid another such occurrence, the anchor position was moved to the center of the 20- by 35-meter sand patch in which it was deployed, and two 115-kg SST anchors were "daisy chained" together to provide a mooring with significantly increased resistance to drag. Additionally, this was a new ATI-SST which, among other intended advantages, is smaller and tethered in-line with an elongate primary float which should present less drag in high current/surf conditions. This deployment will be an excellent test of the new buoy and rigging system as no previous deployment has lasted the duration at this site. Four subsurface temperature recorders (STRs) were recovered and replaced at the established sites, about 10 meters depth, on each side of the island and four additional STRs were deployed down the reef-slope adjacent to each site, about 30 meters depth, to provide a temperature profile time series around the island. This modified STR deployment style is intended to provide data for temperature profiling enhancing oceanographic monitoring and modeling.

B.2.3. Towed-diver Temperature Profiles

Twelve towed-diver surveys were conducted around Jarvis Island totaling 24.24 km in length. Temperature data was recorded at 5-second intervals along each tow survey.

B.3. Benthic Environment

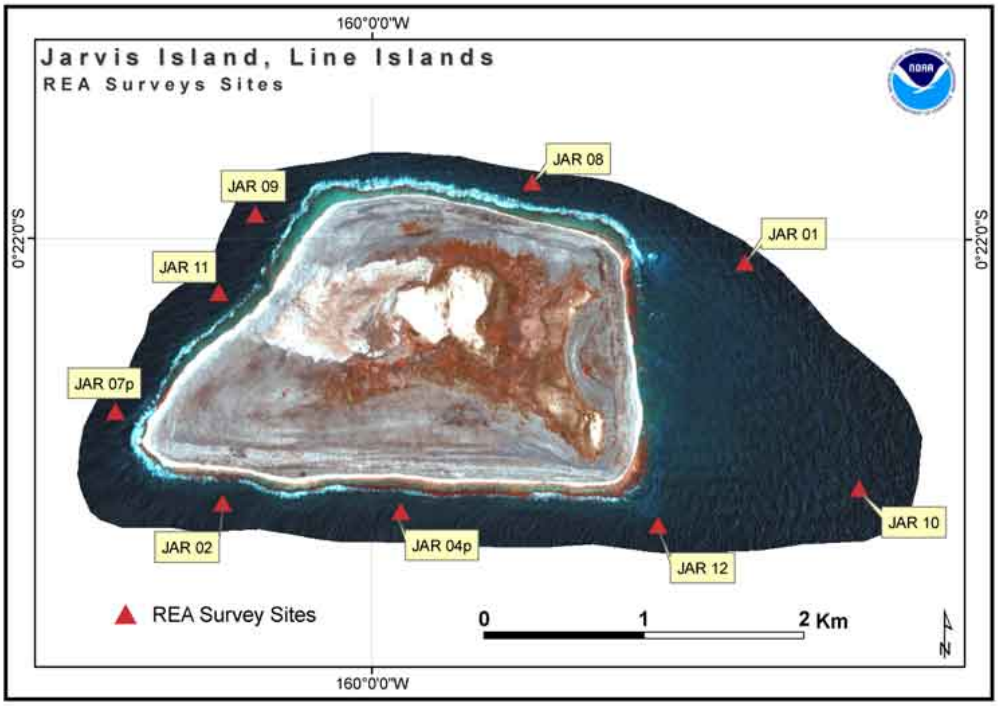


Figure B.3-1: REA survey sites at Jarvis Island

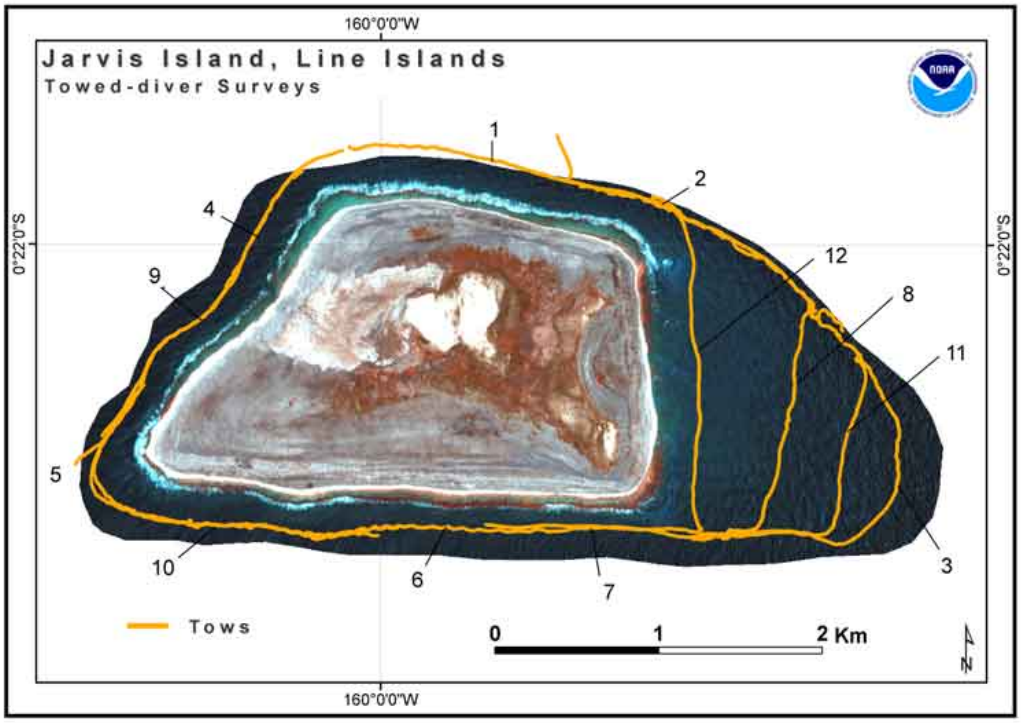


Figure B.3-2: Towed-diver survey transects at Jarvis Island

The purpose of the REA activities onboard the HI-06-04 was to select sites surveyed during previous rapid ecological assessments for long-term monitoring. Selection of sites was based on their year-round accessibility and their representation of the habitats present at each site. Between March 20 and March 22, 2006, rapid ecological assessment (REA) surveys were conducted at 9 sites and 12 towed-diver surveys were completed around Jarvis Island. Dive depths ranged from 9 and 18 m. Calm sea conditions allowed the REA team to accomplish three sites off the north side and two off the east side, providing more complete coverage than had been accomplished during any prior visit to Jarvis.

The algal REA surveys indicated that most abundant macroalgae at Jarvis Island were crustose corallines, green and red turfs, as well as *Lobophora*, and *Dictyosphaeria*. The north side of the island was dominated by two unknown red algae. This contrasted to the macroalgal composition along the south side of the island. The south, east, and west shores were dominated by crustose corallines, green and red turf algae, as well as *Lobophora*, *Valonia*, and *Dictyosphaeria*. A priori, the richness of macroalgae and their relative abundance found at Jarvis in 2006 are similar to those reported in 2004.

Coral population surveys covered 14 of the 22 genera reported from Jarvis, although 5 genera accounted for more than 95% of the corals in 2006: *Montipora, Pocillopora, Pavona, Distichopora,* and *Millepora.* The dominant coral genera of *Acropora* and *Porites* were low in numbers although many of the *Porites* colonies were large. The coral fauna at Jarvis is unusual in being low in diversity compared to all of the other Line Islands surveyed for corals during the past several decades. Geographic isolation and small size compared to the other islands may be responsible for this anomaly. Average generic richness was low at all REA sites, ranging between 5 and 9 genera per 50 m^2 transect area. The eastern and northern (windward) reef sites showed slightly higher generic richness but lower overall abundance (JAR01, 08, 09, 10).

The coral disease REA surveys indicated that the mean percent live coral cover on reefs around Jarvis Island was 37% and dead coral accounted for over 2%. Percent live coral cover was the highest (>70%) along the western slopes, except for site JAR07, where soft corals of the genus *Sinularia* were an important component of the benthos. At Jarvis Island, the dominant coral genera in descending order included *Montipora* and *Pocillopora*; montiporid corals contributed 72.8% of the total coral fauna. Other less abundant, yet ubiquitous scleractinian genera included: *Pavona*, *Favia*, *Porites*, *Psammocora*, *Fungia*, and *Leptoseris*. In addition, the estimated average abundance of coral and coralline algae diseases and syndromes at Jarvis Island was low; ca. < 2 cases per 1000 m^2; no collection of diseased coral tissues samples were conducted.

The abundance of common macroinvertebrate groups was not uniform throughout Jarvis Island. The abundance and diversity were skewed towards the western habitats. The exception was site JAR10 on the southeastern edge of the east reef terrace. This site differed from others on the east side in that the coral cover was greater and the macroinvertebrate diversity was increased by abundant sessile fauna such as sponges and hydrozoans. A new species of hermit crab from the genus *Dardanus* was recorded at

JAR01 and JAR04P. This hermit crab was recently described as a new species (Asakura and Godwin, In Prep) from specimens collected on OES-04-04 (see photo). So far this species has only been described from Howland Island, Baker Island, and Jarvis Island.

B.3.1. Algae

The algae team had the following general observations from their work at Jarvis.

- The west side was much cooler than the other sides of the island because of the upwelling. This creates different environmental conditions controlling algal diversity, abundance, and distribution.
- The north side of the island showed a different cover of macroalgae than the other locations visited during this survey. Macroalgal communities were indeed dominated by two unknown red algae. Crustose corallines and red turf algae were also abundant. Additionally, coral cover at the northern reefs was moderate in comparison to the other reefs. Algae were the major benthic component.
- At the other reefs, macroalgal communities were dominated by crustose corallines, green and red turf algae, *Lobophora*, *Valonia* and *Dictyosphaeria*. The abundance of macroalgae per photoquadrat was variable but in general the coral cover was greater than the algal cover.
- At the island scale, the most abundant algae encountered were crustose corallines (>85% of occurrence in photoquadrats, average rank of 1.6), green and red turf algae (64% and 47% respectively, average rank for both is 3.1), *Lobophora* (70%, average rank of 3.9), and *Dictyosphaeria* (50%, 4.5). Other macroalgae were also abundant and seen all around the island, that of two unkown red algae, *Valonia* and *Halimeda*.
- Blue-green algae were observed but were not very abundant. *A priori*, the richness of macroalgae and their relative abundance found in 2006, is similar to those reported in 2004.
- Table B.3.1-1 summarizes the relative abundance of macroalgae (ranking) per site and at the island scale as well as the percentage of occurrence of each macroalga per site and at the island scale.

B.3.1.1. Algal REA Site Descriptions

JAR09: (3-20-2006: 00°21.925'S, 160°00.385'W)

This reef slope was located northwest of Jarvis Island. Weather conditions were good. Visibility was around 20 m. A lot of zooplankton was observed at this site as well as lots of grey sharks. Coral cover was really high. Coral communities were dominated by *Montipora*, *Pocillopora*, *Favia,* and *Pavona*. Macroalgae were abundant but not very diverse. Macroalgal communities were dominated by two unknown red algae (red 1 being really macroscopic and red 2 showing thin branches), red turf algae, *Dictyosphaeria verslusii*, crustose corallines, and *Lobophora*. *Valonia* was also observed. A qualitative and a quantitative surveys were carried out only along the first transect. It was not possible to do the second transect because of the sharks. Also Bonnie De Joseph and I ran out of air (first dive together).

JAR08: (3-20-2006: 00°21.802'S, 159°59.468'W)
This reef slope declined gradually and was located northeast of Jarvis Island. Weather conditions were good (moderately cloudy). The swell was low (1 m, NE). Visibility was relatively good, around 18 m. Coral cover was limited. The benthic floor was mostly dominated by limestone and coral rubbles covered by algae. Macroalgal diversity was moderate. Algal communities were dominated by crustose corallines, red turf algae, the unknown red 1, *Halimeda*, *Dictyosphaeria,* and *Lobophora*. *Valonia* and blue-green algae were also abundant. Additionally, the unknown red 2 was observed. The last two pictures were not taken at the end of the second transect because of the presence and threat of two huge hammerheads.

JAR01: (3-20-2006: 00°22.070'S, 159°58.772'W)
This reef slope declined gradually and was located northeast of Jarvis Island. Weather conditions were good, moderately cloudy. Visibility was around 18 m. Coral cover was very limited. The benthic floor was mostly composed of limestone and coral rubbles covered by macroalgae. Algal diversity was moderate. Algal communities were dominated by the unknown red 1, crustose corallines, *Dictyosphaeria*, *Halimeda,* and the red turf algae. *Valonia*, the unknown red 2 and *Chondria* were also observed. Blue-green algae were additionally observed but were not very abundant.

JAR10: (3-21-2006: 00°22.835'S, 159°58.385'W)
This reef slope was located in the southeast corner of Jarvis Island. Weather conditions were good. Visibility was higher than 30 m. Coral cover was relatively high. Coral communities were dominated by *Montipora* and *Pocillopora*. The limestone and coral rubbles were covered by diverse algae. Macroalgal communities were dominated by crustose coralline algae, red turf algae, and *Lobophora*. Additionally, red 1, red 2, *Dictyosphaeria* and *Valonia* were observed in relative abundance. Blue-green algae were also present. Because of the environmental conditions, only a qualitative survey of the macroalgal diversity was possible.

JAR04P: (3-21-2006: 00°22.903'S, 159°59.907'W)
This reef slope was located in the south of Jarvis Island. Weather conditions were good and visibility was higher than 35 m. The coral cover was very high. Coral communities were dominated by *Montipora* and *Pocillopora*. The most abundant algae in the photoquadrats were crustose corallines, red turf algae, *Lobophora*, *Valonia,* and *Dictyota*. *Dictyophaeria* (probably two species), *Halimeda,* and red 2 were also seen in abundance. Blue-green algae were present.

JAR02: (3-21-2006: 00°22.878'S, 160°00.494'W)
This reef slope was located in the southwest corner of Jarvis Island. Weather conditions were good. Visibility was around 30 m. Coral cover was very high. Coral communities were dominated by *Montipora* and *Pocillopora*. However, other genera such as *Pavona* and *Millepora* were recorded by the coral team (same as the two previous sites). Algal communities were dominated by crustose corallines, red turf algae, green turf, *Lobophora* and *Valonia*. Red 2 was also observed in abundance as well as blue-green algae. One

undetermined red alga was found in the last photoquadrat of the first transect (creeping, flashy red, 'cartilagenous' and short). *Dictyota* was observed during the random swim.

JAR12: (3-22-2006: 00°22.950'S, 159°09.033'W)
This reef slope was located on the southeast side of Jarvis Island. Weather conditions were good. No swell and no current were recorded. Visibility was higher than 30 m. The coral cover was moderate and coral communities were dominated by *Pocillopora*, *Montipora,* and *Millepora*. Algal diversity was low. Macroalgal communities were dominated by crustose corallines, turf algae, red 1, and *Lobophora*. *Dictyosphaeria*, *Valonia*, red turf algae and red 2 were also seen in abundance along both transects. Blue-green algae were present.

JAR07P: (3-22-2006: 00°22.591'S, 160°00.058'W)
This steep reef slope was located west of Jarvis Island. Weather conditions were good. A moderate current was found at around 14 m. Visibility was higher than 30 m although a lot of plankton was observed. One sting ray, at least five manta rays, and a lot of grey sharks were seen at this site. Coral cover was very important. Coral communities were mostly dominated by soft corals. However, some *Millepora* and *Montipora* as well as a few colonies of *Porites* and *Pocillopora* were recorded. Algal diversity and abundance were low. Crustose corallines, turf algae, and *Lobophora* were the dominant macroalgae at this site. Additionally, *Dictyosphaeria*, *Valonia*, *Peyssonelia*, red turf algae, red 2, and rarely, *Halimeda* were observed along both transects.

JAR11P: (3-22-2006: 00°22.170'S, 160°00.515'W)
This steep reef slope was located northwest of Jarvis Island. Weather conditions were good with few clouds. Visibility underwater was as usual very good (around 40 m). At this location in particular, the upwelling was obvious. The water temperature dropped dramatically below 13 – 15 m. A lot of plankton was observed in the water column. Abundance of coral cover was very high, and the coral communities were dominated mostly by *Montipora*. *Pocillopora*, *Porites,* and *Millepora* were, however, also reported. *Psammocora* were seen but rarely. Algal diversity was low. Macroalgal communities were dominated by crustose *Halimeda* corallines, *Lobophora,* and turf algae. Red 1, *Dictyosphaeria*, *Peyssonellia*, and red 2 were also often observed. Additionally, *Jania* and blue-green algae were present along both transects but were not abundant.

Table B.3.1-1: Relative abundance of macroalgae (ranking) per site and at the island scale as well as the percentage of occurrence (in bold) of each macroalga per site and at the island scale. Standard deviations are given at the island scale in parentheses.

	JAR09	*JAR08*	*JAR01*	*JAR10*	*JAR4P*	*JAR02*	*JAR12*	*JAR7P*	*JAR11P*	*Island average*
GREEN ALGAE										
Caulerpa	*16.7* ***4.0***									*16.7* ***4.0***
Cladophora			*8.3* ***6.0***							*8.3* ***6.0***
Dictyosphaeria	*33.3* ***4.5***	*100* ***3.5***	*83.2* ***4.3***	*33.3* ***4.0***	*33.3* ***6.3***		*83.3* ***4.8***	*8.3* ***3.0***	*25.0* ***5.7***	*50* ***(33.6)*** *4.5* ***(1.1)***
Halimeda		*30.0* ***3.3***	*16.7* ***3.5***		*33.3* ***6.8***	*16.7* ***6.0***	*41.7* ***6.2***	*25.0* ***3.7***	*33.3* ***5.3***	*28.1* ***(9.3)*** *5.0* ***(1.4)***
Microdictyon										*
Ulva					*					*
Valonia	*50.0* ***4.0***	*20.0* ***5.0***	*	*33.3* ***6.0***	*50.0* ***3.0***	*66.7* ***4.5***	*83.3* ***4.6***	*		*50.6* ***(22.6)*** *4.5* ***(1.0)***
RED ALGAE										
Unknown red 1	*33.3* ***5.0***	*100* ***1.2***	*75* ***3.4***	*66.7* ***3.0***	*8.3* ***9.0***		*100* ***1.8***		*8.3* ***5.0***	*56.0* ***(39.6)*** *4.1* ***(2.6)***
Chrysymenia **Gracilaria**	 *16.7* ***2.0***	 *20.0* ***4.0***	*16.7* ***7.0*** *8.3* ***3.0***							*16.7* ***7.0*** *15.0* ***(6.0)*** *3.0* ***(1.0)***
Unknown red 2	*100* ***2.0***	*30.0* ***5.3***	*41.7* ***2.6***	*100* ***3.0***	*33.3* ***5.3***	*33.3* ***3.0***	*91.7* ***4.7***	*50.0* ***4.5***	*33.3* ***4.5***	*57* ***(30.8)*** *3.9* ***(1.2)***
Jania or Amphiroa				*66.7* ***7.0***				*8.3* ***7.0***	*8.3* ***4.0***	*27.8* ***(33.7)*** *6.0* ***(1.7)***
Laurencia /Chondrophycus								*8.3* ***5.0***		*8.3* ***5.0***
Peyssonnelia				*33.3* ***5.0***	*16.7* ***4.0***		*41.7* ***6.4***	*50.0* ***4.2***	*41.7* ***3.6***	*36.7* ***(12.6)*** *4.6* ***(1.1)***
Red Turf	*16.7* ***3.0***		*66.7* ***3.0***	*66.7* ***2.5***	*75.0* ***2.9***	*50.0* ***3.3***	*50.0* ***2.8***	*33.3* ***4.3***	*16.7* ***3.0***	*46.9* ***(22.7)*** *3.1* ***(0.5)***
crustose coralline	*83.3* ***1.6***	*90.0* ***1.9***	*83.3* ***1.0***	*100* ***1.0***	*91.7* ***1.7***	*100* ***2.0***	*75.0* ***2.3***	*83.3* ***1.9***	*91.7* ***1.4***	*88.7* ***(8.3)*** *1.6* ***(0.5)***
BROWN ALGAE										
Dictyota				*33.3* ***5.0***	*75.0* ***5.2***	*			*8.33* ***7.0***	*38.9* ***(33.7)*** *5.7* ***(1.1)***
Lobophora	*66.7* ***5.0***	*70.0* ***4.3***	*66.6* ***4.1***	*33.3* ***3.0***	*83.3* ***4.1***	*83.3* ***4.0***	*66.7* ***5.4***	*75.0* ***2.0***	*83.3* ***3.0***	*69.8* ***(15.6)*** *3.9* ***(1.1)***
CYANO-PHYTES	*33.3* ***6.5***	*30.0* ***5.3***	*8.3* ***5.0***	*33.3* ***8.0***	*50.0* ***2.7***	*83.3* ***3.4***	*41.7* ***6.0***	*25.0* ***5.0***	*33.3* ***3.0***	*37.6* ***(20.6)*** *5.0* ***(1.7)***
TURF	*100* ***3.3***	*30.0* ***3.3***	*58.3* ***2.9***	*66.7* ***5.5***	*75.0* ***3.4***	*66.7* ***1.3***	*33.3* ***4.0***	*58.3* ***2.9***	*91.7* ***2.4***	*64.4* ***(23.3)*** *3.2* ***(1.2)***

B.3.1.2. Benthic Towed-diver Survey—Algae

Macroalgae dominated the northern shore and eastern terrace. A red algal covering dominated the underlying rubble habitat; representing approximately 75% of the total cover. Coralline algae began to replace the red macroalgae and dominate the habitat cover along the southeastern portion of the eastern terrace. Along the southern shore, *Lobophora variegata* and *Valonia fastigiata* dominated the algal cover along with coralline algae. Along the western shore, *Lobophora variegate* had a higher presence than *Valonia fastigiata.*

B.3.2. Corals

Table B.3.2-1 and Figure B.3.2-1 summarize the characteristics of the coral populations at the nine Jarvis sites in 2006. A total of 3237 corals were censused on the transects but there were substantial differences among the sites. The frequency of corals (mean number per m^2) was lowest at windward sites varying from 2 to 4 corals per m^2 at sites JAR01, 08, and 12. Coral frequency values were highest on the south and west sides of the island at sites JAR 11P, 07P, 04P, and 02 with frequencies there ranging from 8 to 13 corals per m^2. These sites along with JAR09 on the northwest corner also supported the largest coral colonies, and the same sites along with JAR02 showed higher mean diameter levels for corals. Jarvis is exposed to large northwest swells because of its more westerly position relative to its northern Line Island neighbors. The REA sites protected from these swells and easterly tradewinds (JAR 11P, 07P, 02, 04P, and 12) appear to support larger and more numerous corals, although windward coral communities appear to be more diverse.

Table B.3.2-1 Numbers of corals per genus, frequency and mean diameter by site reported at Jarvis Island National Wildlife Refuge in March 2006. (after Maragos 2006)

	Site numbers for Jarvis 2006									totals/	% of
coral genus	**8**	**9**	**1**	**10**	**4P**	**2**	**12**	**7P**	**11P**	**genus**	total
Acropora					1	6				**7**	0.22
Cladopsammia										**0**	0
Coscinaraea										**0**	0
Distichopora				87						**87**	2.69
Echinophyllia										**0**	0
Favia		2		1		2		2		**7**	0.22
Favites										**0**	0
Fungia	1	27			7	2	24			**61**	1.88
Hydnophora							1			**1**	0.03
Leptoseris	2	1	1	1						**5**	0.15
Lobophytum										**0**	0
Millepora			1	12	6		22	3	18	**62**	1.92
Montipora	53	182	57	8	240	404	71	322	285	**1622**	50.1
Pavona	20	23	28	34		2	13	6	9	**135**	4.17
Pocillopora	22	123	36	243	390	76	71	131	86	**1178**	36.4
Porites	1	2	2					16	25	**46**	1.42
Psammocora	1	2								**3**	0.1
Sinularia	2	1	1	1				17		**22**	0.67
Tubastraea							1			**1**	0.03
totals per site (per 50m^2)	**102**	**363**	**126**	**387**	**644**	**492**	**203**	**497**	**423**	**3237**	100
mean diameter	12.1	29.3	11.5	15.7	27.4	29.9	16.1	27.2	22.9		
frequency (#/m^2)	2	7.3	2.5	7.7	12.9	9.8	4.1	9.9	8.3		
# of genera	7	9	7	8	5	6	7	7	5		

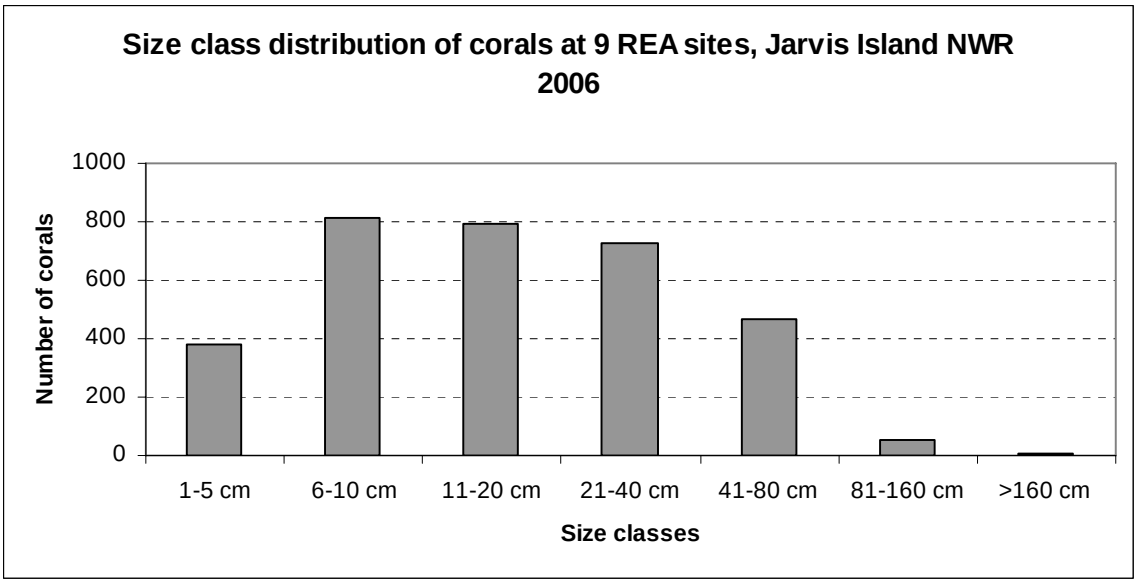


Figure B.3.2-1 Size class distribution for corals at nine REA sites

B.3.2.1. Changes in coral populations over time

Data from the 2004 REA surveys were available for three sites at this time to offer comparisons to 2006 surveys at the same sites (JAR01, 08, 10). In all cases, coral populations were more abundant and diverse in 2006 compared to 2004. Many more corals and higher frequencies were reported at all sites in 2006. For example, 2004 frequency values ranged from 1 to 2.5 corals per m^2, but ranged from 2 to 7 corals per m^2 in 2006. Many smaller size classes were more numerous in 2006, although one larger size class (41–80 cm in diameter) was more abundant at the sites in 2004. Generic diversity increased from 3 to 4 genera in 2004 to 5–8 genera in 2006. Preliminary results from the analysis of permanent data at site JAR4P show dramatic increases in corals from 2000 to 2006 (see Fig. B.3.2-2). Overall, corals appear healthy and growing at Jarvis based upon diversity and population parameters.

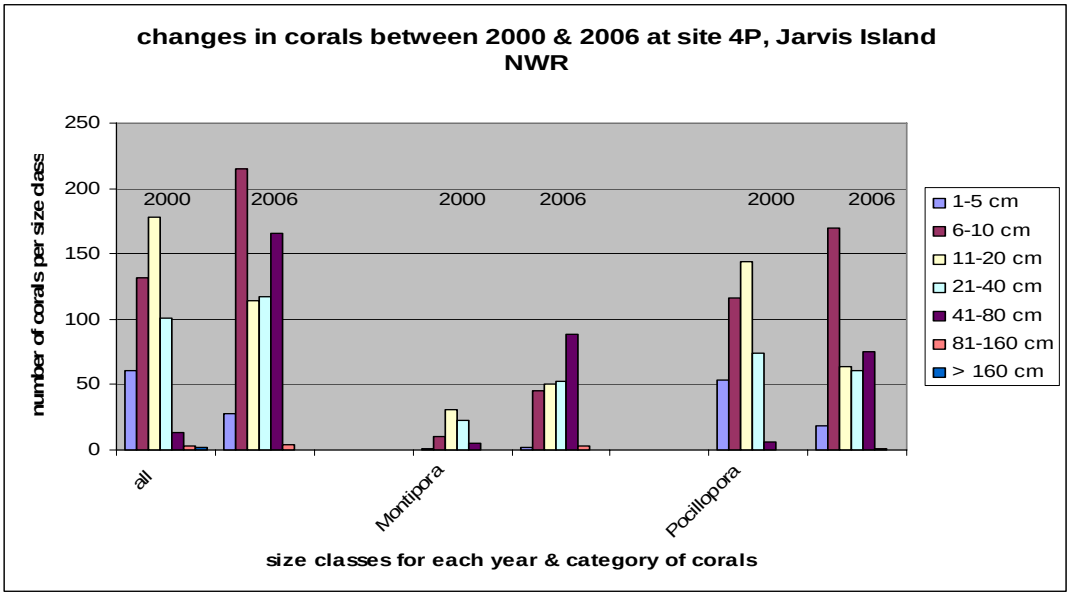


Figure B.3.2-2: Changes in coral size classes between 2000 and 2006 at site 4P

B.3.2.2. General observations on coral community composition

Coral disease REA surveys indicated that the mean percent live coral cover on reefs around Jarvis Island was 37% and dead coral accounted for over 2%. A summary of benthic parameters is presented in Table B.3.2-2. Mean coral cover was the highest along the south and northwest shores; JAR02, JAR09, and JAR11P (72.5–79.4%). At these sites, platy Montiporid corals (cf *Montipora grisea*/*effusa*) comprised over 80% of the scleratinina fauna. Interestingly, coral cover at JAR07P on the west shore was only 23.5%. The influence of upwelling at this site on this side is apparent by the increased abundance of alcyonarian soft corals of the genus *Sinularia*.

Low mean percent coral cover was detected at sites JAR01 and JAR08 (2.9%) on the north and northeast side of the Island. These sites were dominated by mats of creeping red fleshy macroalgae (cf, unknown red alga 1) overgrowing staghorn and tabular *Acropora* rubble and contributing over 40% and 80% of the bottom cover, respectively. It is reasonable to suggest that in the past, these sites were dominated by acroporid corals, which later became diminished by possible environmental disturbance or disease outbreak. In summary, scleractinian coral generic diversity at Jarivs Island was low; 11 in genera total, in addition to the hydrocorals *Millepora* and *Distichopora*. Dominant coral genera in descending order included *Montipora* and *Pocillopora*. Montiporid corals contributed 72.8% of the total coral fauna. Other less abundant, yet ubiquitous scleractinian genera included: *Pavona*, *Porites*, *Psammocora*, *Fungia*, and *Leptoseris*.

Coral disease and health assessment

The average abundance of coral and coralline algae diseases and syndromes at Jarvis Island was low; ca. < 2 cases per 1000 m^2. No collection of diseased coral tissues samples was made. Within the survey areas, four cases of paling were detected in colonies of *Pocillopora verrucosa*; this could be the result of photoadaptation. Also, one case of discoloration was observed on *Montipora*. In addition, discrete patches devoid of tissue

were noted on corals at all stations, mainly on the platy *Montipora* and some colonies of *Pocillopora*. Size and appearance of these marks are suggestive of predation; however, no specific corallivores were observed associated with these blemishes. On *Pocillopora*, these blemishes may be attributed to algal lawn expansion produced by territorial damselfish. More detailed assessment of this condition is needed. At Jarvis Island, predation marks were also observed on colonies of *Hydnophora microconos* at sites JAR04P, JAR11P, and JAR12. Also, at all sites multiple focal to multifocal irritations were observed on the coral living tissue. These are most likely a result of allopathic interactions, surrounding tight adherent zones between coral-coral and coral-algae. Finally, at sites JAR07P and JAR11P, a few large colonies (>100 cm diameter) of *Porites*, *Leptastrea*, as well as some smaller *Montipora* exhibited moderate to marked infestation by tube worms (*Spirobranchus*). These cases were detected outside the survey area. It is likely that this type of infestation may eventually compromise the health condition of these coral colonies. Figure B.3.2-3 illustrates the main types of afflictions affecting scleractinian corals at Jarvis Island.

Table B.3.2-2: Summary statistics (mean) of percent benthic cover parameters at Jarvis Island. CCA*: Crustose coralline algae; Other**: Other benthic elements including: fleshy macroalgae, rubble, rock, soft corals, etc.).

	Coral cover	Dead	Pavement	Sand	CCA	Other
JAR09	**72.5**	**2.9**	**5.9**	**0.0**	**13.7**	**4.9**
JAR08	**2.9**	**0.0**	**9.8**	**0.0**	**1.0**	**86.3**
JAR01	**2.9**	**0.0**	**53.9**	**0.0**	**23.5**	**19.6**
JAR10	**19.6**	**0.0**	**14.7**	**0.0**	**29.4**	**36.3**
JAR04P	**52.0**	**10.8**	**1.0**	**0.0**	**18.6**	**17.6**
JAR02	**72.5**	**2.0**	**0.0**	**0.0**	**25.5**	**0.0**
JAR12	**9.8**	**2.0**	**0.0**	**0.0**	**16.7**	**71.6**
JAR07P	**23.5**	**1.0**	**1.0**	**5.9**	**15.7**	**52.9**
JAR11P	**79.4**	**1.0**	**1.0**	**1.0**	**14.7**	**2.9**
Mean	**31.5**	**3.9**	**18.2**	**2.4**	**11.1**	**31.4**
Std Err	**7.7**	**0.9**	**4.4**	**0.6**	**2.7**	**7.6**

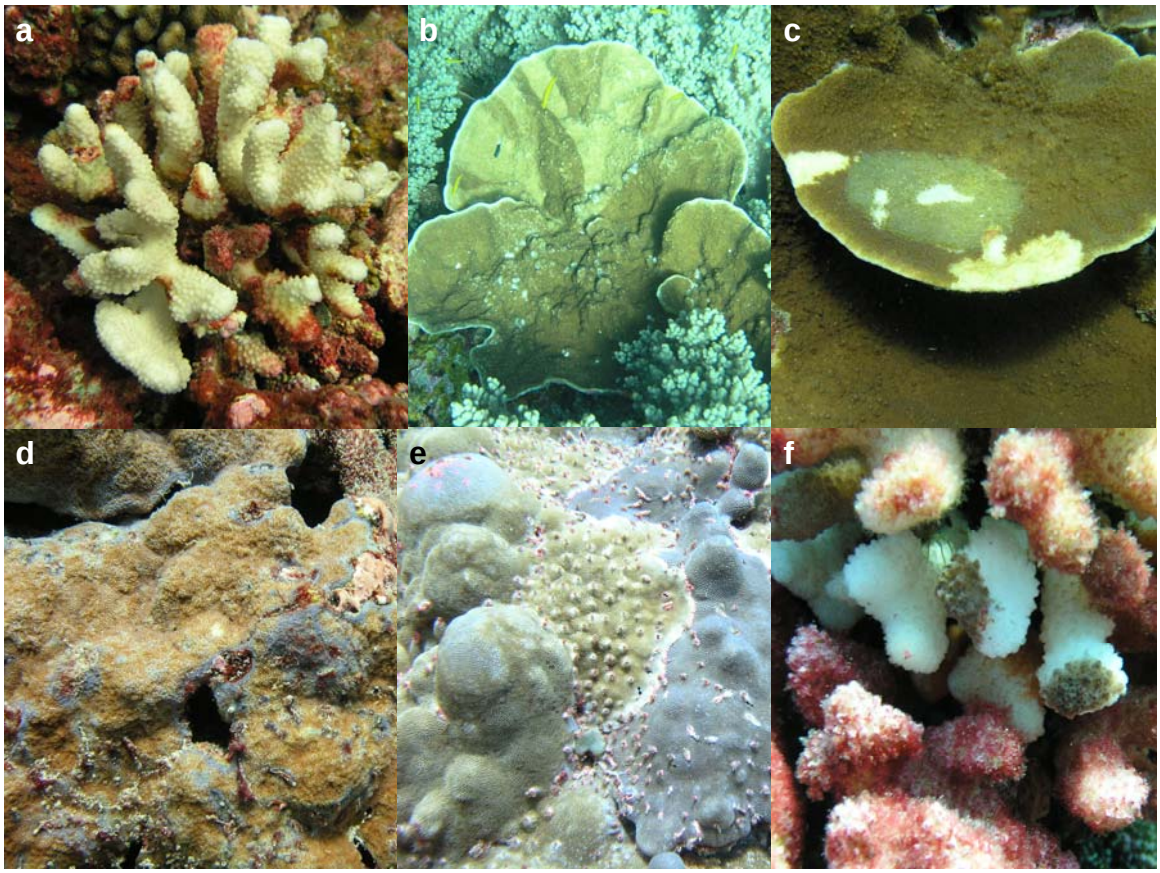


Figure B.3.2-3: Underwater photographs illustrating selected types of afflictions affecting scleractinian corals at Jarvis Island, 2006. a. Discoloration (paling) and partial mortality on *Pocillopora*. b. Discoloration on *Montipora*. c. Predation marks on *Montipora*. d. Irritation and discoloration (shades of blue) on *Montipora* (attributable to coral-algal allopathic interaction). e. Tubeworm (cf. *Spirobranchus*) infestation on *Porites*. f. Tissue loss on *Pocillopora* (attributable to predation and/or damselfish algal lawn expansion).

B.3.2.3. Coral REA Site Description

JAR09: (3-20-2006: 00°21.923'S, 160°00.385'W)
Northwest, ocean fringing reef slope; approx. 50 degree slope. Depth range: 12–14 m. Mean coral cover was 72%. Low coral diversity dominated by *Montipora* cf. *grisea/effusa* and *Pocillopora verrucosa/meandrina/eydouxi*. Crustose coralline algae contributed nearly 17% of the total bottom cover. Other corals observed in the survey area included: *Porites* cf *lobata*, *Favia stelligera*, *Pavona duerdeni*, *Pavona* cf. *chiriquiensis*, *Pavona varians*, *Pavona explanulata*, *Hydnophora microconos*, and *Psammocora*. Coral health and disease assessment: No diseases were observed. Some colonies of *Pocillopora* exhibited partial mortality, mainly associated with damselfish algal gardens.

JAR08: (3-20-2006: 00°21.803'S, 159°59.468'W)
North side of island; ocean fringing reef. Gentle slope, <10 degrees. Depth range: 13–15 m. Mean coral cover was close to 3%. Scleractinian genera observed in the survey area included: *Montipora*, *Pocillopora*, *Pavona*, *Fungia*, *Acropora*, and *Porites*. Community dominated by creeping red fleshy macroalgae overgrowing staghorn and tabular *Acropora* rubble. This algal consortium contributed 86% of the bottom cover. Coral health and disease assessment: No coral diseases observed.

JAR01: (3-20-2006: 00°22.071'S, 159°58.771'W)
East-northeast side of island; ocean fringing reef. Gentle slope, <10 degrees. Depth range: 13–15 m. Mean coral cover was close to 3%. Scleractinian genera observed in the survey area included: *Montipora*, *Pocillopora*, *Pavona* (*P. varians*, *P.* cf. *chiriquiensis*, and *P. maldivensis*), *Fungia*, *Acropora*, *Porites, and Leptoseris*. Several *Pocillopora* recruits were observed settled on tabular *Acropora* rubble. Community dominated by creeping red fleshy macroalgae and crustose coralline algae overgrowing tabular *Acropora* rubble. This algal consortium contributed over 40% of the bottom cover. Coral health and disease assessment: One case of partial bleaching was observed on *Pocillopora* cf. *verrucosa*.

JAR10: (3-21-2006: 00°22.835'S, 159°58.386'W)
Southeast shelf, ocean fringing reef. Depth range: 13–14 m. Mean coral cover was close to 19.6%. Relatively flat bottom mainly composed of staghorn and tabular *Acropora* rubble with crustose coralline and red macroalgal overgrowth. This algal consortium contributed over 55% of the bottom cover. Scleractinian corals observed in the survey area included: *Montipora*, *Pocillopora*, *Pavona* (*P*. cf. *chiriquiensis*, *P. maldivensis*), *Acropora*, and *Porites* and the hydrocoral *Millepora*. Coral health and disease assessment: Three cases of paling were observed on *Pocillopora* cf. *verrucosa*. In addition, several cases of partial mortality were observed on *Pocillopora* and *Montipora*.

JAR04P: (3-21-2006: 00°22.903'S, 159°59.907'W)
South, ocean fringing reef, approx. 40–50 degree slope Depth range: 12–15 m. Mean coral cover was relatively high (51.9%). Relatively low diversity; community dominated by platy *Montipora* (*M*. cf. effusa/grisea) and *Pocillopora* spp. Other scleractinian corals observed in the general area included: *Pavona* (*P*. cf. *chiriquiensis*, and *P. explanulata*), *Favia stelligera*, *Acropora*, *Fungia*, *Psammocora* cf. *superficialis*/*verrilli*, and *Hydnophora*, and the hydrocoral *Millepora*. Coral health and disease assessment: Scattered small blemishes, mainly on platy *Montipora* were observed, probably caused by corallivores. Also, predation marks were observed on colonies of *Hydnophora microconos.*

JAR02: (3-21-2006: 00°22.897'S, 160°00.493'W)
South, ocean fringing reef, approx. 40 degree slope Depth range: 12–15 m. Mean coral cover was high (72.5%). Relatively low diversity; community dominated by platy *Montipora* (M. cf. effusa/grisea? or *M. aequitrabeculata*; J. Maragos) and *Pocillopora* spp. Other scleractinian corals observed in the general area included: *Pavona* (*P*. cf. *chiriquiensis*, and *P. explanulata*), *Favia stelligera*, *Acropora* (at least 2 species; *A.* cf.

clathrata and *A.* cf. *cytherea*), *Fungia*, *Psammocora* cf. *superficialis*/*verrilli*, *Leptoseris*, *Pavona duerdeni*, and *Hydnophora*, and the hydrocoral *Millepora*. Coral health and disease assessment: Scattered small blemishes, mainly on platy *Montipora*, probably caused by corallivores.

JAR12: (3-22-2006: 00°22.950'S, 159°09.033'W)
South-southeast. New site, ocean fringing reef; approx. 45 degree slope Depth range: 12–14 m. Mean coral cover was low (9.8%). Relatively low diversity; community dominated by platy *Montipora* (M. cf. effusa/grisea? or *M. aequitrabeculata*; J. Maragos) and *Pocillopora* spp. Other scleractinian corals observed in the general area included: *Pavona duerdeni, Leptoseris*, *Fungia*, *Hydnophora*, and *Porites*, the hydrocoral *Millepora*. Coral health and disease assessment: Scattered small blemishes, mainly on platy *Montipora*, probably caused by corallivores. Also, partial mortality observed on several colonies of *Pocillopora* spp., most likely caused by herbivorous damselfish.

JAR07P: (3-22-2006: 00°22.592'S, 160°00.883'W)
West-southwest. Upwelling site. Ocean fringing reef; approx. 30 degree slope Depth range: 12 m. Mean coral cover was low (23.5%). Relatively low diversity; community dominated by soft corals of the genus *Sinularia*. Few intermingled scleractinian corals occurred among the Sinularia carpet, including *Montipora* (M. cf. effusa/grisea? or *M. aequitrabeculata*; J. Maragos), *Pocillopora* spp., and *Pavona* cf. *chirquiensis*. Other scleractinian corals observed in the general area included: *Pavona duerdeni, P. explanulata*, *P. varians*, *P. maldivensis*, *Psammocora*, *Leptoseris*, *Fungia*, and *Hydnophora*. Coral health and disease assessment: No coral diseases detected within the survey area. Once, a case of discoloration was observed on *Montipora* cf. *effusa*/*grisea*. Scattered small blemishes, mainly on platy *Montipora*, probably caused by corallivores. In addition, several large colonies of *Porites* cf. *lobata* and *P*. cf. *lutea* exhibited moderate to marked infestation of tube worms (*Spirobranchus*).

JAR11P: (3-22-2006: 00°22.158'S, 160°00.515'W)
West. Upwelling site. Ocean fringing reef; approx. 40 degree slope. Depth range: 12–14 m. Mean coral cover was high (79.4%). Community dominated by *Montipora* (M. cf. effusa/grisea? or *M. aequitrabeculata*; J. Maragos) shingles. Other scleractinians present in order of importance included; *Pocillopora* spp. *Pavona duerdeni, P. varians*, *Leptoseris*, *Favia stelligera*, and *Hydnophora microconos*. Coral health and disease assessment: No coral specific diseases detected within the survey area. However, several large colonies of *Porites*, *Leptastrea*, and a few smaller *Montipora* exhibited moderate to marked infestation of tube worms (*Spirobranchus*).

B.3.2.4. Towed-diver Survey - Corals
The benthic towed-diver surveys corroborated the findings of the REA investigations in that the western and southern shores of Jarvis Island showed an abundance of live hard coral, with the majority of areas exhibiting greater than an estimated 50% cover. *Montipora* appeared to be the dominant coral present along these shorelines. Hard coral cover along the northern shore and heading south along the eastern terrace was low; less

than ~5% cover. Coral cover in the southeastern terrace was dominated by both *Montipora* and *Pocillopora*.

B.3.3. Invertebrates

The purpose of the REA activities for HI-06-04 was to select sites surveyed during previous rapid ecological assessments for long-term monitoring. Selection of sites was based on their year-round accessibility and their representation of the habitats present at each site. Surveys focusing on marine invertebrates other than corals were performed in conjunction with surveys of coral and macroalgae, collectively termed the benthic survey. This benthic survey was conducted collaboratively with fish surveys. This report will cover the non-coral invertebrates encountered and from this point forward any mention of marine invertebrates refers to this particular group.

B.3.3.1. Invertebrate REA Site Descriptions

JAR10: (3-21-2006: 00°22.835'S, 159°58.385'W)
Southeast edge of an extensive reef terrace on the eastern side of the island. Initial impressions were that it is an area that receives heavy currents and wave energy because many filter and suspension feeding sessile organisms were present. A diverse and abundant macroinvertebrate community composed of gastropods, hermit crabs, other mobile crustacea, and a variety of sessile fauna existed at the site. The sessile fauna was made up of sponges, hydrozoans, and bryozoans. The most numerous sessile organisms were a sponge from the genus *Dysidea* (see photo) that had a purple and green morph, and the hydroid *Pennaria*. The hydrozoan *Distichopora* (see photo) was common but was patchy in its distribution.

JAR08: (3-20-2006: 00°21.802'S, 159°59.468'W)
Central north side with a gently fringe reef. Macroinvertebrate populations were low except for cryptic sessile fauna. The only common mobile macroinvertebrates were the sea stars *Linckia multifora* and *Linckia guildingi*. This area has received a grand scale natural disturbance where the majority of corals have been killed. A red turf algae dominates the substrate throughout the site. Cryptic sessile and mobile fauna can be found associated with unconsolidated reef rubble. These cryptic organisms were usually bryozoans and didemnid tunicates and mobile crustaceans (shrimp and crabs). The holothuroid *Holothuria atra* was present but uncommon as was the large hermit crab *Aniculus* sp. (see photo)

JAR09: (3-20-2006: 00°21.925'S, 160°00.385'W)
Northwest side of island with a steep sloped fringing reef. High coral cover of *Montipora*, *Acropora*, and *Pocillopora*. The dominant macroinvertebrate faunas were echinoderms and cryptic crustaceans. The echinoderms present were the sea stars *Linckia multifora* and *Linckia guildingi*, the holothuroid *Holothuria atra,* and the urchin *Echinothrix*. Cryptic trapezid crabs were abundant in the *Pocillopora* heads, as were hermit crabs.

JAR01: (3-20-2006: 00°22.070'S, 159°58.772'W)
Northeast side of island on the northern edge of an extensive terrace formation. This site was similar to JAR-08 but showed signs of historical high coral cover. The unconsolidated rubble at this site showed both massive plate and finger forms of coral, which has been killed by a grand scale natural disturbance. The red turf algae present at JAR-08 was abundant at this site as well. All macroinvertebrate species present were uncommon. These species were the sea stars *Linckia multifora* and *Linckia guildingi*, the holothuroid *Holothuria atra*, the urchin *Echinothrix*, and the diogenid hermit crab *Dardanus*. The *Dardanus* hermit crab has been described as a new species (Asakura and Godwin, In Prep) from specimens collected on OES-04-04 (see photo). So far this species has only been described from Howland Island, Baker Island, and Jarvis Island.

JAR02: (3-21-2006: 00°22.878'S, 160°00.494'W)
Western end of south shore with steep fringing reef in association with a shallow terrace. High coral cover composed most commonly of *Montipora* and *Pocillopora*. Only one transect was completed at this site for the whole REA team because of unforeseen circumstances. Echinoderms were the only common macroinvertebrate species present. These were found along the steep slope and were composed of the sea star *Linckia multifora*, the holothuroids *Holothuria atra,* and *Actinopyga obesa*. An unknown zoanthid was rare at the site.

JAR04P: (3-21-2006: 00°22.903'S, 159°59.907'W)
Central south shore. *Montipora* and *Pocillopora* dominated community with abundant crustacean and gastropod faunas. The dominant macroinvertebrate species were hermit crabs of two genus, *Calcinus* and *Dardanus*, cone shell gastropods and the sea urchin *Echinothrix calamaris*. Octopuses were noted uncommonly throughout the site. Trapezid crabs were seen commonly in *Pocillopora* heads.

JAR07P: (3-22-2006: 00°22.591'S, 160°00.058'W)
Southwest corner of the island. Reef structure composed of buttresses and channels with extensive sand expanse at the base. The habitat was dominated by the soft coral *Sinularia* and the hard coral *Pocillopora*. The sea star *Linckia multifora* and *Echinothrix calamaris* sea urchins were common. A single Tridacnid maxima giant clam was recorded on the upper portion of a buttress. The holothuroid *Holothuria atra* was also common in the sand patch areas.

JAR11P: (3-22-2006: 00°22.170'S, 160°00.515'W)
Central west shore. *Montipora* and *Pocillopora* dominated community inhabited mainly by echinoderms, gastropods, and crustaceans. Two species of sea stars, *Linckia multifora* and *Linckia guildingi* were extremely abundant throughout the habitat. Also abundant were the sea urchins *Echinothrix* and *Diadema*. Octopuses were noted but were uncommon throughout the habitat.

JAR12: (3-22-2006: 00°22.950'S, 159°09.033'W)
Southeastern tip of the island with sloping fringing reef. High coral cover with *Montipora* and *Pocillopora*. The only common macroinvertebrates present were cryptic trapezid

crabs within the *Pocillopora* heads. The hermit crab *Dardanus*, which is a new species (see photo) was present but uncommon. There were sparse echinoderms at the site, these being the sea urchin *Echinothrix* and the holothuroid *Holothuria atra*.

B.3.3.2. Specific Findings for Invertebrates

Table B.3.3.2-1 summarizes the relative abundance data for most common species enumerated during REA surveys and percent cover for sponges and cnidarians.

Table B.3.3.2-1Relative abundance data for most common species enumerated during REA surveys and percent cover for sponges and cnidarians.

Island	Jarvis	Jarvis	Jarvis	Jarvis	Jarvis	Jarvis	Jarvis	Jarvis	Jarvis
Date	3/20/2006	3/20/2006	3/20/2006	3/21/2006	3/21/2006	3/21/2006	3/22/2006	3/22/2006	3/22/2006
Site	JAR-09	JAR-08	JAR-01	JAR-10	JAR-4P	JAR-02	JAR-12	JAR-7P	JAR-11P
Depth(feet)	52	51	45	47	30	49	45	50	52
Habitat	Fringing Reef	Fringing Reef	East Reef Terrace	East Reef Terrace	Fringing Reef	Fringing Reef	East Reef Terrace	Fringing Reef	Fringing Reef
	Avg%Cover/m2	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**
Porifera	0	0	0	7.2	0	0	0	0	0
Cnidaria									
Hydroidea	0	0	0	0	0	0	0.1	0	0
Sinularia	0	0	0	0	0	0	0	54	0
	Avg#/m2	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**
Echinoids									
Echinothrix sp.	0.014	0	0.215	0.064	0.002	0	0.022	0	0.028
Diadema	0	0	0	0	0	0	0	0	0.12
Holothuroids									
Holothuria atra	0.01	0.004	0.002	0	0	0.032	0.006	0.016	0
Actinopyga obesa	0	0	0	0	0	0.008	0	0	0
Other Holothuroid	0	0	0	0	0	0.004	0	0	0
Asteroidea									
Linckia multifora	0.002	0.012	0.002	0.008	0.01	0.032	0	0.01	0.008
Linckia guildingi	0.022	0	0.002	0.002	0.004	0	0	0.004	0.012
Acanthaster planci	0	0	0	0	0	0	0	0	0
Crustacean									
Trapezid crabs	2.8	0	0	2.8	2.6	0	1	1	1.8
Hermit Crabs	1.2	0	0	0	0.4	0	0.2	0	0.2

B.3.3.3. Benthic Towed-diver Survey - Macroinvertebrates

Overall there was a low abundance of observed macroinvertebrates. Although urchins were the most abundant, their numbers never exceeded 75 during a 5-minute segment of a tow. They were observed frequently along the eastern terrace but rarely around the rest of the island. Sea cucumbers were observed around the entire island in low numbers. Although not recorded, the starfish, *Linkia multifora*, was observed and noted to be abundant along the western and southern shores and the eastern terrace. In addition, an unidentified lime green and light purple sponge was observed growing on the live coral heads in the southeastern terrace region.

A pocket of soft coral, *Sinularia*, stretching for approximately 400 m was recorded just north along the southwestern corner. The soft coral in this area covered over ~50% of the habitat surveyed. Soft coral was not documented anywhere else around the island with

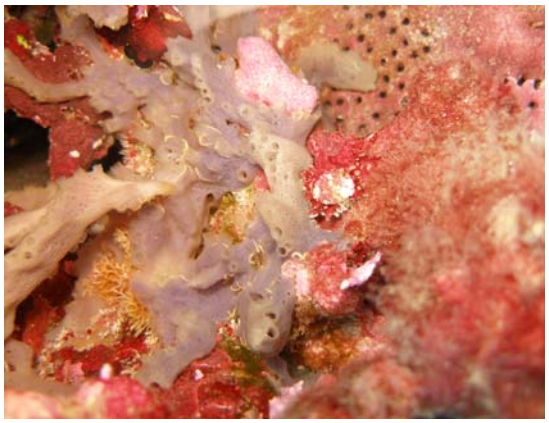
an exception of a small section along the northeast end of the island where divers documented it to cover less than ~10% of the total habitat.

B.3.3.4. Invertebrates Discussion

The abundance of common macroinvertebrates groups was not uniform throughout Jarvis Island. The only macroinvertebrate species seen throughout all sites (although, not always falling within the boundaries of the transect) were the asteroid *Linckia multifora* and the echinoid *Echinothrix*. The abundance and diversity were skewed towards the western habitats. The exception was site JAR10 on the southeastern edge of the east reef terrace. This site differed from others on the east side in that the coral cover was greater and the diversity was increased by abundant sessile fauna such as sponges (*Dysidea?)* and the hydrozoan *Distichopora* (Fig. B.3.3-1). Sites JAR08 and JAR01 are disturbed sites in a state of recovery and are dominated by red turf algae. An extensive coral community with large plate and finger growth forms once existed at both JAR08 and JAR01, which is revealed in the unconsolidated rubble throughout both sites. The southwestern and western regions of the site appear to not have been affected by whatever event that killed off the corals in the northeast region. The upwelling influence on the western side is very apparent by the distinct monotypic stands of soft coral (*Sinularia* sp.) associated with this area. Assemblages of *Sinularia* at this level of cover have not been observed anywhere else around Jarvis Island in 2002, 2004, or the present survey, with the exception of a discrete patch on the northern reef. The unique set of oceanographic conditions at Jarvis Island appear to allow more than adequate levels of larval recruitment and primary productivity to support the diverse and abundant assemblages of mobile and sessile marine invertebrates located on the western end. All these observations are corroborated by benthic towboard surveys, especially the *Sinularia* sp. dominated by habitats on the southwest and central west shorelines.

A new species of hermit crab from the genus *Dardanus* was recorded at JAR01 and JAR04P. This hermit crab was recently described as a new species (Asakura and Godwin, In Prep) from specimens collected on OES-04-04 (Fig. B.3.3-1). So far this species has only been described from Howland Island, Baker Island, and Jarvis Island.

JAR-10, Distichopora sp (Cnidaria, Hydrozoa)



JAR-10, Dysidea (Porifera)

JAR-08 Aniculus sp. (Crustacea; Anomura; Diogenidae)

JAR-12 Dardanus sp. (Crustacea; Anomura; Diogenidae)

Figure B.3.3-1: Underwater photographs of representative components of the macroinvertebrate faunal assemblage at Jarvis Island.

B.4. Fish

The fish REA team (Craig Musburger, Paula Ayotte, and Todd Wass) surveyed nine sites around Jarvis Island while the towed-diver fish survey team (Stephane Charette, Amy Hall, and Edmund Coccagna) conducted twelve towed-diver fish surveys totaling 24.24 km in length. Survey efforts were spread around all shores of the island as weather was excellent and conducive to surveying all exposures.

All of the REA sites were monitoring sites visited during previous cruises except for one new site (JAR12) located on the southeast tip of the emergent land of the island. Quantitative belt transects (BLT), stationary point counts (SPC), and qualitative REA surveys (for species presence) were conducted at each site, using the same methodology as in previous years. At site JAR-02, quantitative survey efforts were cut short after a manta ray (*Manta birostris*) snapped the line securing the team's surface marker float. Safety concerns necessitated that quantitative efforts be cut short as fish team divers

surfaced to replace the broken float. During this dive, fish REA team members successfully completed one of three transects and two of four SPCs. The benthic team (corals, algae, invertebrates) followed the fish team at all survey sites.

The reefs at Jarvis Island support an exceptionally high density of reef fishes. Sharks, groupers, jacks, and snappers were common at every REA site surveyed. A total of 165 fish species were recorded by the fish REA divers at Jarvis. Numerically, three fish species dominated the fish fauna at Jarvis. Collectively, Bartlett's anthias (*Pseudanthias bartlettorum)*, Whitley's splitfin (*Luzonichthys whitleyi)*, and the fusilier damselfish (*Lepidozygous tapeinosoma)* made up 60% of all the fish observed. Schools of these three species of small-bodied planktivores were observed at nearly every site with groups sometimes including thousands of individuals. Among larger-bodied fishes, black jacks (*Caranx lugubris*), spotted hind (*Cephalopholis miniata*), doublebar goatfish (*Parupeneus insularis*) along with several species of surgeonfish including the bluespotted bristletooth (*Ctenochaetus marginatus*), the bluelip bristletooth (*C. cyanocheilus*), and the goldrim surgeonfish (*Acanthurus nigricans*) were most abundant. Grey reef sharks (*Carcharhinus amblyrhynchos*), whitetip reef sharks (*Triaenodon obesus*), and manta rays (*M. birostris*) were also abundant.

The towed-diver surveyors recorded a total of 2551 fishes at Jarvis, with the most abundant species observed being the bigeye trevally (*Caranx sexfasciatus*); 1000 individuals were counted in one large aggregation. The blackmargin barracuda *(Sphyraena qenie*) was the second most frequently observed fish with a total of 333 recorded, the majority of which were counted in two large assemblages. Other notable observations included nine manta rays (*M. birostris*), two Napoleon wrasses (*Cheilinus undulatus*) and one bumphead parrotfish (*Bolbometopon muricatum*). The gray reef shark (*Carcharhinus amblyrhyncos*) was the most frequently observed species that was not part of a large aggregation, followed by the sleek unicornfish (*Naso hexacanthus*) with 309 and 213 observations, respectively.

The most commonly observed family by towed-diver surveyors was the Carangids with 1278 sightings, 1000 of which were observed in the one large school of *C. sexfasciatus*. The Carcharhinids were the second most frequently observed family with 369 counted. The grey reef shark (*C. amblyrhynchos*) accounted for the majority of these with 309 sightings, followed by the white tip reef shark (*Triaenodon obesus*) and the black tip reef shark (*C. melanopterus*) with 32 and 22 observations, respectively. Another notable family observed was the *Sphyrnidae*s (hammerheads) with eight recordings of which six were the scalloped hammerhead (*Sphyrna lewini*) and two great hammerheads (*Sphyrna mokarran*).

B.4.1. Regional Summary

Jarvis Island can be divided into four regions: (1) A Northern Reef Slope, (2) a Western Reef Slope, (3) a Southern Reef Slope, and (4) an Eastern Terrace. Following are brief summaries of the fish observations of the fish REA team and the towed-diver fish observers by region. Please refer to the map of REA sites (Fig. B.3-1) and the map of towed-diver surveys (Fig. B.3-2) for specific site and tow track locations. Because of the small size of the island, tows frequently overlapped between the four regions.

Northern Reef Slope
REA sites JAR-01 and JAR-08; Towed-Diver Surveys 1, 2, and 12

SPCs on the Northern Reef Slope revealed a high abundance of grey reef sharks (*Carcharhinus amblyrhynchos)*, with individuals up to 190 cm TL being observed. As many as 10 individuals were observed during a single SPC. Among jacks (family Carangidae), black jacks (*Caranx lugubris*) were most common and a school of nearly 20 extremely large (up to 120 cm TL) rainbow runners (*Elegatis bipinnulata)* were observed. Manta rays (*Manta birostris)* were also common, with three individuals being recorded within the boundaries of SPCs. Snappers were relatively scarce and consisted of smalltooth jobfish (*Aphareus furca)*, twinspot snapper *(Lutjanus bohar)*, and onespot snapper (*L. bohar)* only. Groupers, mostly the coral hind (*Cephalopholis miniata*) and peacock hind (*Cephalopholis argus*) were common, and a few large lyretail groupers (*Variola louti*) were observed. Parrotfish were scarce on SPCs on the Northern Reef Slope.

Belt Transects in this region were largely dominated by the three extremely abundant schooling planktivores: Bartlett's anthias (*Pseudanthias bartlettorum)*, Whitley's splitfin (*Luzonichthys whitleyi)*, and fusilier damselfish (*Lepidozygous tapeinosoma)*. Also present among these schools, but drastically lower in abundance, were yellowtail anthias (*P. olivaceus)*. The most diverse family observed along transects in this region was the wrasse family (Labridae) with 4-10 species observed per transect. Surgeonfish (family Acanthuridae) were also common and diverse with approximately four different species observed along each transect. Other fish that were extremely abundant along belt transects in this region were bicolor chromis *(Chromis margaritifer*) and flame angelfish (*Centropyge loricula),* which were especially abundant at site JAR-08.

On the north side, one full and two partial towed-diver surveys were conducted totaling 2.54 km.The grey reef shark (*C. amblyrhyncos*) was the most frequently seen species with 75 observations. The black trevally (*C. lugubris*) was the next most frequently seen fish species with 58 observations. Out of 16 species, 188 individual fish were recorded in this area, and no large aggregations were observed.

Western Reef Slope
(REA sites JAR-07, JAR-11, and JAR-09; Towed-Diver Surveys 4, 5, and 9)
Along the Western Reef Slope, SPC divers again recorded many grey reef sharks (*Carcharhinus amblyrhynchos)* ranging in size from 120-150 cm TL. Whitetip reef sharks (*Triaenodon obesus*) were also common here. Small- to medium-sized groupers were abundant, especially coral hind (*Cephalopholis miniata*), which was most common at site JAR-11 and lyretail grouper (*Variola louti)* with individuals ranging from 30 to 60 cm TL. Parrotfish (family Scaridae) were scarce; most individuals were either redlip parrotfish (*Scarus rubroviolaceus*) or bridled parrotfish (*S. frenatus*). Surgeon/Unicornfish were abundant and dominated by sleek unicornfish (*Naso hexacanthus)* and it was difficult to distinguish grey unicornfish (*N. caesius),* with

schools of up to 50 individuals observed at site JAR-07. Snapper consisted mostly of twinspot snapper *(Lutjanus bohar)* and smalltooth jobfish (*Aphareus furca).*

Based on BLT surveys, the three schooling planktivores, Bartlett's anthias (*Pseudanthias bartlettorum)*, Whitley's splitfin (*Luzonichthys whitleyi)*, and fusilier damselfish (*Lepidozygous tapeinosoma)* again dominated with up to 2000 individuals observed on a single transect. There appeared, however, to be relatively fewer fusilier damsels in these aggregations than in other regions of the island. Wrasses and damselfish showed the highest diversity along Western Reef Slope sites. Two wrasse species, the sixstripe wrasse (*Pseudocheilinus hexataenia*) and the eightstripe wrasse (*P. octotaenia*), were especially common. One large black-blotched stingray (*Taeniurus meyeni*) was observed in this region. Surgeonfish consisted mostly of bluespotted bristletooth (*Ctenochaetus marginatus*) and goldrim surgeonfish (*Acanthurus nigricans*) as well as large schools of sleek unicornfish (*N. hexacanthus*). Hawkfishes (family Cirrhitidae) were especially abundant and diverse at Western Reef Slope REA sites. Six species were observed from this family, including the often rare yellow hawkfish (*Paracirrhitus xanthus*) and whitespotted hawkfish (*Cirrhitops hubbardi*). Angelfish (family Pomacanthidae) were also common and were dominated by flame angels (*Centropyge loricula*) and lemonpeel angels (*C. flavissima*). Occasionally recorded were emperor angelfish (*Pomacanthus imperator),* gold-spotted angelfish (*Apolemichthys xanthopunctatus),* and Griffis' angelfish (*Apoemichthys griffisi).*

Two full tows and one partial tow were completed in this region totaling 4.73 km. The bigeye trevally (*Caranx sexfasciatus*) was the most frequently observed fish species with 1000 individuals observed. These fish were all seen in one large aggregation. The next most commonly observed fish species was the blackmargin barracuda (*Sphyraena qenie*), with 183 individuals that were observed in two large schools. The grey reef shark (*C. amblyrhyncos*) and the sleek unicornfish (*N. hexacanthus*) were the most commonly observed species in this region that were not in aggregations, with 93 and 87 individuals counted respectively. Out of 21 species, 1515 individual fish were counted in this area.

Southern Reef Slope
(REA Sites JAR-02, JAR-04, and JAR-12; Towed-Diver Surveys 5, 6, 7, 10, and 11)

SPC divers on the Southern Reef Slope again recorded a high abundance of sharks consisting mostly of grey reef sharks (*Carcharhinus amblyrhynchos)* and a few whitetip reef sharks (*Triaenodon obesus).* A single manta ray (*Manta birostris)* was recorded quantitatively in this region. This individual was exceptionally large – estimated at nearly 4 m in wingspan and took interest in and eventually dislodged the surface float the REA divers had secured to the substrate to mark the transect location. Jacks (family Carangidae) were represented here solely by the black jack (*Caranx lugubris),* which was quite abundant. Schools of sleek unicornfish (*Naso hexacanthus*) were common with up to 17 individuals recorded during a single SPC. Twinspot snapper *(Lutjanus bohar)* were common, and individuals up to 70 cm TL were recorded. Also of note in this region were a school of approximately 65 blackmargin barracuda (*Sphyraena qenie*) and a large school of black triggerfish (*Melichthys niger*), with 50 individuals over 25 cm TL and

many more individuals that were too small to be included in the SPC count. Few groupers or parrotfishes were recorded in this region, although several individual Pacific steephead parrots (*Chlorurus microrhinos)* up to 45 cm TL were recorded.

Based on BLT surveys, the three dominant schooling planktivores were all less common than in other regions, except at site JAR-02 where they remained high. Wrasses (family Labridae) showed highest diversity along Southern Reef Slope sites, with up to 12 species recorded per transect. Soldier/squirrelfishes (family Holocentridae) appeared to be more common here than in other regions, especially bigscale soldierfish (*Myripristis berndti*) and the Tahitian squirrelfish (*Sargocentron tiere*). Butterflyfish were extremely rare, with only five species present and rarely within the boundaries of BLT surveys. Damselfish (family Pomacentridae) were very abundant, with fusilier damsels (*Lepidozygous tapeinosoma*), bicolor chromis *(Chromis margaritifer*), dwarf chromis (*C. acares),* Vanderbilt's chromis (*C. vanderbilti*), and Dick's damsel (*Plectroglyphidodon dickii*) all common. Surgeonfish (family Acanthuridae) were dominated by goldrim surgeonfish (*Acanthurus nigricans*) and bluespotted bristletooth (*Ctenochaetus marginatus*), with bluelip bristletooth (*Ctenochaetus cyanocheilus*) and whitetail bristletooth (*C. flavicauda)* also common. At site JAR-02 a school of more than 20 elongate surgeons (*Acanthurus mata*) of 30 cm TL was observed.

Two full tows and three partial tows were conducted in this region totaling 6.53 km. The blackmargin barracuda (*Sphyraena qenie*) was the most frequently seen fish species in this area. This species was seen in one large school numbering 150 individuals. The next most commonly observed species was the grey reef shark (*C. amblyrhyncos*), with 65 individuals observed. The sole sighting of a bumphead parrotfish (*Bolbometopon muricatum*) was in this southern area. Out of 22 species, 391 individual fish were counted in this region .

Eastern Terrace
(REA Site JAR-10; Towed-Diver Surveys 2, 3, 7, 8, 11, and 12)

A single REA site was conducted on the expansive Eastern Terrace of Jarvis Island. The SPC diver at this site recorded up to as many as five sharks on a single SPC replicate. Grey reef sharks (C*archarhinus amblyrhynchos)* from 60 to 150 cm TL were observed, as were three whitetip reef sharks (*Triaenodon obesus*). Black jacks (*Caranx lugubris)* were again abundant, and several bluefin trevally (*C. melampygus*) were also recorded. Snapper (family Lutjanidae) were abundant and were represented by twinspot snapper (*Lutjanus bohar)* and one-spot snapper (*L. monostigma).* Parrotfish (family Scaridae) appeared to be more common than in other regions, with redlip parrotfish (*Scarus rubroviolaceus*) and bridled parrotfish (*S. frenatus*) dominant. Pacific longnose parrotfish (*Hipposcarus longiceps*) were also recorded here.

Eastern Terrace BLT surveys were dominated by Bartlett's anthias (*Pseudanthias bartlettorrum),* with 1000-2000 individuals recorded per transect. Whitley's splitfin (*Luzonichthys whitleyi)* and fusilier damsels (*Lepidozygus tapeinosoma)* were also extremely abundant, but not as numerous as Bartlett's anthias. Wrasses were abundant

and most common among them were bluntheaded wrasse (*Thalassoma amblycephalum),* fivestriped wrasse (*T. quinquevittatum),* and bird wrasse (*Gomphosus varius).* Several bird wrasses were observed in excess of 25 cm TL, which is quite large for this species. Surgeonfish (family Acanthuridae) were not especially abundant, but were dominated by goldrim surgeonfish (*Acanthurus nigricans*) and bluespotted bristletooth (*Ctenochaetus marginatus*) with a few large (40 cm TL) individual yellowfin surgeons (*Acanthurus xanthopterus)* observed. Butterflyfish (family Chaetodontidae) were more common and diverse here than in other regions with ornate butterflyfish (*Chaetodon ornatissimus)*, raccoon butterflyfish (*C. lunula)*, saddled butterflyfish (*C. ephippium),* Meyer's butterflyfish (*C. meyeri),* and forcepsfish *(Forcipiger flavissimus)* all common. Also of note along BLTs in this region were two large broomtail filefish (*Aluterus scriptus)* and a high abundance of darkfin hind (*Cephalopholis hind)*.

Two full tows and four partial tows were conducted in this region totaling 10.44 km. The sleek unicornfish (*Naso hexacanthus*) was the most frequently seen fish specie with 87 observations. The grey reef shark (*C. amblyrhyncos*) and the twinspot snapper (*L. bohar*) were the next most commonly observed fish species with 82 and 81 individuals, respectively. The Carcharhinids and Carangids were the two most commonly observed fish families in this region with 108 and 93 individuals accounted for respectively. Out of 27 species, 457 individual fish were observed in this area.

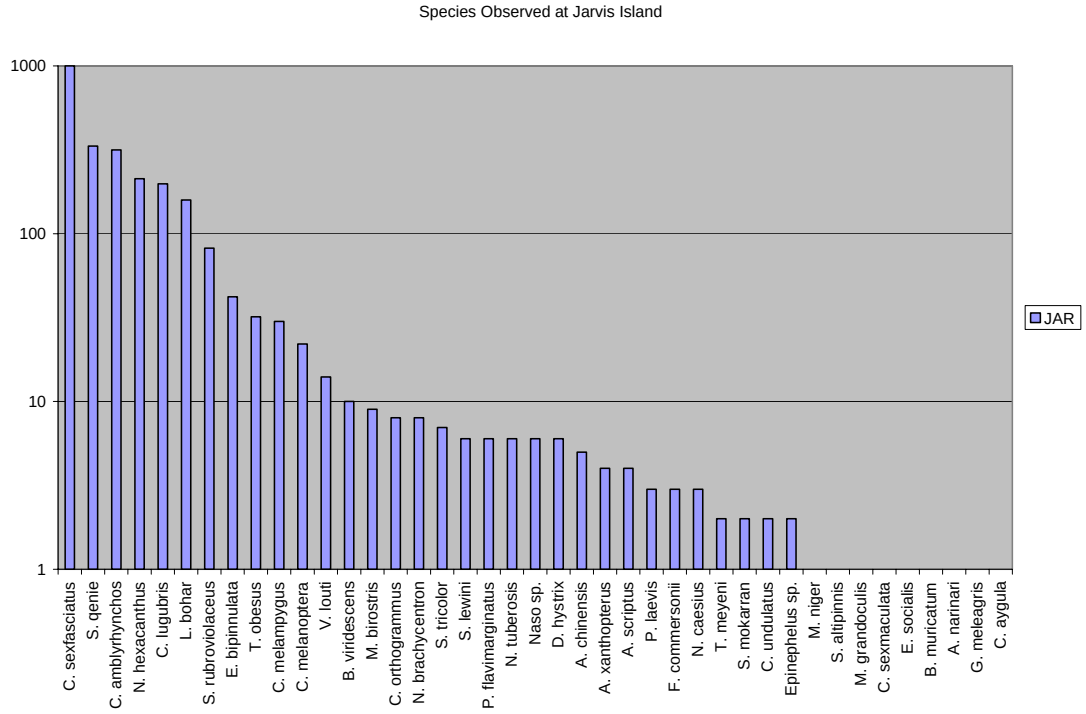


Figure B.4-3: Species observed during towed-diver surveys at Jarvis Island.

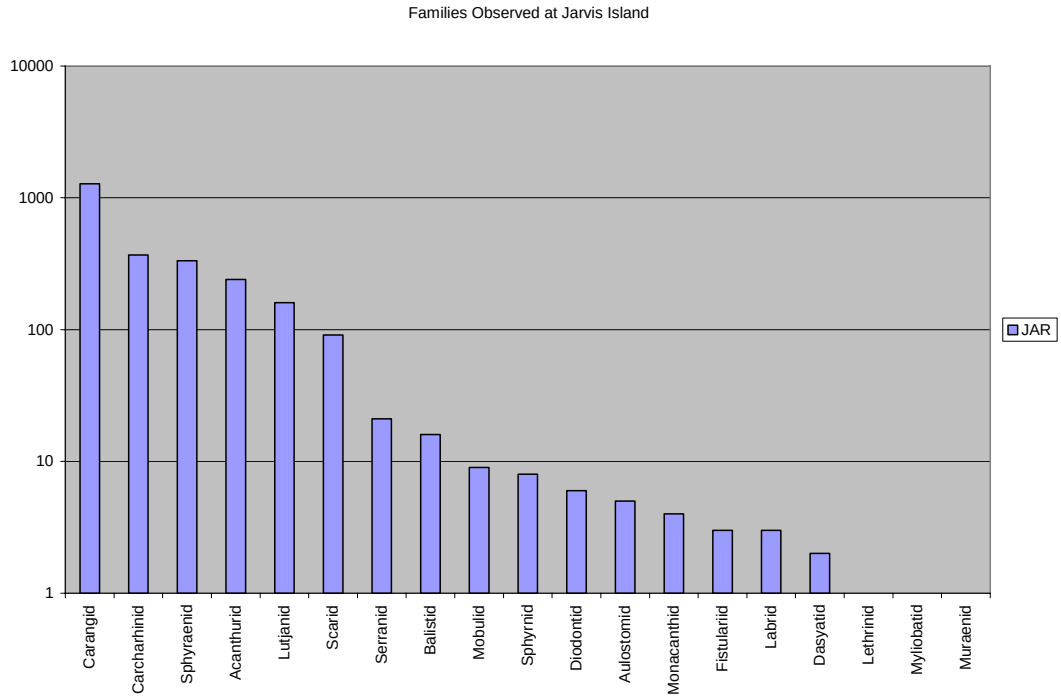


Figure B.4-4: Families observed during towed-diver surveys at Jarvis Island.

B.5. Terrestrial Studies

Terrestrial surveys were not conducted during HI-06-04.

Appendix C: Palmyra Atoll

C.1. Benthic Habitat Mapping

Between the 24th and 28th of March 2006, HI0604 multibeam mapping efforts resulted in nearly complete coverage of the seafloor in and around Palmyra Atoll. Approximately 1082 sq. km. of bathymetry were collected in waters ranging from <10 to 3500 meters below sea level (Fig. C.1-1).

The AHI mapped the south shore during the day of March 24 while the ship continued that night by mapping once around the island and adding to the coverage on the south shore. Multibeam coverage collected during July of 2005 by the University of Hawaii research vessel *Kai'imikai O Kanaloa* (KOK) using the SeaBeam Classic was used for reference during the first night of shipboard mapping. The area covered by the KOK was covered again in order to add higher resolution bathymetry and backscatter imagery to the collective multibeam coverage.

Day 2 at Palmyra allowed the *AHI* to map the north shore and the ship to use the nighttime hours to complete the north side and begin mapping on the west side of the atoll. On March 26, the *AHI* went into the west lagoon after a late launch because of passing squalls that morning. Most of the west lagoon was finished and two possible shipwrecks were noted. One shipwreck was previously known, and upon the discovery of its exact location, the oceanography team later (March 28) did an exploratory scuba dive on the wreck to note that it is, in fact, an old fishing vessel. The name of the vessel is yet unknown. The second possible shipwreck was not explored and did not actually show up clearly in the bathymetry during post processing. On the night of March 26th, the mapping team supported the oceanography team with an acoustic Doppler current profiler (ADCP) box around the island. Gaps were mapped where they existed along the track for the ADCP box. On day 4, March 27, the *AHI* finished the west lagoon and central lagoon (Fig. C.1-2), and the day was finished by starting on the shoals of the west bank. The ship continued mapping that night to finish the south side and the east side of the bank. Finally, on the last day, the *AHI* covered more of the shoals on the west bank. With shipboard mapping limits almost reached, mapping supported another night of oceanography efforts by conducting five conductivity-temperature-depth (CTD) casts off the west side of the atoll. The night was finished with one line of multibeam coverage on the far west side, and the ship continued mapping during the transit to Kingman Reef that night from the northwest corner to the launch site at the southeast pass on Kingman.

During the Palmyra portion of HI0604, CTD casts were conducted to 500 m each night before shipboard mapping began.

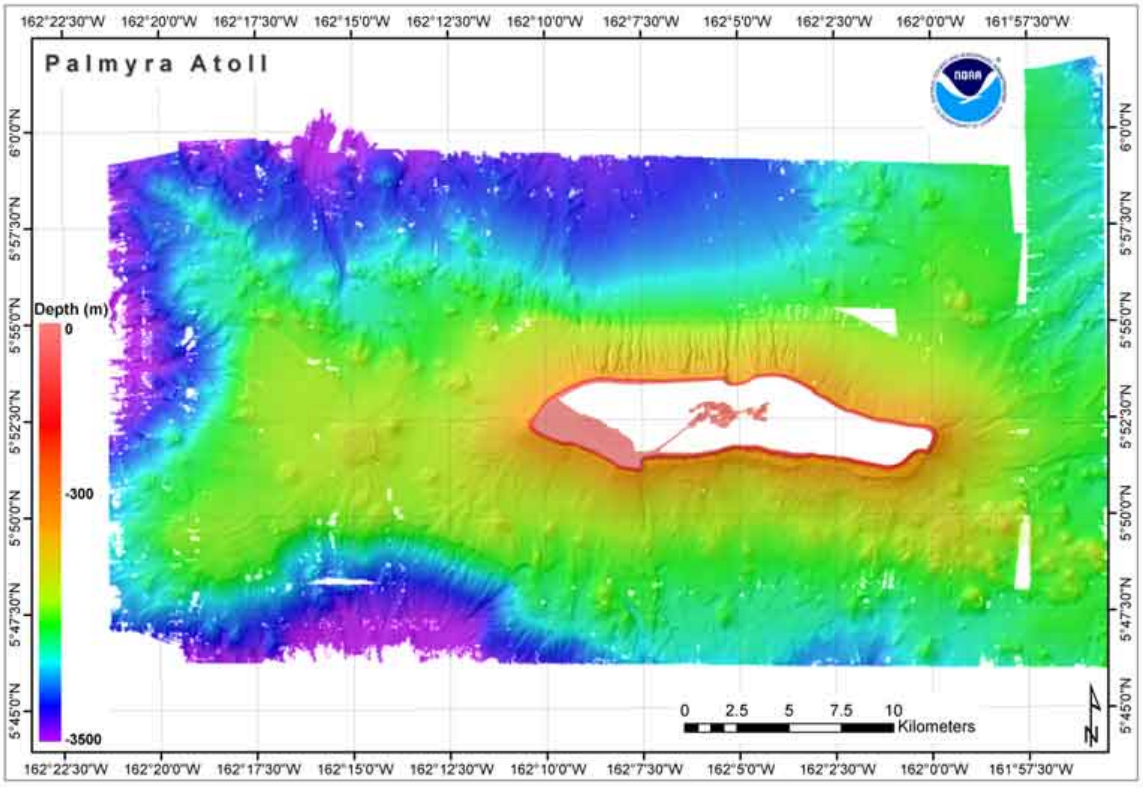


Figure C.1-1: Palmyra Atoll multibeam bathymetry

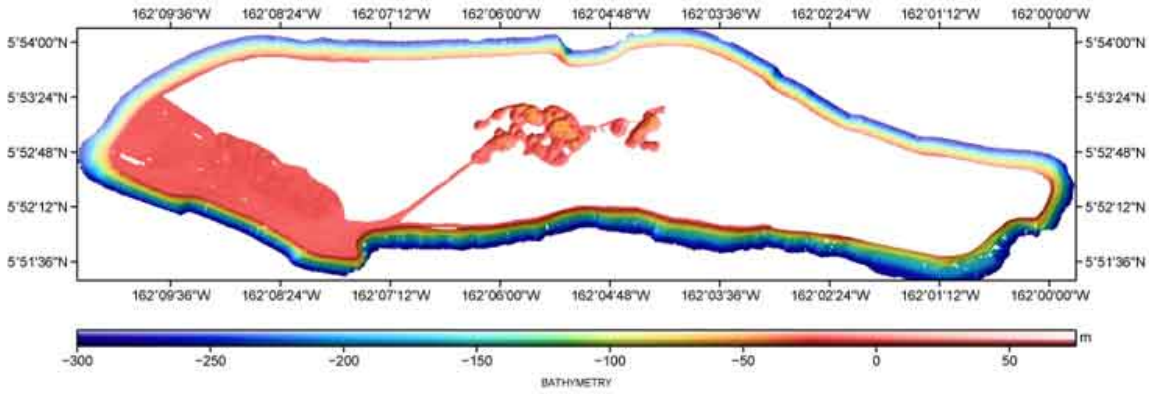


Figure C.1-2: Palmyra Atoll bank top and lagoons multibeam bathymetry

Palmyra Atoll is surrounded by a shallow bank that is less than 100 m below sea level and in most places less than 50 m. The bank is broad on the west but drops off abruptly from the shoal areas on all other sides (Fig. C.1-2). The edges of the bank are incised by canyons, the largest of which are located on the northern side of the atoll (Fig. C.1-3). The northern canyons extend from the bank edge to depths greater than 3000 m. Away from the bank the seafloor around Palmyra is characterized by a number of seafloor highs that vary in relief in size. Some of these, such as those at the southeast base of the bank

may be related to mass wasting. Others such as the flat-topped seafloor high west of the bank are clearly volcanic in origin. The broader, elevated area west of Palmyra is probably an extension of the bank.

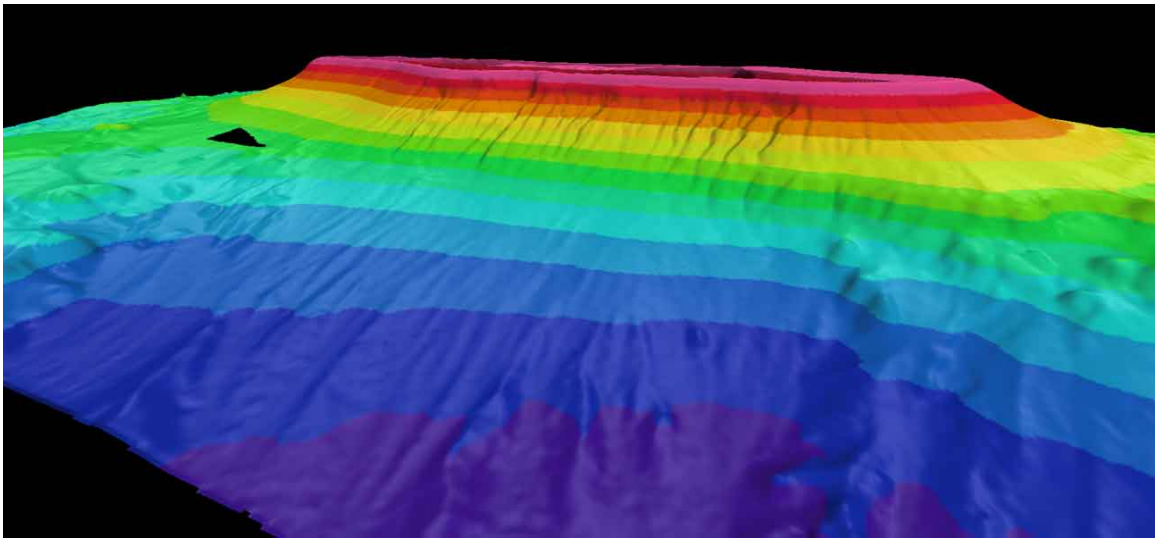


Figure C.1-3: Palmyra Atoll bathymetry on the north side incised by deep canyons.

The lagoons inside the atoll are reached by a dredged channel on the southwest corner; the lagoons (Fig. C.1-4) reach a maximum depth of 52 m. The bathymetry of the lagoons reveals several pockets with shallow, sometimes impassible water depths, connecting them.

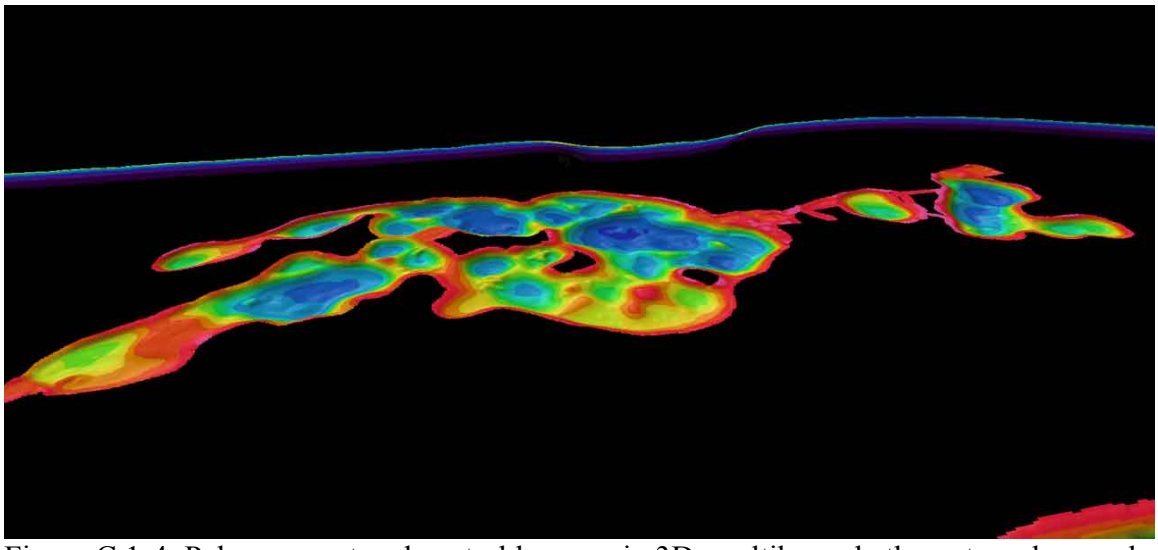


Figure C.1-4: Palmyra west and central lagoons in 3D, multibeam bathymetry where reds to blues are from depths of less than 10 m to ~52 m, respectively.

The mapping team encountered a problem generating bathymetry grids from the Palmyra data using the standard product generation techniques. The problem arose when gridding UTM XYZ data exported from SABER. Typically, grids are generated from UTM XYZ

data using the GMT command xyz2grd and specifying geographic boundaries and appropriate grid cell sizes in the command line. The Palmyra UTM XYZ data resulted in an xyz2grd program termination with a segmentation fault (core dumped) error. This type of error contains no real diagnostic information. Although the geographic coordinates of the UTM XYZ data are reasonable for the atoll's location we speculate that the xyz2grd error may stem from the program's inability to properly locate Palmyra Atoll, which straddles UTM zones 3 and 4 north. To circumvent this problem, we chose an alternative GMT nearest neighbor gridding algorithm (nearneighbor) to create bathymetry grids. The alternative method successfully accepts the Palmyra UTM XYZ data but requires that we specify a search radius in addition to the grid cell size. An average value is assigned to each node that has one or more points within a radius centered on the node. We chose a search radius of 2 times the grid cell size. See the GMT website (www.soest.hawaii.edu/gmt) for more information.

C.2. Oceanography & Water Quality

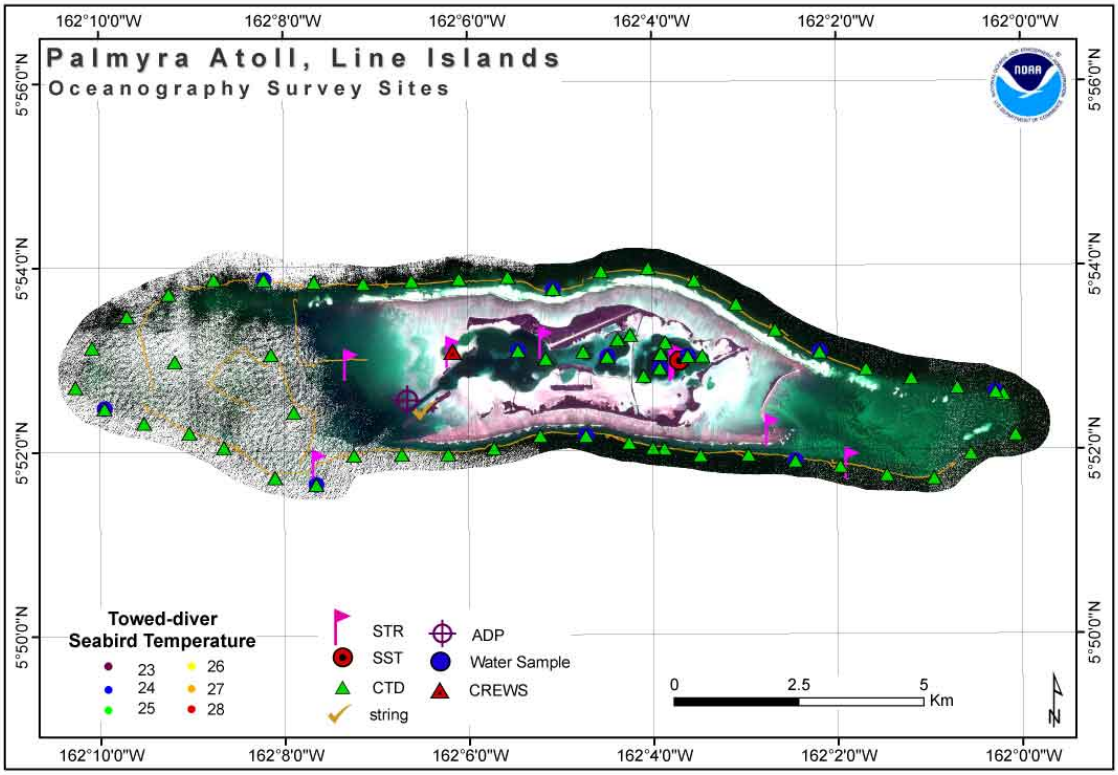


Figure C.2-1: Oceanography sites at Palmyra Atoll

C.2.1. CTD Casts and Water Samples

Fifty-one CTD casts to 33 meters were conducted around the periphery and on the west terrace of the atoll at a 1-km interval in as close to 35 meters of depth as possible, considering the slope of the island and surf conditions. Water quality profiles were conducted at 8 of these sites from which 32 chlorophyll and 32 nutrient samples were

collected. In addition to this circumferential sampling of the atoll, 13 CTD casts were conducted in the lagoons of the atoll to depths allowed at the cast site with 4 water quality profiles being collected from which 16 chlorophyll and 16 nutrient samples were collected.

Nine 500-meter CTD/water quality profile casts were conducted off of the *Hi'ialakai* during night operations. Four of these casts were conducted concurrently with the running of an ADCP box transect around the atoll collecting 24 chlorophyll and 24 nutrient samples. The 5 remaining casts were conducted along an east/west line transect at a 1.8-km interval on the west side of the atoll collecting 30 chlorophyll and 30 nutrient samples. The completed shipboard CTD sampling plan is included in Figure C.2.1-1

Six CTD casts were conducted from the *AHI* to 200 m, and three CTD casts were conducted to 500 meters in support of the mapping effort.

Shipboard CTD, ADCP and Water Sampling Plan
Palmyra Atoll - HI0604

Transect 1: 03/26/06 (CTD/Water Sampling/ADCP)
This will be an 85-km box transect around the island that will hit four of CRED's historical CTD stations. Begin the ADCP transect at pt "CTD001" (the north-central point). Either begin CTD casts or the ADCP transect at this point depending on the 'druthers' of the Survey Tech. Proceed around the transect in a clockwise direction with CTD casts with water samples being conducted at the center of each side of the box. The closest that the transect comes to any shoal area is about 3 km at its closest approach so that proximity is within vessel safety protocols. All casts will be to 500 meters presuming seafloor depth is > 600 meters; if not, cast depth will be reduced (though this should not be an issue). Water samples will be collected according to CRED protocols on all casts.

Transect Positions:

ID	LAT_DEG	LAT_MIN	LAT_H	LONG_DEG	LONG_MIN	LONG_H
CTD001	5	55.73820	N	162	4.87207	W
CNR001	5	55.73820	N	161	58.39100	W
CTD002	5	52.89390	N	161	58.39100	W
CNR002	5	49.94790	N	161	58.39100	W
CTD003	5	49.94790	N	162	4.91270	W
CNR003	5	49.94790	N	162	12.14550	W
CTD004	5	52.87360	N	162	12.14550	W
CNR004	5	55.73820	N	162	12.14550	W

Transect 2: 03/28/06 (CTD/Water Sampling)
This will be a 7-km line transect to the west of the atoll to gather data on any potential upwelling of the subequatorial current. After pumping operations, run back into "CTD005" and work east to "CTD001" (which is 1 mile from the atoll and should be within vessel safety parameters). Each cast will be made to 500 meters of depth and water samples will be collected at 150, 125, 100, 80, 30 and 3 meters in accordance with CRED protocols.

ID	LAT_DEG	LAT_MIN	LAT_H	LONG_DEG	LONG_MIN	LONG_H
CTD001	5	52.76920	N	162	11.16150	W
CTD001	5	52.76220	N	162	12.03530	W
CTD003	5	52.76220	N	162	12.90900	W
CTD004	5	52.76220	N	162	13.78280	W
CTD005	5	52.75530	N	162	14.66350	W

Figure C.2.1-1: Palmyra Atoll Shipboard CTD, ADCP and Water Sampling Plan

C.2.2. Oceanographic Instrumentation Deployments

One Coral Reef Early Warning System (CREWS) buoy was recovered and replaced with a new 540-kg, 3 padeye anchor and recruitment plate array installed. One new sea surface temperature (SST) site was established, while four subsurface temperature recorders (STRs) were recovered and replaced and five new STRs were installed. The new SST site entails the installation of an ATI-SST in East Lagoon in affiliation with a series of three STRs to enable heat flux modeling within the lagoon. The shallowest STR is installed on the anchor of the SST at 4 meters with the other two at 17 and 28 meters down the slope of the lagoon. Because of extreme siltation and poor visibility within the

lagoon, stakes were driven into the substrate to affix the STRs and the installations are connected by a line to facilitate location and retrieval at a later date. The two remaining new STR installations entail one on the CREWS anchor and one on the western terrace of the atoll to monitor for the flow of heated water from the lagoons out onto the reef flats.

In addition to these standard deployments, one new instrument and one new deployment style were utilized to both test their utility and study the movement of heated water from West Lagoon out of the channel during the full range of tidal cycles. A Nortek Aquadopp acoustic Doppler profiler (ADP) was deployed at the midpoint of the channel, just before it opens out into the reef flat and the reef slope drops off into deeper water, in 8 meters deep to monitor temperature, direction, and intensity of the current and tide level. Approximately 15 m further inside the channel from the ADP, positioned so that it would not interfere with the beam, a string of three SBE39's (STRs without weights) was deployed to augment the ADP's temperature readings. The string was stretched between a 115-kg clump anchor and a surface float with the sensors positioned at 1, 3, and 6 meters deep. Both the ADP and STR string were deployed on the first day and retrieved on the last day of operations collecting 5 days of data.

C.2.3. Towed-diver Temperature Profiles

Eighteen towed-diver surveys were conducted at Palmyra Atoll totaling 42.40 km in length. Temperature data was recorded at 5-second intervals along each tow survey.

C.2.4. Palmyra Channel Experiment

During WWII, the U.S. Navy significantly modified the lagoon of Palmyra by dredging the lagoon and building causeways connecting all of the islets. This cut off much of the flow through the lagoon. A channel was also dredged on the southwest side to allow passage of large vessels. Very little coral or algae cover remains inside the lagoon which is characterized by fine sediment. Today, several sections of the causeway have broken down allowing a small exchange with the ocean. However, it is assumed that the dredged channel is still the primary egress with wind and wave setup allowing water to flow into the lagoon through breaks in the causeway and tidal forcing allowing minimal exchange through the channel. High turbidity and anoxic conditions are thought to be the primary reason for the low coral and algae cover.

The U.S. Fish and Wildlife Service is now debating the merits of removing the causeways to allow increased exchange between the ocean and the lagoon with the end result being increased growth inside the lagoon. In order to do this, however, an environmental model is required.

In order to test the current assumptions of flow in and out of the lagoon, a 4-day preliminary study running from March 24, 2006 at 20:00 (UTC) until March 29, 2006 at 20:00 (UTC) was performed in the channel. A Nortek Aquadopp 2 MHz acoustic Doppler profiler (ADP) was deployed in approximately 7 meters of water (low tide) in the center of the channel near a choked section between an island and a shallow reef flat (Fig. C.2-1). The Aquadopp is capable of measuring flow velocities throughout the water column as well as pressure to approximate the tides and water temperature at the

instrument. The Aquadopp was set up with a 20-cm blanking distance and 50-cm bins. Additionally, a thermistor chain was deployed near the Aquadopp to measure water temperatures through the water column. Three Seabird 39 temperature recorders were deployed at approximately 1-m, 3-m and 5-m depths. Finally, the R/V *AHI* was able to map the channel and provide an accurate cross sectional profile at the instrument location.

Preliminary results show a net horizontal flow of about 0.12 m/s out of the lagoon through the channel. There is some reverse flow that is well linked to tidal forcing with a slight time lag. Vertical mixing is an order of magnitude lower than the horizontal mixing which is expected, with a net vertical mixing of nearly zero. Temperatures appear to be primarily linked to meterological conditions with max temperatures occurring around 14:00 local time and cold temperatures stabilizing across the water column around 08:00 local time. The hottest day of the experiment showed significantly warmer surface temperatures than stormy days, particularly in the surface layer. The 4-day record does show a couple of anomalous nighttime temperature spikes that suggest some hydraulic coupling.

The first order assumption of net outflow from the lagoon through the channel was confirmed for this 4-day test period. An important next step will be to determine the residence time for water in the lagoon and to develop a hydraulic model of the current flow regime across the lagoon. Longer term, higher coverage testing will be required to provide an accurate model including additional flow studies using acoustic Doppler profilers, the study of wave and wind setup around the lagoon, and water sampling inside the lagoon.

Table C.2.4-1. Average Velocities, Palmyra Channel, March 24, 2006, 20:00 through March 29, 2006, 20:00. Negative velocity values refer to west, south and down respectively.

Bin Distance From Instrument (m)	**East Velocity (m/s)**	**North Velocity (m/s)**	**Up Velocity (m/s)**
0.45	-0.036	-0.013	-0.003
0.95	-0.042	-0.017	-0.003
1.45	-0.047	-0.022	-0.002
1.95	-0.054	-0.025	-0.002
2.45	-0.061	-0.031	-0.002
2.95	-0.067	-0.035	-0.002
3.45	-0.074	-0.042	-0.002
3.95	-0.081	-0.049	-0.002
4.45	-0.087	-0.052	-0.003
4.95	-0.095	-0.059	-0.003
5.45	-0.104	-0.067	-0.003
5.95	-0.119	-0.068	-0.003
6.45	-0.208	-0.061	0.008
6.95	-0.311	-0.038	0.012
7.45	-0.240	-0.024	-0.003
Depth Average	-0.110	-0.039	-0.005
Horizontal Average	**-0.117**	***Horizonatal Net Direction***	**250 Degrees**

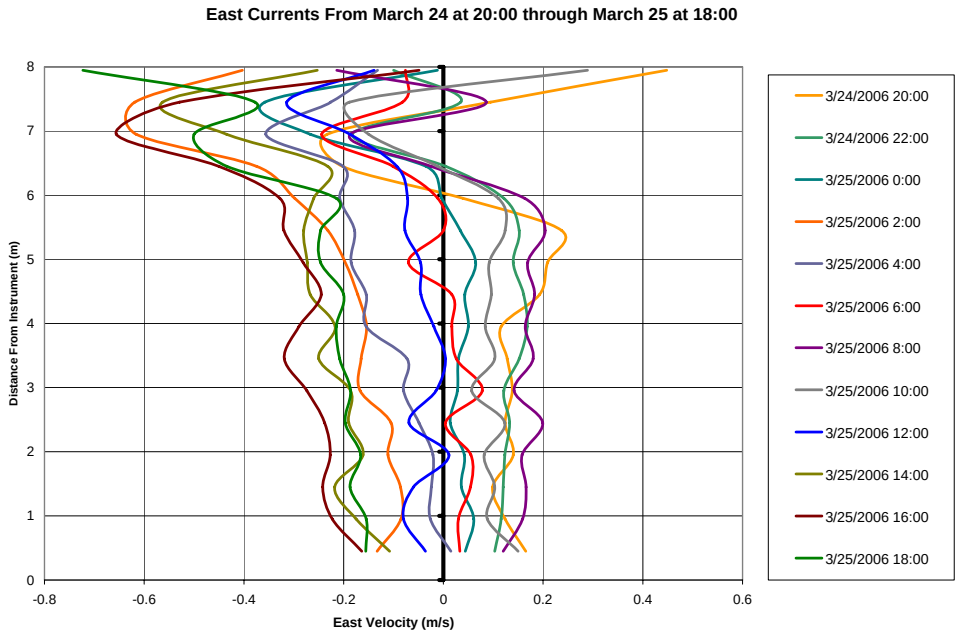


Figure C.2.4-1. East currents in Palmyra Channel over 1 day (One tidal cycle). Velocities shown between 7 and 8 meters are noisy, likely because of surface effects. Negative velocities refer to west flow.

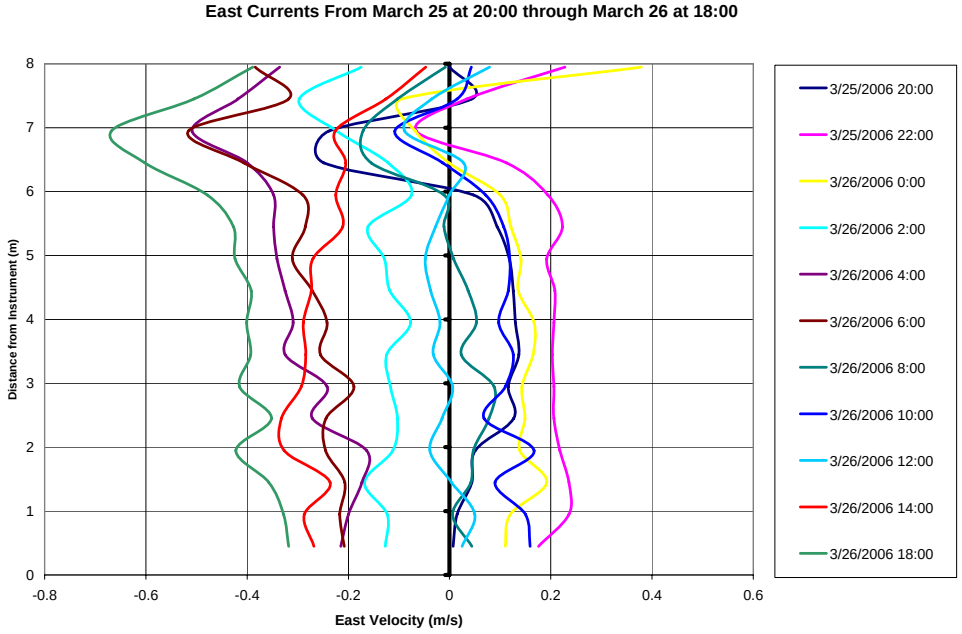


Figure C.2.4-2. East currents in Palmyra Channel over 1 day (One tidal cycle). Velocities shown between 7 and 8 meters are noisy, likely because of surface effects. Negative velocities refer to west flow.

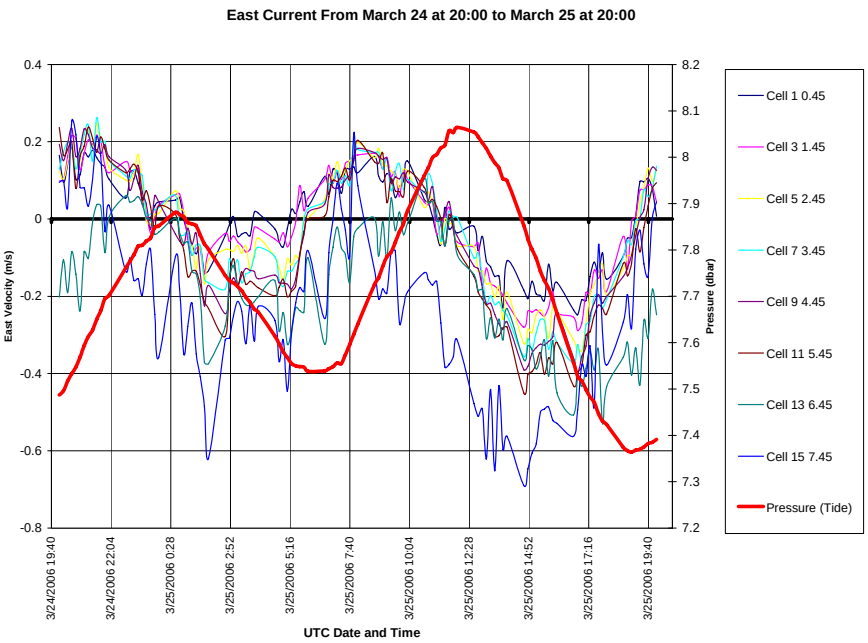


Figure C.2.4-3. East velocities over 1 day (One tidal cycle). Flow direction and magnitude follow the tidal forcing with a slight time lag.

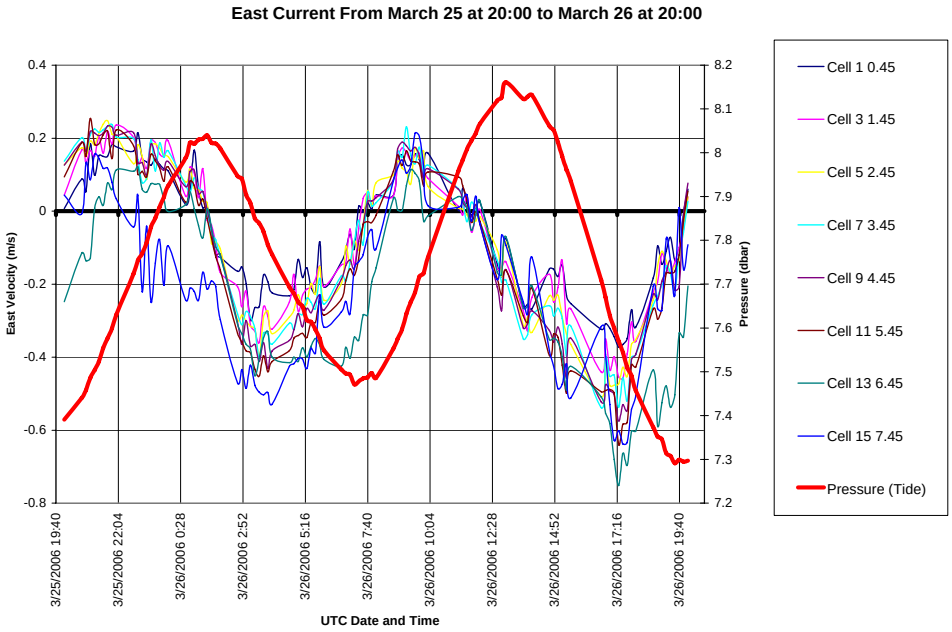


Figure C.2.4-4. East velocities over 1 day (One tidal cycle). Flow direction and magnitude follow the tidal forcing with a slight time lag.

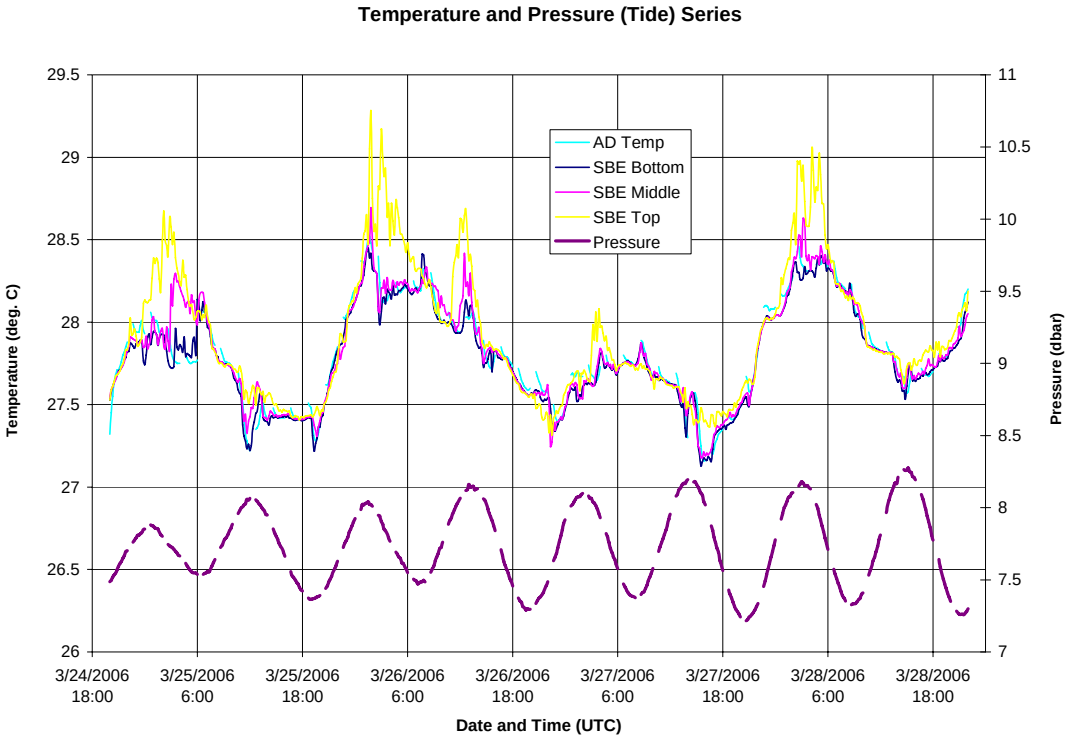


Figure C.2.4-5. Water column temperature fluctuations from March 24, 2006, 20:00 until March 29, 2006, 20:00 with pressure signal (Tide). At low tide, the Aquadopp (AD) temperature was approximately 7 meters, SBE Bottom 5 meters, SBE Middle 3 meters and SBE Top 1 meter.

C.3. Benthic Environment

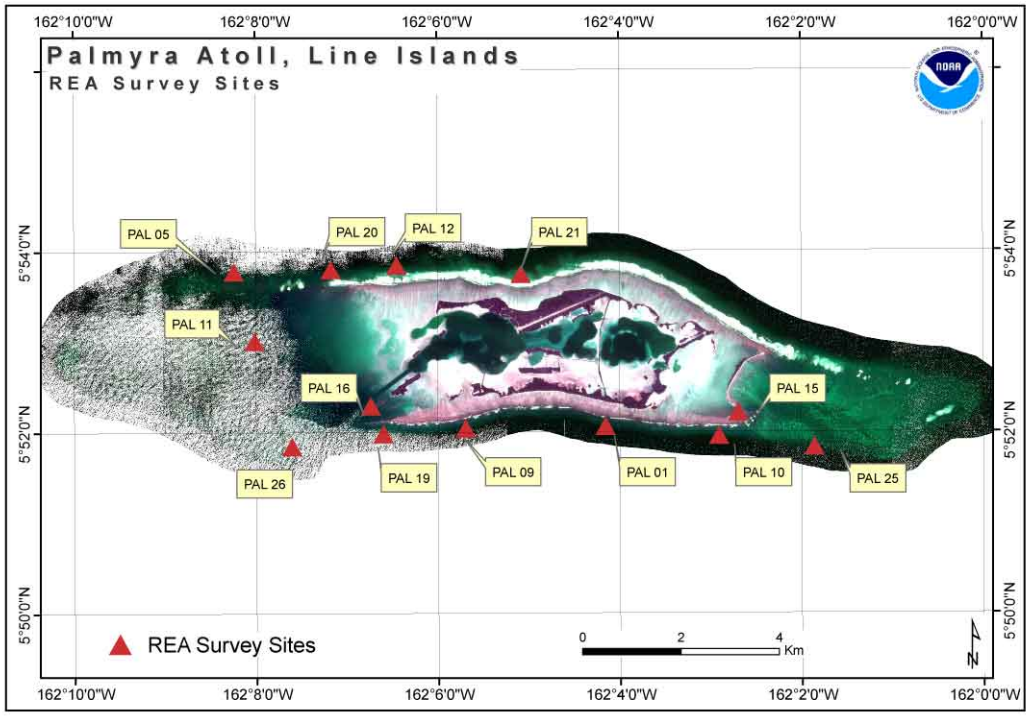


Figure C.3-1: REA survey sites at Palmyra Atoll

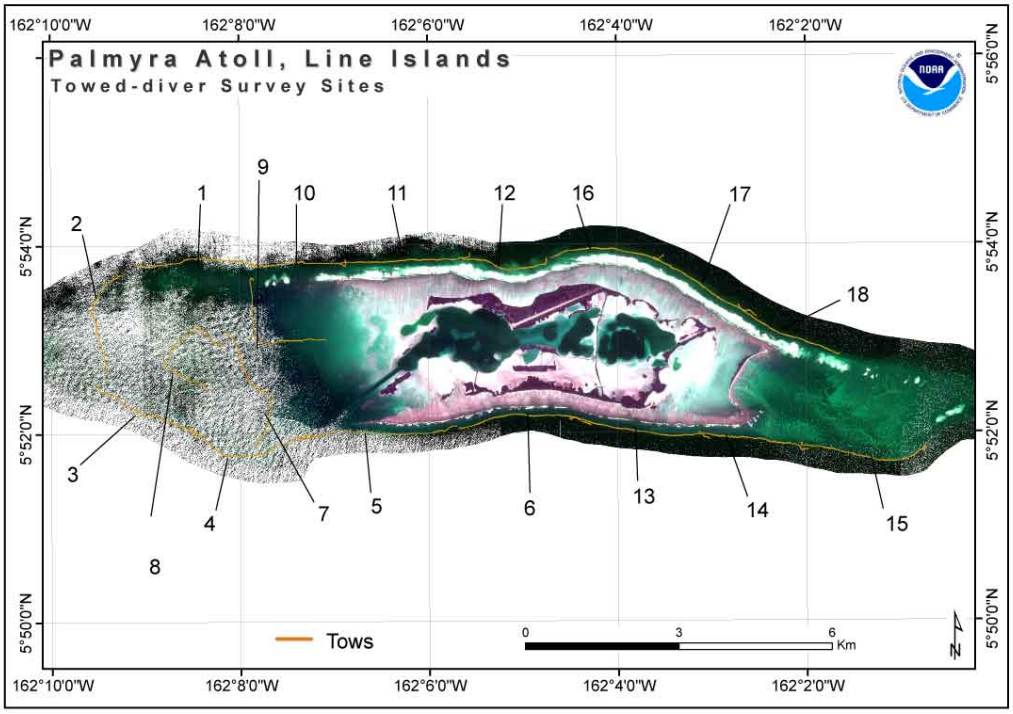


Figure C.3-2: Towed-diver survey transects at Palmyra Atoll

The purpose of the rapid ecological assessments (REA) activities onboard the HI-06-04 was to select sites surveyed during previous rapid ecological assessments for long-term monitoring. Selection of sites was based on their year-round accessibility and their representation of the different types of habitats present at each location. Between March 23 and March 28, 2006, the benthic REA team surveyed 13 sites around Palmyra Atoll, while the Towed-diver benthic survey team conducted a total of 18 surveys totaling 42.40 km. REA dive depths ranged from 4 and 15 m. Sea conditions allowed the REA team to accomplish three sites off the north shore, four off the south shore, three sites in the western terrace, one site in the western lagoon, next to the ship channel, and two sites in the eastern lagoon and eastern terrace.

The benthic REA surveys indicated that richness of macroalgae at Palmyra Atoll in 2006 was higher (19 genera + 4 functional groups) than in 2004 (10 genera + 5 functional groups). However, the dominant macroalgal groups at the island scale remain comparable, i.e., crustose corallines, green turfs, *Halimeda* and *Dictyosphaeria*. Interestingly, *Dictyosphaeria* was found more often in the photoquadrats in 2006 (53% of occurrence) than in 2004 (26%).

The transect surveys counted 35 of the 50 genera reported from Palmyra and another 5 were close to the transects. No one genus accounted for more than 18% of the corals. In descending order, the top 10 most numerous genera were: *Porites, Pocillopora, Lobophytum, Pavona, Fungia, Montipora, Sarcophyton, Turbinaria, Favia,* and *Acropora.* The abundance of the soft corals was surprising, especially *Lobophytum* which was much less abundant in 2004.

Coral community health and disease REA surveys indicated that the mean percent of live coral cover on reefs around Palmyra Atoll for all sites combined was close to 27%, while dead coral accounted for over 0.5%, and crustose coralline algae represented nearly 28%. Other benthic components, including rubble, algae, soft corals, and non-scleractinian sessile invertebrates accounted for 33% of the bottom cover. Highest percent live coral cover (>50%) was documented at two sites; one on the western terrace and the other one on the southeastern back-reef (coral gardens). In contrast percent live coral cover was lower along the north and south shores probably because of the vigorous wave and current regime. In addition, the coral community health and disease surveys documented a total of 101 cases of diseases on corals, soft corals, and coralline algae. Stations PAL19, and PAL11 (north and west) and stations PAL20 and PAL09 (south) exhibited the greatest number of cases of coral diseases and coralline algae disease, respectively. The estimated relative abundance of diseases on scleractinian corals for Palmyra Atoll was ~20.8 cases per 1000 m^2 and 12.1 cases per 1000 m^2 for coralline algae, respectively.

The lack of abundant macroinvertebrate fauna throughout the outer reef habitats at Palmyra Atoll is a main point of interest from all surveys. Echinoderms, which are usually the dominant macroinvertebrate component of coral reefs, were absent from most transect enumerations. Giant clams were recorded at five sites but were rare at each.

A note of interest is the record of a hermit crab species that resembles *Calcinus laurentae* from site PAL19. This is of interest because *Calcinus laurentae* is considered endemic to the Hawaiian Archipelago.

C.3.1. Algae

Crustose corallines, green turfs, *Halimeda*, and *Dictyosphaeria* dominated at Palmyra at all sites. *Lobophora*, *Peyssonellia*, *Avrainvillea*, *Microdictyon*, red turfs and the unknown red alga 2 were also found in relative high abundance in photoquadrats at most sites. Blue-green algae were not very abundant. In 2004, *Microdictyon* was not reported and *Avrainvillea* was not present at all sites. Macroalgal richness seems more important in 2006 than in 2004. A detailed summary of the occurrence of macroalgae in photoquadrats and algal richness at each site is presented in Table C.3.1-1 (see below).

C.3.1.1. Algal REA sites description

PAL10 (3-24-2006: 05°51.961'N, 162°02.909'W)

This reef slope was located in the southeast side of Palmyra Island. Weather conditions were good although the swell was important (> 1 m). Visibility was about 25 m. Coral cover and coral diversity were high at this location. Algal diversity was low. Macroalgal communities were dominated by *Halimeda*, crustose corallines, turf algae, and *Avrainvillea*. *Dictyosphaeria* was also observed. A qualitative survey was carried out at this site (collection of macroalgae during the random swim) and photos were taken with the photoquadrat.

PAL19 (3-24-2006: 05°51.984'N, 162°06.598'W)

This reef slope was located southwest of Palmyra Island. Weather conditions were cloudy and rainy. Visibility was around 25 m. Benthos was mostly limestone and coral rubbles. Coral cover was limited. Algal cover was important while algal diversity was low. The most abundant macroalgae found at this reef were crustose corallines and turf algae, as well as *Halimeda*. Additionally *Avrainvillea* and *Dictyosphaeria* were observed in abundance. A qualitative survey was carried out at this site (collection of macroalgae during the random swim) and photos were taken with the photoquadrat along both transects.

PAL11 (3-25-2006: 05°53.009'N, 162°08.014'W)

This reef flat was located west of Palmyra Island. Weather conditions were cloudy. The swell was important and visibility was higher than 30 m. Coral cover was moderate. Coral communities were dominated by *Montipora* and *Pocillopora*. Algal diversity was important. Communities were dominated by crustose corallines and *Dictyosphaeria* (at least two species were observed and collected; *D. cavernosa* and *D. versluysii*). Additionally, *Lobophora*, *Halimeda*, turf algae, *Avrainvillea,* and red 2 were abundant in photoquadrats. *Peyssonellia*, *Valonia*, *Microdictyon* (or *Phyllodictyon*), and *Grateloupia* (or *Gelidium*) were also found in photoquadrats.

PAL26 (3-25-2006: 05°51.844'N, 162°07.605'W)
This reef flat (14–15 m depth) was located in the southwestern corner of Palmyra. Weather conditions were cloudy. The swell was important and visibility was higher than 30 m. Coral cover was important. Coral communities were dominated by *Porites*, soft corals, and *Pocillopora*. Algal diversity was moderate or low. Crustose coralline and turf algae were the major macroalgae in photoquadrats. Additionally, *Lobophora*, *Peyssonellia*, *Halimeda,* and *Dictyosphaeria* were seen in abundance. *Avrainvillea*, *Microdictyon* (or *Phyllodictyon*), red 2, *Valonia,* and *Jania* were observed. Blue-green algae were not abundant.

PAL09P (3-26-2006: 05°52.044'N, 162°05.693'W)
This reef slope was located south of Palmyra. Weather conditions were cloudy. Visibility was around 30 m. Coral cover and coral diversity were relatively high. Coral communities were dominated by *Pocillopora*, *Porites*, *Millepora,* and *Acropora*. Algal diversity was moderate. Algal communities were dominated by crustose corallines, *Halimeda,* and *Lobophora. Peyssonellia*, turf algae, and *Grateloupia* were also abundant. Some blue-green algae, *Avrainvillea* and *Valonia*, as well as *Dictyosphaeria* were also observed.

PAL01P (3-26-2006: 05°52'066'N, 162°04.138'W)
This reef slope was located southeast of Palmyra. Weather conditions were cloudy and windy. A significant current was noticed at the surface. Visibility was around 25 m. Coral cover was moderate. The floor was covered by a lot of coral rubble. Coral communities were dominated by *Pocillopra*. Macroalgae were not very diverse and were dominated by crustose corallines, *Lobophora*, *Halimeda,* and turf algae. Nevertheless, other algae were also observed: *Peyssonellia*, *Avrainvillea*, *Microdictyon* (or *Phyllodictyon*), red 2 (or *Laurencia* or *Chondria*?), and *Grateloupia*.

PAL21 (3-27-2006: 05°53.747'N, 162°05.081'W)
This reef slope was located north of Palmyra. Weather conditions were good. Visibility was about 30 m. Coral cover was moderate. Coral communities were dominated by *Porites* and *Pocillopora*. Soft corals were also abundant. Algal communities were dominated by crustose coralline and turf algae as well as by *Halimeda*. Additionally, *Lobophora*, *Laurencia*, *Grateloupia*, *Avrainvillea*, and *Galaxaura* were seen in abundance in photoquadrats. *Valonia*, *Dictyota,* and blue-green algae were also recorded but were not very abundant.

PAL12 (3-27-2006: 05°53.845'N, 162°06.452'W)
This reef slope was located north of Palmyra. Weather conditions were good although a significant current was noticed at the surface. Swell was also significant. Visibility was around 30 m. Coral cover was relatively high. Coral communities were dominated by *Porites*, soft corals, *Pocillopora,* and *Millepora*. Algal diversity was moderate. Algal communities were dominated by crustose corallines, turf algae, *Halimeda,* and *Lobophora*. *Galaxaura* and *Grateloupia* were also abundant. Additionally, *Microdictyon* (or *Phyllodictyon*) and red 2 were encountered in photoquadrats. *Neomeris* was recorded also.

PAL20 (3-27-2006: 05°53.801'N, 162°07.173'W)
This reef flat was located northwest of Palmyra. Weather conditions were good. A significant current was noticed on the bottom. Visibility was about 30 m. Coral cover was limited; lots of coral rubble. Coral communities were dominated by soft corals, *Millepora*, *Porites,* and *Pocillopora*. Algal diversity was moderate. Algal communities were dominated by crustose corallines, turf algae, *Lobophora*, *Peyssonellia*, *Halimeda,* and red 2. Additional algae were observed such as *Grateloupia*, *Valonia*, *Jania*, *Avrainvillea,* and *Microdictyon*. Exceptionally, *Boodlea* and *Cladophora* were also observed within photoquadrats.

PAL16P (3-28-2006: 05°52.294'N, 162°06.738'W)
This reef flat was located in the channel on the west side of Palmyra (lagoon). Weather conditions were good. Visibility was about 40 m. Coral cover was moderate. The reef floor was covered by lots of coral rubble and dead colonies of branched corals, upside down. Algal diversity was relatively high. Algal communities were dominated by *Lobophora*, crustose corallines, turf algae, *Galaxaura,* and *Halimeda*. Additionally, macroalgae such as *Boodlea*, *Avrainvillea,* and *red 2* were recorded. Blue-green algae were also present in photoquadrats.

PAL15P (3-28-2006: 05°52.221'N, 162°02.697'W)
This shallow reef is called the 'coral garden' and is located in an eastern shallow reef pool of Palmyra. Weather conditions were good and visibility was about 35m. Coral cover was important. Coral communities were dominated by different species of *Acropora*. Algal diversity was relatively similar to the general algal diversity around Palmyra. It was not possible to collect samples because this area is protected (marine sanctuary). Algal communities were dominated by crustose corallines, turf algae, *Halimeda* and *Dictyosphaeria*. Blue-green algae were relatively abundant.

Table C.3.1-1 Relative abundance of macroalgae (ranking) per site and at the island scale as well as the percentage of occurrence (in bold) of each macroalga per site and at the island scale. Standard deviations are given at the island scale in parenthesis.

	PAL11	PAL26	PAL09	PAL01	PAL21	PAL12	PAL20	PAL16P	Island	SD
Green Algae										
Avrainvillea	**66.7**	**25.0**	**25.0**	**25.0**	**16.7**	**8.3**	**33.3**	**41.7**	**30.2**	(12.1)
	5.5	4.3	7.7	5.7	7.0	7.0	6.8	7.8	6.5	(1.2)
Boodlea					**8.3**		**16.7**	**33.3**	**19.4**	(12.7)
					9.0		8.5	8.3	8.6	(0.4)
Caulerpa						**8.3**		*	**8.3**	
						5.0			5.0	
Cladophora			*				*		**8.3**	**8.3**
									6.0	6.0
Dictyosphaeria	**100.0**	**25.0**	**50.0**	*		*		**50.0**	**41.7**	**53.3** (20.4)
	2.2	2.7	5.8					4.3	5.6	4.1 (1.7)
Halimeda	**75.0**	**58.3**	**100.0**	**91.7**	**83.3**	**83.3**	**91.7**	**83.3**	**83.3**	(31.1)
	3.6	2.9	3.1	2.9	2.5	3.1	4.3	3.3	3.2	(0.5)
Microdictyon	**16.7**	**16.7**	**25.0**	**8.3**		**25.0**	**33.3**	**25.0**	**21.4**	(9.4)
	8.5	5.0	8.0	7.0		5.7	7.0	8.7	7.1	(1.4)
Neomeris						**8.3**			**8.3**	
						7.0			7.0	
Valonia	**25.0**	**8.3**	**41.7**		**25.0**	**8.3**	**25.0**	**33.3**	**23.8**	(13.8)
	6.3	6.0	7.4		7.0	6.0	7.0	7.5	6.7	(0.6)
Red algae										
Digenea				**8.3**					**8.3**	
				5.0					5.0	
Galaxaura	**66.7**		**91.7**		**41.7**	**58.3**	**50.0**	**91.7**	**66.7**	(32.8)
	5.0		4.3		4.4	4.6	6.0	3.5	4.6	(0.8)
Grateloupia	**16.7**		**16.7**	**16.7**	**41.7**	**16.7**	**16.7**		**20.8**	(11.6)
	7.5		8.0	5.0	7.2	6.5	6.5		6.8	(1.0)
Gracilaria	**8.3**								**8.3**	(7.0)
	7.0									
unknown red alga 2	**66.7**	**16.7**	**8.3**	**33.3**		**16.7**	**91.7**	**41.7**	**39.3**	(29.8)
	6.1	5.0	6.0	3.5		6.5	3.5	6.0	5.2	(1.3)
Jania		**16.7**	**8.3**			**8.3**	**8.3**		**10.4**	(4.2)
		5.0	9.0			6.0	9.0		7.3	(2.1)
Laurencia/ Chondrophycus	**8.3**	**8.3**			**50.0**	**8.3**		**25.0**	**20.0**	(18.5)
	7.0	5.0			6.0	7.0		5.3	6.1	(0.9)
Peyssonnelia	**41.7**	**33.3**	**25.0**	**8.3**			**66.7**		**35.0**	(24.9)
	4.2	4.5	4.3	4.0			2.8		4.0	(0.7)
red turf				**25.0**	**25.0**	**16.7**		**25.0**	**22.9**	(4.2)
				4.0	5.0	5.0		1.3	3.8	(1.7)
crustose coralline	**91.7**	**100.0**	**91.7**	**83.3**	**100.0**	**100.0**	**100.0**	**83.3**	**93.8**	(33.5)
	1.5	1.7	1.7	1.8	1.5	1.1	1.3	2.2	1.6	(0.3)
Brown algae										
Dictyota	**8.3**				**50.0**			**16.7**	**25.0**	(23.0)
	6.0				5.8			4.5	5.4	(0.8)
Lobophora	**83.3**	**41.7**	**91.7**	**66.7**	**83.3**	**83.3**	**41.7**	**83.3**	**71.9**	(30.4)
	3.9	2.6	3.2	2.8	3.8	3.5	5.0	1.9	3.3	(0.9)
Others										
Blue-green	**25.0**	**66.7**	**75.0**	**75.0**	**50.0**	**58.3**	**33.3**	**50.0**	**54.2**	(22.9)
	7.3	3.9	5.1	4.6	4.7	4.9	5.8	6.3	5.3	(1.1)
turf	**41.7**	**75.0**	**83.3**	**100.0**	**100.0**	**100.0**	**66.7**	**83.3**	**81.3**	(31.9)
	4.0	2.1	3.0	2.7	3.2	2.4	3.1	3.9	3.0	(0.7)

C.3.1.2. Benthic Towed-diver Survey—Algae

Coralline and macroalgae, observed throughout the atoll, dominated the substrate on the southern forereef. Coralline algae dominated the rubble substrate along the exposed eastern terrace and the macroalgae, *Halimeda*, dominated the forereef substrate from the channel to the eastern shore of Bird Island. *Halimeda* sand was prevalent in the western terrace and along the southern shoreline.

C.3.2. Corals

C.3.2.1. Coral diversity and population dynamics

Palmyra has been extensively surveyed for corals on eight separate occasions since 1987, and more than 190 species and 50 genera of corals and other cnidarians have been reported at the atoll. Despite previous efforts, new sightings continue to be reported, including two new records reported during the 2006 visit: the octocoral *Pachyclavularia violacea* and an unidentified scleractinian, *Echinophyllia* sp. The transect surveys counted 35 of the 50 genera reported from Palmyra and another five were close to the transects. No one genus accounted for more than 18% of the corals. In descending order, the top 10 most numerous genera were: *Porites, Pocillopora, Lobophytum, Pavona, Fungia, Montipora, Sarcophyton, Turbinaria, Favia,* and *Acropora.* The abundance of the soft corals was surprising, especially *Lobophytum* which was much less abundant in 2004.

During the past several decades, the coral fauna at Palmyra has been unusual because of having the highest diversity of all of the other Line Islands, except for nearby Kingman Reef. Possible reasons are that Palmyra has been much better sampled than the others and is large with more habitat variety compared to the reef islands (Jarvis, Teraina). Another possible reason is that the atoll and nearby Kingman are often in the path of the eastward flowing Equatorial Countercurrent which may be transporting larvae of additional species of corals from the more diverse western Pacific. Generic richness was high at most REA sites, with all but one forereef site (PAL01 on the south side) accounting for 18 or more genera. The highest generic richness (24-26) was reported at eastern and northern reef sites (PAL10, 20, 25), with several adjacent northern and southwestern sites (PAL06, 19, 21, 26) showing slightly lower levels of generic richness. The lowest generic richness (7) was reported near the southwest channel (PAL16P) whose coral populations are still in the early stages of recovering from a coral bleaching event that killed most of the corals at the site, probably in 1997. Dead standing and the complex rugosity at the site are testament to the previous level of biodiversity at the site, as noted by Maragos (1987).

Table C.3.2.1-1 and Figure C.3.2.1-1 summarize the characteristics of the coral populations at the 13 Palmyra REA sites in 2006, and there were substantial differences in frequencies among the sites. The lowest frequencies (four to eight corals per m^2) were reported at south sites (PAL 16P, 9) and one southwest site (PAL26). Slightly higher values (10 to 13 corals per m^2) were reported at northwestern sites (PAL05, 11) and southern site PAL25. The highest frequencies (18 to 27 corals per m^2) were reported at widely scattered sites, PAL 10 in the southeast and PAL 12 and 20 in the north. Coral frequency values were highest at sites far from the southwest channel and lagoon. Larger mean diameter values (22 to 24 cm) at the transects were reported at two southeastern

sites (PAL15P, 25) and one southwestern site (PAL26). These sites are protected from heavy wave action from the northwest and tradewinds from the northeast. Clearly the coral gardens (PAL 15 P) submerged in shallow reef pools are protected from heavy seas. These same sites and two others in the south (PAL 19, 10) also support the largest concentrations of larger, more mature corals, indicators of stable, enduring conditions for corals. In contrast, three southern sites (PAL 1, 16P, 9) and two northern sites (PAL 5, 12) showed the smallest mean diameters. One is recovering from a bleaching event (PAL 16P) and two others in the south appeared to have suffered from recent wave damage (PAL 1, 9). The remaining two are northern sites exposed to periodic heavy swells from the north.

C.3.2.1.1 Changes in coral populations over time

Data from the 2004 REA surveys were available for six sites at this time to offer comparisons to 2006 surveys at the same sites (PAL01, 10, 16P, 19, 25, 26), all of them on the south side of the atoll. In all cases, coral populations showed larger mean diameters in 2004 compared to 2006 and smaller frequency levels, except for a slightly higher frequency at site PAL01 in 2004. Generic richness levels were generally the same for both survey periods. Much of the shift to a smaller mean size is attributed to more numerous small coral recruits in 2006. As noted earlier, the soft coral *Lobophytum* showed phenomenal increases in 2006, and another octocoral *Sterionephthya* also increased in abundance. The stony lobe coral *Porites,* and to a lesser extent the encrusting and disc coral *Pavona* showed dramatic increases in the smaller and middle size classes at most of these sites. The brain corals and relatives *Montastrea, Leptastrea, Lobophyllia, Hydnophora, Favites;* and the agaricid corals *Gardineroseris, Leptoseris* all showed increases at one to several sites in 2006, with no coral genera showing declines over the same time span. At PAL 6 a corallomorph, *Rhodactis howsii,* is undergoing a population explosion at the longliner wreck site, perhaps stimulated by dissolved iron from the wreck, just north of the dredged channel. This site should be added for future monitoring since the corallomorph appears to be reaching nuisance/invasive levels quickly.

Preliminary results from the analysis of permanent data at site PAL16P shows only slight increase in population levels from 2004 to 2006. However, other parameters did not reflect much change; there were higher levels of smaller corals in 2006 compared to higher levels of medium-sized corals in 2004. The indications are that coral populations are still recovering at a very slow level after their collapse from coral bleaching nearly a decade ago.

Table 3.2.1-1 Numbers of corals, their frequency, diameters and size distribution reported at 13 rapid ecological assessment sites, Palmyra Atoll National Wildlife Refuge in March 2006. (source: Maragos 2006)

PAL REA site #	**25**	**10**	**19**	**26**	**11**	**5**	**9**	**1**	**21**	**12**	**20**	**16P**	**15P**	**totals/**	**% of**
atoll locale	E	SE	SW	SW	W	NW	SW	S	N	N	N	SW	E	**genus**	**total**
mean diam	22.7	18.2	19.9	24.4	17.2	14.8	14.7	12.5	16.1	14.6	15.7	13.7	24.3		
Frequency	12.6	13.5	19.2	11.8	11.3	10.2	8.5	4.1	11.3	27.4	18.8	4.5	11.6		
# of genera	24	26	23	22	20	22	18	11	21	21	24	7	10		
coral genera															
Acropora	3	2	1	1		2	3		1	14	3	14	208	**252**	3.1
Astreopora				4		1							33	**38**	0.47
Cladiella		3				1			21		2			**27**	0.33
Cycloseris			3	2										**5**	0.061
Fungia	29	56	30		52		8	37	13	28	225	20	6	**506**	6.2
Sterionephthya	5	1		23		15								**44**	0.54
Distichopora					1									**1**	0.012
Echinophyllia		1								2				**3**	0.036
Favia	26	57	38	22	11	8	27	8	17	66	41	4	6	**331**	4.1
Favites	1	11	25	14	4	11	17		3	50	23			**159**	1.96
Gardineroseris		8	1				1							**10**	0.12
Halomitra	3													**3**	0.036
Herpolitha		1	1	1	4	1			1	4	3			**16**	0.2
Heteractis	1													**1**	0.012
Hydnophora	8	8	21	18		6	21		4	20	10			**116**	1.43
Leptastrea	4	7	8	2	3	10			3	18	10		21	**86**	1.06
Leptoseris	13	16	9	1		4	2	1	10	16	13			**85**	1.05
Lobophyllia	8	42	5		1		1	15			39			**111**	1.37
Millepora											1			**1**	0.012
Montastrea	2	4	12	22	1	15	8	1	1	54	9		3	**122**	1.5
Montipora	9	13	15	24	27	13	13	1	8	16	21	41	275	**476**	5.9
Pachyclavularia									39	54				**93**	1.14
Palythoa	9	12	8	9		10	3		23	16	2			**92**	1.13
Pavona	43	81	71	69	133	23	61	20	62	120	121	7	8	**819**	10.1
Platygyra	4	1	15	5	2	3			1	28	6			**65**	0.8
Pocillopora	28	92	126	96	83	66	137	58	49	80	211	140	53	**1219**	15
Porites	194	131	228	189	91	109	68	58	87	222	83		2	**1462**	18
Psammocora	1	7	9		2	5	3	3	15	8	8	1		**62**	0.76
Rhodactis					4									**4**	0.049
Sandalolitha			1											**1**	0.012
Sarcophyton	34	22	11	15		70	16		34	264				**466**	5.7
Stylaster	24	4		6	15		2				4			**55**	0.68
Stylophora	13	2			68						1			**84**	1.03
Turbinaria	35	10	151	53	5	28			19	32	21			**354**	4.36
Lobophytum	97	85	171	13	60	111	37	4	153	266	83			**1080**	13.3
totals per site	**502**	**676**	**960**	**591**	**567**	**512**	**428**	**206**	**564**	**1368**	**940**	**227**	**582**	**8123**	101

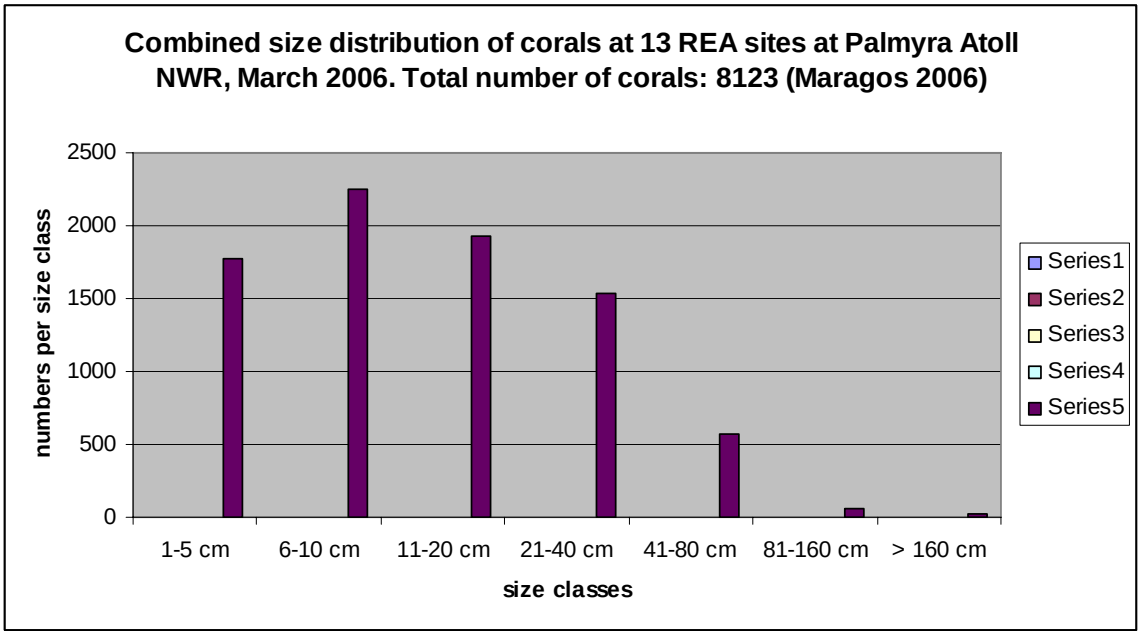


Figure C.3.2.1-1 Size class distribution for corals at 13 REA sites

C.3.2.2. General assessment of percent live coral cover

Coral community health and disease REA surveys indicated that the mean percent of live coral cover on reefs around Palmyra Atoll for all sites combined was close to 27%, dead coral accounted for over 0.5%, and crustose coralline algae represented nearly 28%. Other benthic components, including rubble, macroalgae, soft corals, and non-scleractinian sessile invertebrates accounted for 33% of the bottom cover. A summary list of benthic parameters is presented in Table 3.2.2-1 Mean percent coral cover was the highest at sites PAL26 and PAL15P (53.9% and 66.7%, respectively), on the southwest terrace, and the south eastern backreef, respectively. Salient characteristics at these sites included high generic diversity and relative increased abundance of *Porites* at PAL26. Site PAL15P, known as "the coral garden," exhibited high abundance and diversity of tabular, staghorn, and corymbose acroporids.

Lower mean percent of live coral cover, ranging from 4% to 11% was documented at sites along the north and south ocean-fringing reef slopes (PAL21, PAL12, PAL09P, and PAL01P). Sites PAL01P and PAL09P exhibited increased abundance of staghorn *Acropora* rubble, encrusted and overgrown with crustose coralline algae, *Halimeda*, and a green Didemnid tunicate. Sites on the north-facing shore (PAL21 and PAL12) also exhibited increased expanses dominated by coralline algae-encrusted rubble; the acyonarian corals *Sinularia*, *Sarcophyton*, and *Lobophytum* were also relatively abundant at these sites. Sites PAL10, PAL19, and PAL20 on the southeast, southwest, and northwest corners, respectively, exhibited moderate live coral cover ranging between 20 and 45%.

Table C.3.2.1-1 Summary statistics of percent benthic cover parameters at Palmyra Atoll. CCA: Crustose coralline algae; Other: Other benthic elements including: fleshy macroalgae, rubble, rock, soft corals, etc).

	Coral cover	Dead	Pavement	Sand	CCA	Other
PAL25	42.2	0.0	1.0	0.0	41.2	15.7
PAL10	30.4	0.0	6.9	3.9	26.5	32.4
PAL19	31.4	0.0	2.0	2.9	32.4	31.4
PAL26	53.9	0.0	6.9	5.9	22.5	10.8
PAL11	20.6	0.0	8.8	2.9	36.3	31.4
PAL05	10.8	0.0	41.2	11.8	4.9	31.4
PAL09P	10.8	0.0	6.9	2.9	31.4	48.0
PAL01P	10.8	0.0	3.9	0.0	12.7	72.5
PAL21	4.9	0.0	9.8	1.0	30.4	53.9
PAL12	18.6	0.0	7.8	4.9	25.5	43.1
PAL20	36.3	0.0	4.9	0.0	35.3	23.5
PAL16P	10.8	0.0	6.9	0.0	53.9	28.4
PAL15P	66.7	6.9	10.8	1.0	7.8	6.9
Mean	26.8	0.5	9.0	2.9	27.8	33.0
Std Err	3.8	0.5	2.3	0.7	2.8	3.6

C.3.2.3. Coral health and disease assessment

At Palmyra Atoll, a total reef area of 4850 m^2 was surveyed for the occurrence of disease. Within this area, 100 cases were detected on scleractinian corals and 59 cases on crustose coralline algae (~20.8 and 12.1 cases per 1000 m^2, respectively). Additionally, one case of tissue loss and necrosis was detected on the alcyonarian *Sinularia* sp. Figures 3.2.3-1, 3.2.3-2, and 3.2.3-3 illustrate the relative abundance of coral and coralline algal disease per site, as well as the prevalence of disease.

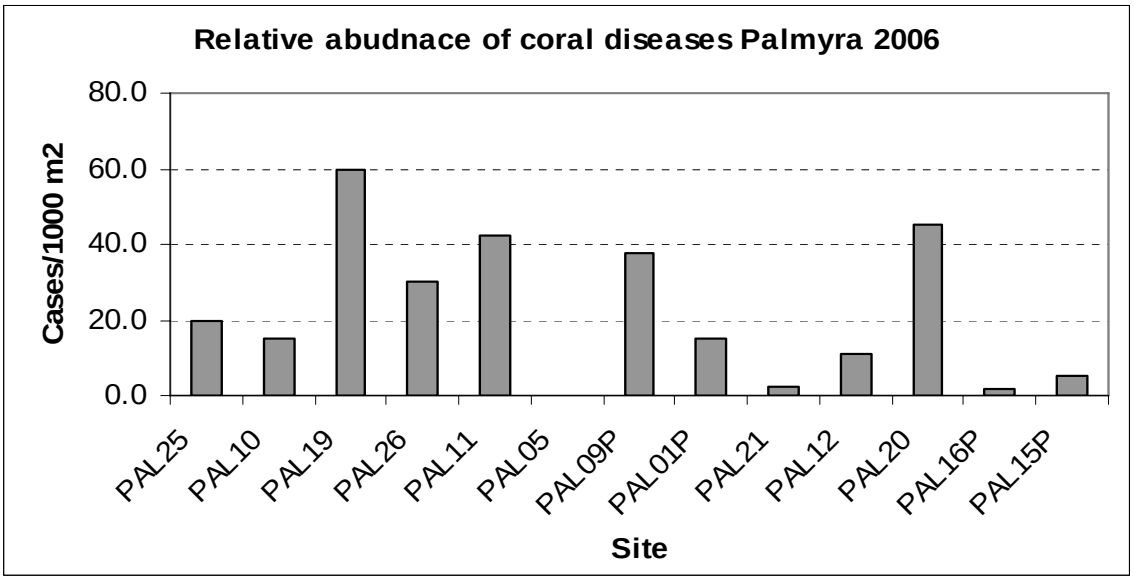


Figure 3.2.3-1. Estimated relative abundance of coral disease per site at Palmyra Atoll, 2006

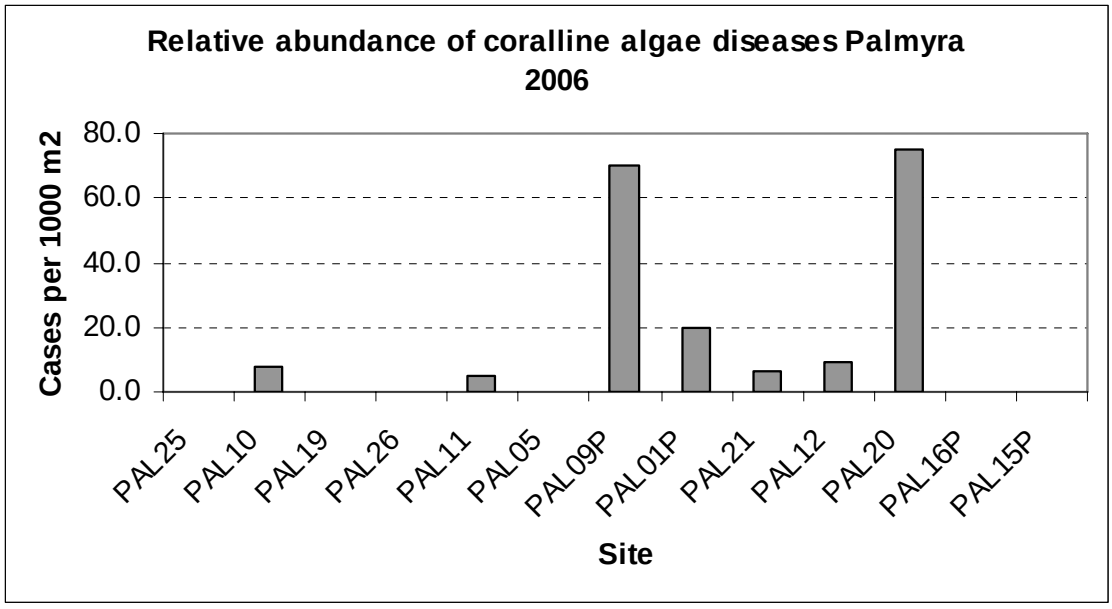


Figure 3.2.3-2. Estimated relative abundance of coralline fungal disease per site at Palmyra Atoll, 2006

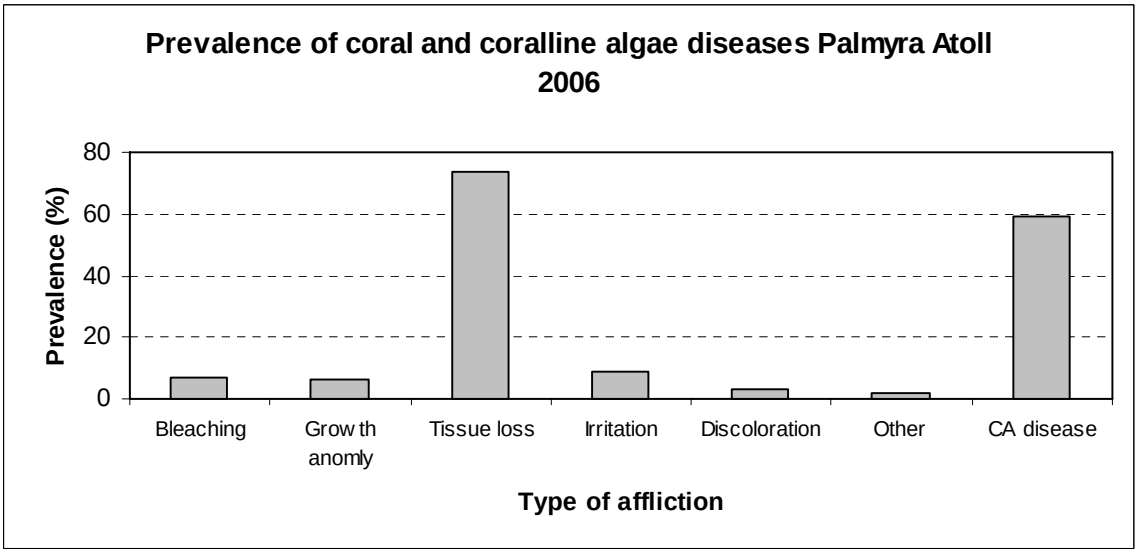


Figure 3.2.3-3. Prevalence (% cases) of disease and afflictions on scleractinian corals and coralline algae at Palmyra Atoll, 2006. Other = tubeworm infestation and tissue loss and necrosis on the soft coral *Sinularia* sp, .CA disease = coralline fungal disease.

At Palmyra, the most abundant affliction to scleractinian corals was tissue loss on colonies of *Pocillopora spp*. This was observed at 85% of the sites surveyed, and generally occurred on a few branches at the same time, and progressing from the lower portion of the branch toward the apex, leaving behind a clean band, where tissue was completely removed from the skeleton. A clear succession of algae generally trailed the exposed skeleton. This affliction was generally associated with paling/discoloration of

the remaining tissue on the branches where tissue loss was observed. In addition, territorial damselfish as well as discrete algal lawns were commonly observed among or in association with the areas of exposed skeleton. Like at Jarvis Island, the size and appearance of these marks are suggestive of predation; however, no specific corallivores were observed associated with these blemishes. These lesions may also be attributed to algal lawn expansion by territorial damselfish. Tissue samples were collected in order to further our understanding on the possible cause of this affliction. More detailed assessment of this condition is needed. The second most abundant affliction was irritations, most likely caused by algal colonization over scrapes created by corallivore fishes. All cases were observed on colonies of *Porites*. Partial bleaching, as well as discoloration was also observed, mostly affecting colonies of *Pocillopora* spp, but also *Gardineroseris planulata*. Interestingly, 70% of all bleaching and paling cases occurred at sites PAL19 and PAL26 on the southeastern sector. Additionally, six cases of skeletal growth anomalies were observed within the REA quantitative survey areas at Palmyra Atoll. These occurred in several different species, including the lobe coral *Porites*, as well as *Pocillopora eydouxi*, *Acropora cytherea,* and *Favites* sp. At site PAL26, one colony of *Porites* exhibited moderate infestation by tube worms (*Spirobranchus*); it is likely that this type of infestation may eventually compromise the health condition of this coral. Finally, one case of tissue loss and necrosis was detected on the alcyonarian *Sinularia* sp. As for afflictions to coralline algae, 59 cases of coralline fungal disease were detected; 91% of these occurred at five sites along the north- and south-facing shores. The estimated relative abundance of coralline algae diseases was 12 cases per 1000 m^2. Figure 3.2.3-4 illustrates some examples of the main types of afflictions affecting scleractinian corals at Palmyra Atoll.

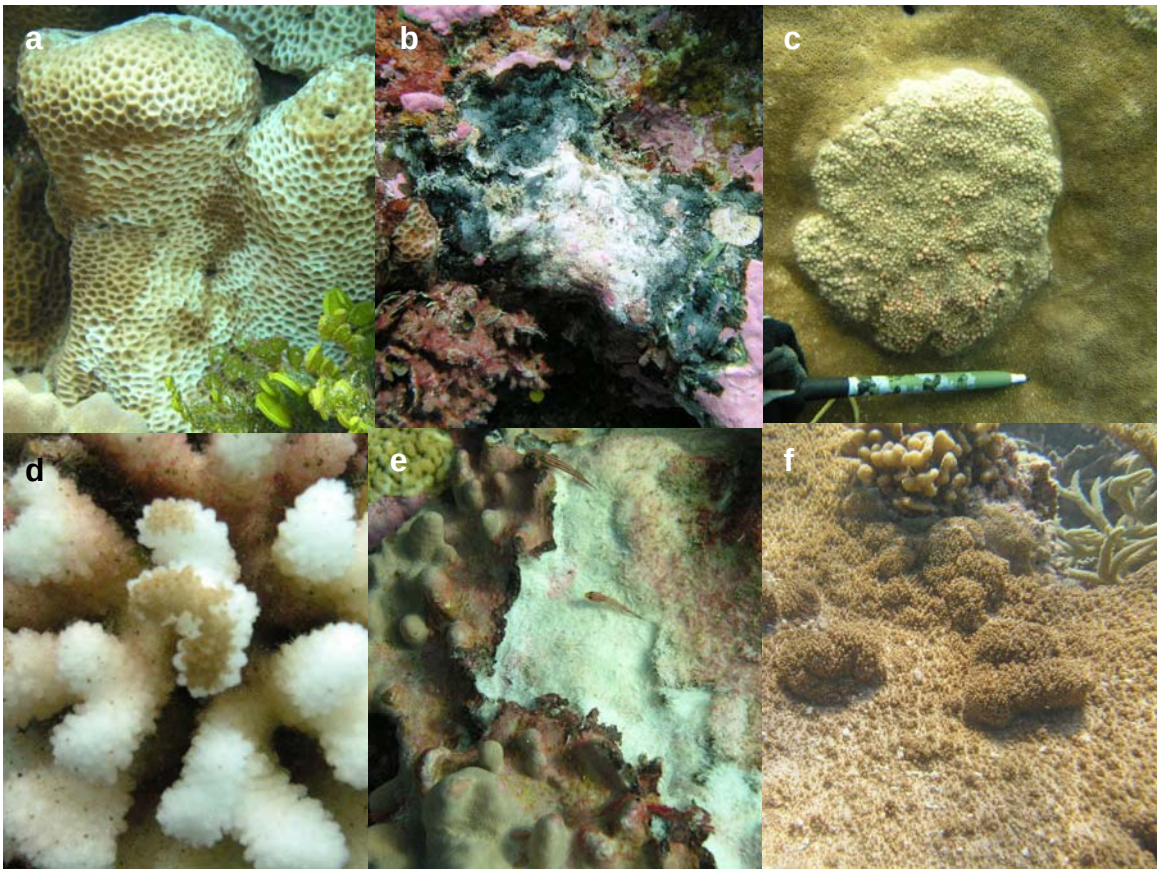


Figure 3.2.3-4 Field appearance of selected types of diseases, syndromes, and other afflictions affecting scleractinian corals, soft corals, and coralline algae at Palmyra Atoll, 2006. a. Partial bleaching on *Gardineroseris planulata*. b. Crustose coralline algae fungal disease. c. Growth anomaly on *Porites*; d. Tissue loss on *Pocillopora* (possible attributable to predation and/or damselfish lawn expansion). e. Tissue loss, necrosis, and algal colonization on *Sinularia* sp. F. Growth anomaly on *Acropora cytherea*.

C.3.2.4. Coral REA sites description

PAL25 (3-24-2006: 05°51.838'N; 162°01.860' W)

Southeast, ocean fringing reef slope; gentle slope, approx. 5–10 degrees. Depth range: 12–15 m. Mean coral cover was 42%. Relative high coral diversity dominated by *Porites* spp. and *Pocillopora verrucosa/meandrina/eydouxi*. Crustose coralline algae contributed nearly 42% of the total bottom cover. Other corals observed in the survey area included: *Turbinaria reniformis*, *Favia stelligera*, *Pavona duerdeni*, *Pavona* cf. *chiriquiensis*, *Pavona varians*, *Pavona explanulata*, *Hydnophora microconos*, *Lobophyllia* and *Psammocora*. In addition, a relative high abundance of soft corals (*Sinularia*, *Sarcophytun*) were observed. Coral health and disease assessment indicated that within the total area surveyed (~250m^2), two cases of growth anomalies were detected on colonies of *Porites*. Additionally, two cases of tissue loss were observed on *Pocillopora* cf. *verrucosa*. Finally, one case of tube worm (*Spirobranchus*) was detected on one colony of *Porites*. The estimated relative abundance of coral diseases for this site was 22.2 cases/1000 m^2.

PAL10 (3-24-2006: 05°51.961'N; 162°02.909'W)
South–Southeast, ocean fringing reef slope; gentle slope, approx. 5–10 degrees. Depth range: 13–15 m. Mean coral cover was 30.9%. Relative high coral diversity dominated by *Porites* spp. and *Pocillopora verrucosa/meandrina/eydouxi*. Other corals observed in the survey area included: Turbinaria, *Favia stelligera*, *Pavona duerdeni*, *Pavona* cf. *chiriquiensis*, *Pavona varians*, *Pavona explanulata*, *Hydnophora microconos*, *Lobophyllia*, *Montastrea*, and *Psammocora*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), five cases of tissue loss were detected on colonies of *Pocillopora* cf. *verrucosa*. Also, one case of discoloration (paling) was observed on *Porites*. The estimated relative abundance of coral diseases for this site was 15 cases/1000 m^2. Finally, three cases of coralline algae fungal disease were observed.

PAL19 (3-24-2006: 05°51.984'N; 162°06.598'W)
South–Southwest, ocean fringing reef slope; gentle slope, approx. 5–10 degrees. Depth range: 14 m. Mean coral cover was 31.3%. Relative high coral diversity dominated by *Porites* spp. and *Pocillopora verrucosa/meandrina/eydouxi*. Other corals observed in the survey area included: Turbinaria, *Favia stelligera*, *Pavona duerdeni*, *Pavona* cf. *chiriquiensis*, *Pavona varians*, *Pavona explanulata*, *Hydnophora microconos*, *Lobophyllia*, *Montastrea*, and *Psammocora*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), four cases of discoloration (paling) were detected on colonies of *Pocillopora eydouxi*, *Porites*, and *Gardieneroseris planulata*. Also, one case of growth anomaly was observed on *Pocillopora eydouxi*, and 15 cases of tissue loss were observed on *Pocillopora* cf. *verrucosa*. Additionally four cases of tissue loss and algal colonization were observed on colonies of *Porites*. Also, four cases of irritation were on *Porites* cf. *lobata*. The estimated relative abundance of coral diseases for this site was 60 cases/1000 m^2. Finally, once case of necrosis was detected on a colony of *Sinularia* sp. Peripheral to the survey area, one case of growth anomaly was detected on a colony of *Porties*.

PAL26 (3-26-2006: 05°51.844'N; 162°07.605'W)
South–Southwest, ocean fringing reef slope; West platform gentle slope, approx. <5 degrees. Depth range: 14–15 m. Mean coral cover was 53.9%. Relative high coral diversity dominated by *Porites* cf. lutea and *Pocillopora verrucosa/meandrina/eydouxi*. Other corals observed in the survey area included: Turbinaria, *Favia stelligera*, *Pavona duerdeni*, *Pavona* cf. *chiriquiensis*, *Pavona varians*, *Turbinaria reniformis*, *Hydnophora microconos*, *Lobophyllia*, *Montastrea*, and *Psammocora*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), two cases of discoloration (paling) were observed on *Porties* cf. *lutea* and *Pocillopora verrucosa*, respectively. Also, seven cases of tissue loss were detected on colonies of *Pocillopora* cf. *verrucosa*. Additionally, two cases of irritation and filamentous algal overgrowth were observed on *Porites* sp. Finally, one case of tube worm (*Spyrobranchus*) was observed on *Porites* sp. The estimated relative abundance of coral disease for this site was 30 cases/1000 m^2.

PAL11 (3-26-2006: 05°53.009'N; 162°08.014'W)
West, ocean fringing reef slope; West platform gentle slope, approx. <5 degrees. Depth range: 13–15 m. Mean coral cover was 20.6%. Community dominated by *Porites* cf. *lutea.* Other corals observed in the survey area included: *Favia stelligera*, Pocillopora verrucosa, and *Turbinaria reniformis*. This community exhibited relatively high abundance of the green macroalga, *Dictyosphaeria* (17%). Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), one case of growth anomaly was detected on a colony of *Favites*. Also, 12 cases of tissue loss were detected on colonies of *Pocillopora* cf. *verrucosa*; 6 of these colonies also exhibited discoloration (paling). Additionally, two cases of irritation and filamentous algal overgrowth were observed on *Porites* sp., as well as two cases of discoloration on *Porites* sp. (one case) and *Hydnophora microconos* (one case). Finally one case of tube worm (*Spyrobranchus*) was observed on *Porites* sp. The estimated relative abundance of coral diseases for this site was 50 cases/1000 m^2. Finally, two cases of coralline algae fungal disease were observed.

PAL05 (3-26-2006: 05°53.777'N; 162°08.241'W)
West-Northwest, ocean fringing reef slope; scoured bottom dominated by staghorn and table *Acropora* rubble covered with crustose coralline algae. Depth range: 12–14 m. Mean coral cover was relatively low: 10.7%. Scleractinian corals in order of abundance: *Porites*, *Favia stelligera*, *Pavona varians*, and *Montastrea*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), no afflictions to scleractinian corals or coralline algae were observed.

PAL09P (3-26-2006: 05°52.044'N; 162°05.694'W)
South; ocean fringing reef; gentle slope (<5 degrees). Depth range 10–12 m. Jim Maragos' permanent transect. Disturbed bottom, staghorn and table *Acropora* rubble covered with crustose coralline algae and *Halimeda*. The soft corals, *Sinularia* and *Sarcophyton,* were also relatively abundant. Mean coral cover was relatively low: 10.7%. Scleractinian corals in order of abundance: *Favia stelligera*, *Pavona varians*, *Favites*, and *Montastrea*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), 14 cases of partial paling and tissue loss were observed on *Pocillopora* cf. *verrucosa*. Additionally, one case of paling was detected on *Pocillopora*. The estimated incidence of scleractinian coral disease was 37.5 cases/1000 m^2. Also, within the survey area, 28 cases of coralline fungal disease were observed. The estimated incidence for coralline disease was 70 cases/1000 m^2

PAL01P (3-26-2006: 05°52.066'N; 162°04.155'W)
South; ocean fringing reef; gentle slope (<5 degrees). Depth range 10–12 m. Jim Maragos' permanent transect. Disturbed bottom composed mainly of old staghorn *Acropora* rubble. Crustose coralline algae, *Halimeda*, and a green Didemnid tunicate were important components of the benthic substrate. The Acyonarians, *Sinularia* and *Sarcophyton,* were also relatively abundant. Mean percent live coral cover was relatively low: 10.7%. Scleractinian corals in order of abundance: *Porites rus*, *Pavona varians*, *Favites*, and *Montastrea*. Coral health and disease assessment indicated that within the total area surveyed (~200 m^2), two cases of partial paling and tissue loss were observed

on *Pocillopora* cf *verrucosa*. In addition, one case of paling was detected on *Pocillpora eydouxi*. The estimated incidence of scleractinian coral diseases at this site was low: 15 cases/1000 m^2. Also, within the survey area, four cases of coralline fungal disease were observed. The estimated incidence for coralline algae disease was: 20 cases/1000 m^2.

PAL21 (3-27-2006: 05°53.747'N; 162°05.081'W)
North; ocean fringing reef; gentle slope (<5 degrees). Depth range 12–15 m. Mean percent live coral cover was relatively low: 4.9%. Scleractinian corals in order of abundance: *Porites* and *Montipora*. The Alcyonarinas, *Sinularia* and *Sarcophyton,* were also important components of the benthic substrate. Coral health and disease assessment indicated that within the total area surveyed (~450 m^2), one case of tissue loss was observed on *Pocillopora* cf. *verrucosa*. The estimated incidence of scleractinian coral diseases at this site was low: 2.2 cases/1000 m^2. Also, within the survey area, three cases of coralline fungal disease were observed. The estimated incidence for coralline algae disease was: 8.9 cases/1000 m^2. Finally, two specimens of *Palythoa* and *Lobophytum,* respectively exhibited patchy bleaching.

PAL12 (3-27-2006: 05°53.845'N; 162°06.452'W)
North; ocean fringing reef; gentle slope (<5 degrees). Depth range 12–15 m. Mean percent live coral cover was relatively low: 18.6%. Scleractinian corals in order of abundance: *Porites*, *Montipora*, *Favia stelligera*, and *Pavona varians*. The Alcyonarinas, *Sinularia* and *Sarcophyton,* were also important components of the benthos. Coral health and disease assessment indicated that within the total area surveyed (~450 m^2), five cases of discoloration and tissue loss were observed on *Pocillopora* cf. *verrucosa*. The estimated incidence of scleractinian coral diseases at this site was low:
11.1 cases/1000 m^2. Also, within the survey area, four cases of coralline fungal disease were observed. The estimated incidence for coralline algae disease was:
8.9 cases/1000 m^2.

PAL20 (3-27-2006: 05°53.801'N; 162°07.173'W)
North; ocean fringing reef; gentle slope (<5 degrees). Depth range 12–15 m. Mean percent live coral cover was relatively high: 36.2%. Scleractinian generic diversity was also high: 17, including *Porites*, *Montipora*, *Favia*, Favites, *Pavona*, *Acropora*, *Hydnophora*, *Turbinaria*, *Montastrea*, *Platygyra*, etc. Interestingly, the Alcyonarinas, *Sinularia* and *Sarcophyton,* were common, but not as abundant as at sites PAL21 and PAL12. Coral health and disease assessment indicated that within the total area surveyed (~200 m^2), nine cases of tissue loss were observed on *Pocillopora* cf. *verrucosa*. The estimated incidence of scleractinian coral diseases at this site was low: 45 cases/1000 m^2. Also, within the survey area, 15 cases of coralline fungal disease were observed. The estimated incidence for coralline algae disease was 75 cases/1000 m^2.

PAL16P (3-28-2006: 05°52.294'N; 162°06.737'W)
South-Southwest; patch reef; ship channel. Depth range 3–7 m. Mean percent live coral cover was low: 10.7%. Dominant corals in order of importance: *Montipora*, *Pocillopora*. High percent of benthos composed by rubble and crustose coralline algae. Coral health and disease assessment: Within the total area surveyed (~500 m^2), one case of tissue loss

was observed on *Pocillopora* cf. *verrucosa*. The estimated incidence of scleractinian coral diseases at this site was low: 2 cases/1000 m^2.

PAL15P (3-28-2006: 05°52.221'N; 162°02.697'W)
East; patch reef; inside lagoon; coral garden. Depth range 3–7 m. Mean percent live coral cover was high: 67%. Community dominated by tabular and staghorn *Acropora*. Other scleractinian's order of importance: *Montipora*, *Pocillopora, Porites, Hydnophora, Montastrea, Psammocora*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), two cases of growth anomalies were detected on tabular *Acropora*. The estimated incidence of scleractinian coral diseases at this site was low: 5 cases/1000 m^2. No afflictions to crustose coralline algae were observed at this site.

C.3.2.5. Benthic Towed-diver Survey—Corals

The western terrace exhibited the highest abundance of live hard coral with coverage averaging an estimated ~20-30%. Interspersed along the western terrace were habitats that contained an estimated average of 62–75% live hard coral coverage. Stressed coral was observed in low abundance (<5%) throughout the atoll. This corroborates observations by the REA coral team at site PAL11. Approximately 20% of the total coral observed in a small isolated area just inside of the northwestern breakers appeared to be stressed.

C.3.3. Invertebrates

The purpose of the REA activities for HI-06-04 was to select sites surveyed during previous rapid ecological assessments for long-term monitoring. Selection of sites was based on their year-round accessibility and their representation of the habitats present at each site. Surveys focusing on marine invertebrates other than corals were performed in conjunction with surveys of coral and macroalgae, collectively termed the benthic survey. This benthic survey was conducted collaboratively with fish surveys. This report will cover the non-coral invertebrates encountered and from this point forward any mention of marine invertebrates refers to this particular group.

C.3.3.1. Invertebrate REA Site Descriptions

PAL25
No invertebrate dive

PAL10 (3-24-2006: 05°51.961'N, 162°02.909'W),
PAL19 (3-24-2006: 05°51.984'N, 162°06.598'W)
South shore with forereef habitat. High coral cover with abundant soft corals made up of *Sinularia*, *Lobophytum,* and *Sarcophyton*. Both sites were devoid of macroinvertebrates except for mollusks, which were rare, and the hermit crab *Calcinus haigae*, which were common. The hermit crab, *Calcinus laurentae,* was recorded at PAL19, which is considered an endemic to the Hawaiian Archipelago. This would constitute the first record outside of Hawaii. The hydrozoans, *Distichopora* and *Stylaster,* were abundant throughout both sites.

PAL26 (3-25-2006: 05°51.844'N, 162°07.605'W)
Southwest side of western terrace. High coral cover with a high percentage of the soft corals, *Sarcophyton* and *Lobophytum*. There was rare occurrence of another soft coral, *Dendronephtya*. A single large giant clam (*Tridacna maxima*) was seen in the vicinity of the transect. The hydrozoans, *Distichopora* and *Stylaster,* were common but cryptic. A rust colored sponge was common throughout the site. A conspicuous absence of echinoderm fauna other than cryptic ophiuroid fauna was noted at this site.

PAL11 (3-25-2006: 05°53.009'N, 162°08.014'W)
Central east region of the western terrace. Similar to PAL-26 but with lower coral cover. The soft corals, *Sarcophyton* and *Lobophytum,* were common. The holothuroid, *Holothuria atra,* was recorded but was rare. There was an absence of any other echinoderm fauna other than cryptic ophiuroid fauna. A single *Tridacna maxima* that was roughly 60 cm in length was noted in the vicinity of the survey area. The hydrozoans, *Stylaster* and *Distichopora,* were common throughout the site. *Turbo argyrostomus* was also noted at the site but was rare.

PAL05 (3-26-2006: 05°53.777'N; 162°08.241'W)
Central north side of western terrace. Dominated by the soft corals, *Sarcophyton* and *Lobophytum,* with very little hard corals. *Cryptic ophiuroid* fauna were the only mobile echinoderms noted at the site. The anemone, *Crytodendrum adhaesivum,* was recorded at the site but was rare, as was the gastropod *Pleuroploca*.

PAL09P (3-26-2006: 05°52.044'N, 162°05.693'W)
Central south shore with moderate coral cover. The soft corals, *Sarcophyton* and *Lobophytum,* were abundant throughout the site. Large quantities of coral rubble were consolidated in sand channels and this provided refuge for hermit crabs and brittle stars. A green didemnid tunicate was pervasive at this site and was associated with old coral rubble. No large echinoderm species were recorded at this site.

PAL01P (3-26-2006: 05°52'066'N, 162°04.138'W)
Southeast shore with low coral cover and abundant coral rubble from a previous coral die-off. The only abundant mobile macroinvertebrates were the hermit crab, *Calcinus haigae*. A single sea star, *Echinaster luzonicus,* was recorded but no other macro-echinoderms were present.

PAL21 (3-27-2006: 05°53.747'N, 162°05.081'W)
Central north shore with fringing reef slope. The holothuroid, *Holothuria atra,* and the sea star, *Echinaster luzonicus,* were the only large macroinvertebrate to be recorded. The hydrozoans, *Distichopora* and *Stylaster,* were abundant in cryptic habitats. The hermit crab, *Calcinus haigae,* was very abundant, while *Dardanus* and *Ciliopagurus* were rare. Soft coral were dominant and the most common were *Sarcophyton* and *Lobophytum*.

PAL12 (3-27-2006: 05°53.845'N, 162°06.452'W)
Central north shore with a sloping fringe reef. No large echinoderms were recorded at the site. Only cryptic brittle stars, mostly *Ophiocoma dentata* and *Ophiocoma erinaceus*, were present under rubble. Soft corals were abundant (*Sarcophyton* and *Lobophytum*), as was the hard coral *Pocillopora*. The hermit crab, *Calcinus haigae,* was abundant at the site.

PAL20 (3-27-2006: 05°53.801'N, 162°07.173'W)
West end of north shore with sloping fringe reef. No large echinoderms were present but brittle stars were present under rubble. The soft corals, *Sarcophyton* and *Lobophytum*, were abundant as were a variety of hard corals including *Acropora*. The hermit crab *Calcinus haigae* was abundant, as were the hydozoans *Distichopora* and *Stylaster*.

PAL16P (3-28-2006: 05°52.294'N, 162°06.738'W)
East side of navigation channel. This site has experienced a severe bleaching event in the recent past and is in the early stages of recovery. Two *Tridacna maxima* were recorded from the site, otherwise the only other macroinvertebrate recorded was the gastropod, *Cypraea moneta*.

PAL15P (3-28-2006: 05°52.221'N, 162°02.697'W)
Eastern lagoon site at the "Coral Gardens." Macroinvertebrates other than *Tridacna maxima* were scarce at this site.

C.3.3.2. Specific Findings for Invertebrates

Table C.3.3.2-1 summarizes the relative abundance data for most common species enumerated during REA surveys and percent cover for sponges and cnidarians.

Island	Palmyra	Palmyra	Palmyra	Palmyra	Palmyra	Palmyra	Palmyra	Palmyra	Palmyra	Palmyra	Palmyra	Palmyra	Palmyra
Date	3/24/2006	3/24/2006	3/24/2006	3/25/2006	3/25/2006	3/25/2006	3/26/2006	3/26/2006	3/27/2006	3/27/2006	3/27/2006	3/28/2006	3/28/2006
Site	PAL-25	PAL-10	PAL-19	PAL-26	PAL-11	PAL-05	PAL-9P	PAL-01P	PAL-21	PAL-12	PAL-20	PAL-16P	PAL-15P
Depth(feet)	50	50	52	53	49	44	35	35	50	47	42	12	10
Habitat	Forereef	Forereef	Forereef	West Terrace	West Terrace	West Terrace	South Shore	South Shore	North Shore	North Shore	North Shore	Channel	Coral Garden
	Avg%Cover/m2	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**
Porifera	No Data	0	0	0.220	0.060	0.240	0	0	0	0	0	0	0
Cnidaria		0	0	0	0	0	0	0	0	0	0	0	0
Zoanthid		0	0	0.040	0	0	0.020	0	0.160	0.100	0	0	0
Hydroidea		0.800	0.600	0	0.080	0	0	0	0	0.060	0	0	0
Sinularia		7.100	0	0	0	0	0	0	0.120	0.200	0	0	0
Sarcophyton		1.250	0	0.300	0	0	0	0	0.920	1.000	0	0	0
Lobophyton		5.350	10.450	0	0.700	0.940	0.300	0	1.080	0.600	0.720	0	0
	Avg#/m2	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**
Mollusca	No Data	0	0	0	0	0	0	0	0	0	0	0	0
Spondylus		0	0.008	0	0	0	0	0	0	0.002	0	0	0
Tridacna sp		0	0.006	0	0	0	0	0	0	0	0	0.004	0.014
Holothuroids		0	0	0	0	0	0	0	0	0	0	0	0
Holothuria atra		0	0	0	0	0.004	0	0	0.002	0.002	0	0	0
Crustacean		0	0	0	0	0	0	0	0	0	0	0	0
Trapezid crabs		0.2	0.4	0.8	0.6	0	0.6	0.2	0.2	0.2	0.2	0	0
Hermit Crabs		0.8	1.6	0.6	0	0	0.8	0.8	1.6	1	0.4	0	0

Table C.3.3.2-1. Relative abundance data for most common species enumerated during REA surveys and percent cover for sponges and cnidarians.

C.3.3.3. Benthic Towed-diver Survey - Macroinvertebrates

Soft corals were observed during all tows conducted around Palmyra with the dominant genera being *Sarcophyton* and *Sinularia*. The north and southeastern shores contained the highest abundance averaging an estimated 20–30% of the coverage. In addition, few conspicuous macroinvertebrates were observed. Twelve sea cucumbers and three giant clams were recorded but neither sea urchins nor crown-of-thorns starfish were observed. A dideminid tunicate was observed dominating ~ 75% of the substrate along ~ 500 m of a rubble habitat in the western terrace.

C.3.3.4. Invertebrates Discussion

The lack of abundant macroinvertebrate fauna throughout the reef habitats at Palmyra Atoll is the main point of interest from all surveys. Echinoderms, which are usually the dominant macroinvertebrate component of coral reefs, were absent from most transect enumerations. The only echinoderm species recorded on belt transects were the holothuroid, *Holothuria atra,* and the asteroid, *Echinaster luzonicus,* at a single site (PAL-21). The giant clam, *Tridacna maxima,* was recorded from five sites but was rare at each and only fell within transect at three sites (PAL-19, PAL-16P, and PAL-15P). The most common mobile macroinvertebrates were Trapezid crabs and hermit crabs, which were mostly associated with *Pocillopora* corals. The most commonly seen hermit crab species was the diogenid, *Calcinus haigae* (Fig. C.3.3-1). The majority of sites had high cover of the soft corals *Sinularia*, *Sarcophyton*, and *Lobophytum*, with minor components of zoanthids and hydroids. Coral cover and diversity were highest on the eastern end of the atoll and decreased towards the west. Sites such as PAL-01P on the southeast side and PAL-16P on the western side of the atoll have had their coral communities wiped out by coral bleaching events and are in a state of slow recovery. In the vicinity of site PAL-16P, a large growth of the corallimorpharian, *Rhodactis howseii,* (Fig. C.3.3-1) was seen. This corallimorpharian appears to be acting invasively, especially near the wreck of a long-line vessel. Overgrowth of *Montipora* coral colonies by this species was noted. These stressed sites had sporadic records of mollusks such as small cowries and Tridacnid clams and hermit crabs. Sites that appear to have healthy coral communities, such as site PAL-15P, had few macroinvertebrates other than small numbers of Tridacnid clams. Past surveys in 2002 and 2004 have shown more speciose communities of sponges, crustaceans, echinoderms, and gastropod mollusks associated with supralittoral and littoral zones in the lagoon. There is no clear explanation for the lack of macroinvertebrate fauna on the outside reef habitats.

One note of interest is the record of a hermit crab species that resembles *Calcinus laurentae* from site PAL-19 (Fig. C.3.3-1). This record is of interest because *Calcinus laurentae* is considered endemic to the Hawaiian Archipelago.

Figure C.3.3-1. L to R: *Rhodactis howseii* (Cnidaria; Corallimorpharian), *Calcinus cf. laurentae* and *Calcinus haigae*

C.4. Fish

Overview map of REA stations and towed-diver survey transects, if the same as the benthic team then refer to that map. (Timmers, Musburger, and Lundblad)

From March 24 to March 28, 2006, the fish REA team (Craig Musburger, Paula Ayotte, and Todd Wass) surveyed 13 sites around Palmyra Atoll while the towed-diver fish survey team (Stephane Charette, Amy Hall, and Edmund Coccagna) conducted 18 towed-diver fish surveys totaling 42.4 km in length.

All of the REA sites were monitoring sites previously visited by CRED teams. Quantitative belt transects (BLT), stationary point counts (SPC), and qualitative REA surveys (for species presence) were conducted at each site, using the same methodology as in previous years except at site PAL-15 where quantitative surveys were not conducted and REA team divers only conducted qualitative species presence surveys. The benthic team (corals, algae, invertebrates) followed the fish team at all survey sites.

The fish observers collectively recorded 176 species of reef fishes at Palmyra. The three schooling planktivores that dominate the fish fauna of Jarvis Island were not nearly as abundant at Palmyra. The most abundant fish species based on REA surveys were dwarf chromis (*Chromis acares*), Vanderbilt's chromis (*C. vanderbilti*), and bicolor chromis (*C. margaritifer*). Diversity was highest among wrasses (35 species recorded) and surgeonfish/unicornfish (25 species). Large fish, including sharks, were generally less abundant than at Jarvis with the exception of the twinspot snapper (*Lutjanus bohar*), which was quite common. Napoleon wrasses (*Cheilinus undulatus*) and manta rays (*Manta birostris*) were encountered frequently but were rarely recorded within the boundaries of quantitative REA surveys.

A total of 794 fishes were observed during the 18 tows conducted at Palmyra Atoll. The most abundant species observed was the twinspot snapper (*L. bohar*) with 444 individuals counted. The Pacific steephead parrotfish (*Chlorurus microrhinos*) was the

second most frequently observed fish with a total of 61 individuals recorded. These were closely followed by the grey reef shark (*Carcharhinus amblyrhyncos*), which was the third most frequently observed species with 58 individuals recorded. Other notable observations included 2 bumphead parrotfish (*Bolbometopon muricatum*) and 18 Napoleon wrasses (*Cheilinus undulatus*). Another species of interest, the giant trevally (*Caranx ignobolis*), was observed 29 times at Palmyra, which was more frequent than any other of the Line Islands.

The most commonly observed family was the snappers (family Lutjanidae) with 446 individual sightings. Sharks (family Carcharhinidae) were the second most frequently observed family with 96 individual counts. The grey reef shark (*C. amblyrhynchos*) accounted for the majority of these with 58 sightings, followed by the black tip reef shark (*C. melanopterus*) and the white tip reef shark (*Triaenodon obesus*) with 29 and 9 observations, respectively.

C.4.1. Regional Summary

Palmyra Atoll can be divided into four regions: (1) a Northern Reef Slope, (2) a Southern Reef Slope, (3) an East Terrace, and (4) a Western Terrace. Because of inclement weather, surveying was not possible on the exposed Eastern Terrace. One REA site (PAL-16) was located on the edge of the channel in the atoll lagoon and is included here separately. Following are brief summaries of the fish observations of the fish REA team and the towed-diver fish team by region. Please refer to the map of REA sites (Fig. C.3-1) and the map of towed-diver surveys (Fig. C.3-2) for specific site and tow track locations. Tows occasionally overlapped in some regions resulting in partial tows.

Northern Reef Slope

REA Sites PAL-05, PAL-20, PAL-12, PAL-21; Towed-Diver Surveys 11, 12, 16, 17, 18

SPC divers did not observe many sharks along the Northern Reef Slope. A single grey reef shark (*Carcharhinus amblyrhynchos),* two whitetip reef sharks (*Triaenodon obesus*), and five blacktip reef sharks (*C. melanopterus*) were recorded during the sixteen SPC replicates performed along this shore. The most common fish species recorded by SPC divers were twinspot snappers (*Lutjanus bohar*), flametail snappers (*L. fulvus),* yellowback fusiliers (*Caesio teres*), and bullethead parrotfish (*Chlorurus sordidus*). One species that was unusually common at sites PAL-20 and PAL-21 was the yellowmargin triggerfish (*Pseudobalistes flavimarginatus*). Unicornfish (family Acanthuridae) were not especially abundant but were diverse, with five different species being recorded. Groupers were not especially common. Peacock grouper (*Cephalopholis argus*) were most common and a few camouflage grouper (*Epinephelus polyphekadion*) and lyretail grouper (*Variola louti*) were observed. Of special note, three Napoleon wrasse (*Cheilinus undulatus*) ranging from 45 to 65 cm TL were recorded at site PAL-12, and a 50 cm TL giant trevally (*Caranx ignobilis)* was recorded at site PAL-21.

Based on Belt Transect surveys, the most abundant family along the Northern Reef Slope was the damselfish. Neon damselfish (*Pomacentrus coelestis*), dwarf chromis (*Chromis*

acares), Vanderbilt's chromis (*C. vanderbilti*), and bicolor chromis (*C. margaritifer*) were all abundant. The wrasses (family Labridae) were especially diverse in this region and were dominated by bluntheaded wrasses (*Thalassoma amblycephalum*). Other common wrasse species recorded included the endemic Central Pacific coris (*Coris centralis)*, the fivestriped wrasse (*T. quinquevittatum*), the eightlined wrasse (*Pseudocheilinus octotaenia*), and the bird wrasse (*Gomphosus varius)*. Butterflyfish and angelfish were rare in this region with occasional sightings made of lemonpeel angelfish (*Centropyge flavissima)* and raccoon butterflyfish (*Chaetodon lunula).* Surgeonfish (family Acanthuridae) and parrotfish (family Scaridae) were not especially abundant along the Northern Reef Slope, except at site PAL-20 where large groups of up to 200 goldrim surgeonfish (*Acanthurus nigricans)* and a single group of 80 bullethead parrotfish (*Chlorurus sordidus)* were recorded. A single species of anthias, the olive anthias (*Pseudanthias olivaceus)* was recorded on BLT surveys along the Northern Reef Slope and was not especially numerous. One giant trevally (*C. ignobilis)* estimated at 75 cm TL and one Napoleon wrasse (*C. undulatus)* were recorded within the boundaries of the BLT survey at site PAL-21.

Five complete towed-diver surveys were conducted in this region totaling 11.04 km. The twinspot snapper (*L. bohar*) was the most frequently recorded fish species with 200 observations. The second most frequently seen species was the giant trevally (*C. ignobolis*) with 24 individuals recorded. These observations make up the bulk of the total giant trevally sightings at Palmyra. Sharks (family Carcharhinidae) were the second most frequently recorded fish family with 35 observations. Out of 15 species, 315 individual fish were recorded in this region.

Southern Reef Slope
Rea Sites PAL-26, PAL-19, PAL-09, PAL-01, PAL-10, PAL-25; Towed-Diver Surveys 6, 13, 14, 15, 5 (last 7 segments)

The most abundant fish recorded by SPC divers on the Southern Reef Slope was the twinspot snapper (*Lutjanus bohar*) with a total of 60 individuals recorded at site PAL-26 alone. Sharks were moderately common and were represented by three species. Three napoleon wrasses (*Cheilinus undulatus)* were recorded on SPCs in this region and at site PAL-26 seven milkfish (*Chanos chanos*) from 70 to 90 cm TL were recorded. A large school of Heller's barracuda (*Sphyraena helleri)* was also recorded here. Groupers (family Serranidae) were represented by four species including peacock grouper (*Cephalopholis argus*), lyretail grouper (*Variola louti*), and slenderspine grouper (*Gracila albomarginata*). Parrotfish were dominated by bullethead parrotfish (*Chlorurus sordidus*) and Pacific steephead parrotfish (*C. microrhinos*) but were not especially common at any site in this region. Eight different species of surgeonfish/unicornfish (family Acanthuridae) were recorded, including groups of up to 14 individual bluespine unicornfish (*Naso unicornis)*. Also common were two species of emperors (family Lethrinidae) including bigeye emperors (*Monotaxis grandoculis*) and yellowlip emperors (*Lethrinus xanthocheilus*).

The BLT divers recorded two species of damselfish (family Pomacentridae) as being abundant at all sites in this region: midget chromis (*Chromis acares*) and bicolor chromis (*C. margaritifer*). Olive anthias (*Pseudanthias olivaceus*) were very abundant in this region as were juvenile bluntheaded wrasses (*Thalassoma amblycephalum*). Sixline wrasse (*Pseudocheilinus hexataenia*) and eightline wrasse (*P. octotaenia)* were slightly less abundant but still quite common. Surgeonfish (family Acanthuridae) along belt transects consisted mainly of bluelip bristletooth (*Ctenochaetus cyanocheilus*), bluespotted bristletooth (*C. marginatus*), and goldrim surgeonfish (*Acanthurus nigricans*). The arc-eye hawkfish (*Paracirhitus arcatus*) was observed with high frequency and appeared on transects at every site along the Southern Reef Slope.

On the South side, one partial and four full towed-diver surveys were completed totaling 11.95 km. The twinspot snapper (*L. bohar*), with 146 observations, was the most frequently recorded fish species in this region. The second most frequently recorded fish species was the Napoleon wrasse (*C. undulatus*) with 13 observations and the grey reef shark (*Carcharhinus amblyrhyncos*), also with 13 observations. Out of 22 species, 230 individual fish were recorded in this region.

Western Reef Terrace
Rea Site PAL-11; Towed-Diver Surveys 1, 2, 3, 4, 7, 8, 9, 10, 5 (first 3 segments)

SPC results at the single REA station on the Western Reef Terrace at Palmyra demonstrate that twinspot snapper (*Lutjanus bohar*) were most abundant. A total of five sharks were recorded here, all 120 cm TL or smaller. Also abundant were humpback snapper (*L. gibbus*), and two giant trevally (*Caranx ignobilis*) were recorded. In general, fish over 25 cm were rare here.

The Belt Transects at this site were composed mostly of two species of damselfish, bicolor chromis (*Chromis margaritifer*) and Vanderbilt's chromis (*C. vanderbilti*). The most diverse family was the wrasses (family Labridae) with nine different species recorded along transects. Damselfish and surgeonfish followed with seven and six species, respectively. Groupers and snappers were nearly absent from the transect at this site.

One partial and eight complete towed-diver surveys were conducted in this region totaling 19.41 km. The twinspot snapper (*L. bohar*), with 98 observations, was the most frequently recorded fish species. The Pacific steephead parrotfish (*Chlorurus microrhinos*), with 46 observations, was the second most frequently recorded species. The bumphead parrotfish (*Bolbometopon muricatum*) was recorded twice in this region, and a third individual was sighted here but not within the swath distance. Out of 24 species, 249 individual fish were recorded in this region.

Lagoon Channel
Rea Site PAL-16P

This site was situated on the edge of the channel passing into the Palmyra Lagoon. The REA site was approximately 3 meters deep, and towed-diver surveys were not possible. Fish density was extremely low as recorded by the REA team. Based on the SPC, the Pacific steephead parrotfish (*Chlorurus microrhinos*) and twinspot snapper (*Lutjanus bohar*) were most abundant. Orangespine unicornfish (*Naso lituratus*) were also fairly common. Surgeonfish (family Acanthuridae) dominated the Belt Transects with striped bristletooth (*Ctenochaetus striatus*) and gold-rimmed surgeonfish (*Acanthurus nigricans*) being the most common. The usually common damselfishes and wrasses were much less abundant at this site.

C.5. Terrestrial Studies

Terrestrial surveys were not conducted during HI-06-04.

Appendix D: Kingman Reef

D.1. Benthic Habitat Mapping

Between March 29 and April 4, 2006, multibeam mapping on and around Kingman Reef resulted in approximately 926 sq. km. of bathymetry collected in water depths ranging from 2 to 3500 meters below sea level (Fig. D.1-1) Daytime mapping was conducted primarily by the R/V Acoustic Habitat Investigator (*AHI)* (Fig. D.1-2), and night operations were conducted aboard the NOAA Ship *Hi'ialakai*. Limited daytime mapping was conducted by the *Hi'ialakai* when conditions were favorable.

The *Hi'ialakai* arrived at Kingman Reef early on the morning of March 29 and the *AHI* was deployed and mapped the southern reef margin, entered the interior of the reef, and defined the depth and width of the southeast pass. At night, the *Hi'ialakai* mapped south of Reef. Multibeam data collected by the R/V Ka imikai-o-kanaloa in 2005 was initially used as a depth reference. On March 30, the *AHI* mapped the western reef margin. At night, the *Hi'ialakai* mapped west and southwest of the Reef. On March 31, the *AHI* mapped portions of the outer, northeastern reef and the shallow northwestern reef. At night, the *Hi'ialakai* mapped north of the Reef. On April 1, the *AHI* mapped portions of the southern and western reef margins and defined the edge of the western, inner reef. After a small boat deployment, the *Hi'ialakai* mapped the gap between the *AHI* coverage and previous *Hi'ialakai* coverage around the entire Reef perimeter. Poor weather conditions forced the *AHI* and other small boats to return to the *Hi'ialakai* shortly after lunch. At night, the *Hi'ialakai* mapped east and south of the Reef. On April 2, the *AHI* continued to map the inner Reef and ran four lines across the center of the Reef for seafloor characterization and to acquire ground control points for planned IKONOS depth derivatives. Night mapping aboard the *Hi'ialakai* occurred west of the Reef and included mapping the eastern toe of a bank to greater than 1000 m below sea level (Fig. D.1-1). Mapping on the *AHI* was called off on April 3 because of rough weather conditions, although other small boats were launched and deployed according to schedule. The *Hi'ialakai* departed Kingman Reef and began transiting to the Main Hawaiian Islands after small boat recovery on the afternoon of April 3.

During the Kingman Reef portion of HI0604, conductivity-temperature-depth (CTD) casts were conducted to 500 m each night at about 1800 before shipboard mapping began. CTD casts aboard the *AHI* were performed to variable depths depending on the intended survey location at the start of each day, shortly after deployment.

Kingman Reef is a triangular shaped atoll that is shallow along its outer edges (0 to 25 m) and separated from its interior by sand bars and shallow reefs. The seafloor inside the reef varies in morphology and depth. In some places, such as the southeastern pass, the bottom is hard and coral rich whereas in other places, such as the eastern interior, the bottom is soft and hummocky and probably composed of sand. Seafloor depths in the interior of the atoll range from a few meters below sea level to greater than 50 m. The seafloor surrounding Kingman Reef is quite variable and complex. Channels incise most of the bank edges and extend down to greater than 3500 m. The seafloor adjacent to the western and eastern tips of the triangular atoll is dotted with small seafloor highs at 1000 to 1500 m. Many of these are pointed and appear to be volcanic in origin (Fig. D.1-1).

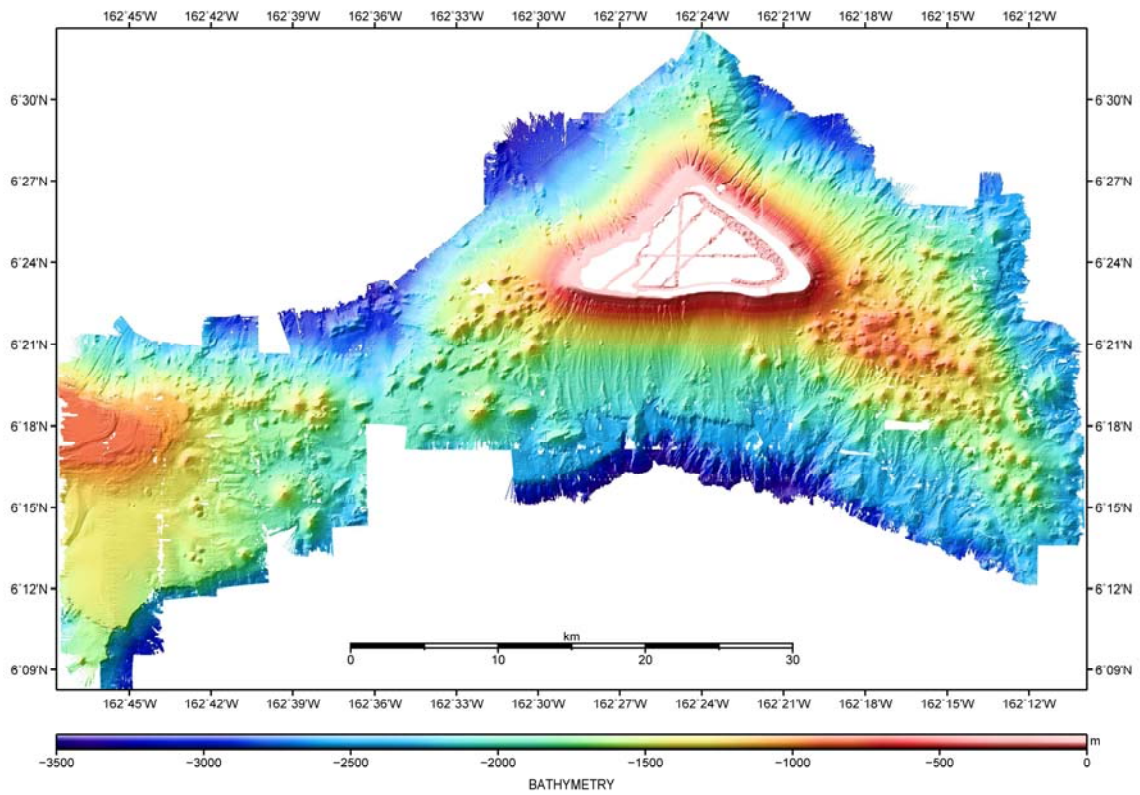


Figure D.1-1: Illuminated and color-shaded multibeam bathymetry collected at Kingman Reef during HI0604.

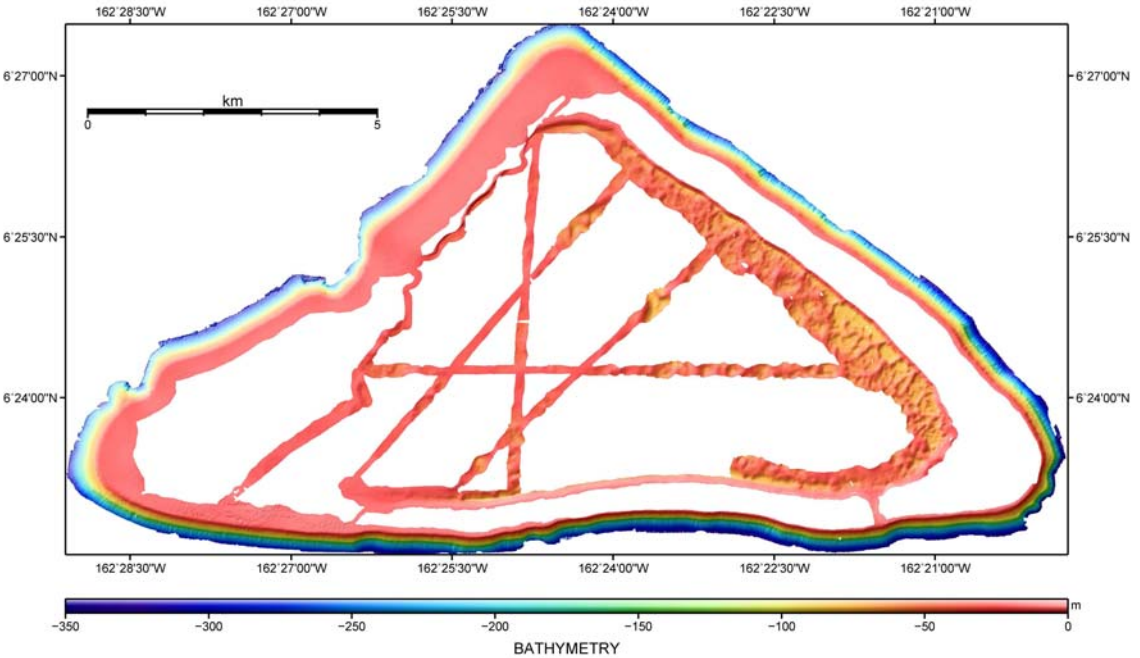


Figure D.1-2: Illuminated and color-shaded multibeam bathymetry of the Kingman Reef banktop collected during HI0604.

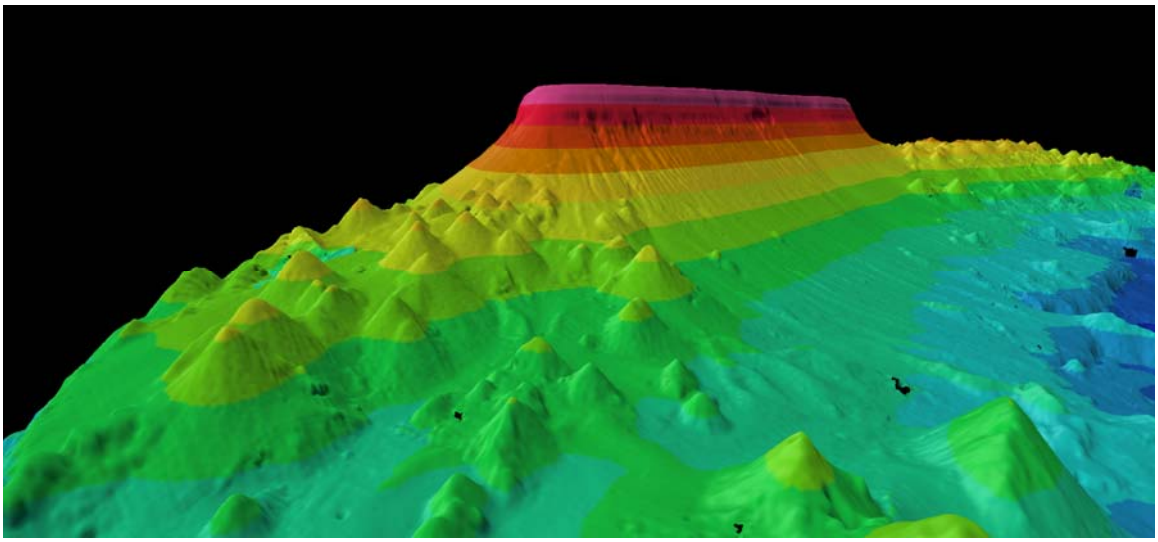


Figure D.1-3: 3D perspective view of Kingman Reef looking west. Pointed seafloor highs can be seen in the foreground. The tops of these features are at about 1000-1500 m. Canyons can be seen along the southern bank margin, and additional seafloor highs off of the western bank can be seen in the background.

D.2. Oceanography & Water Quality

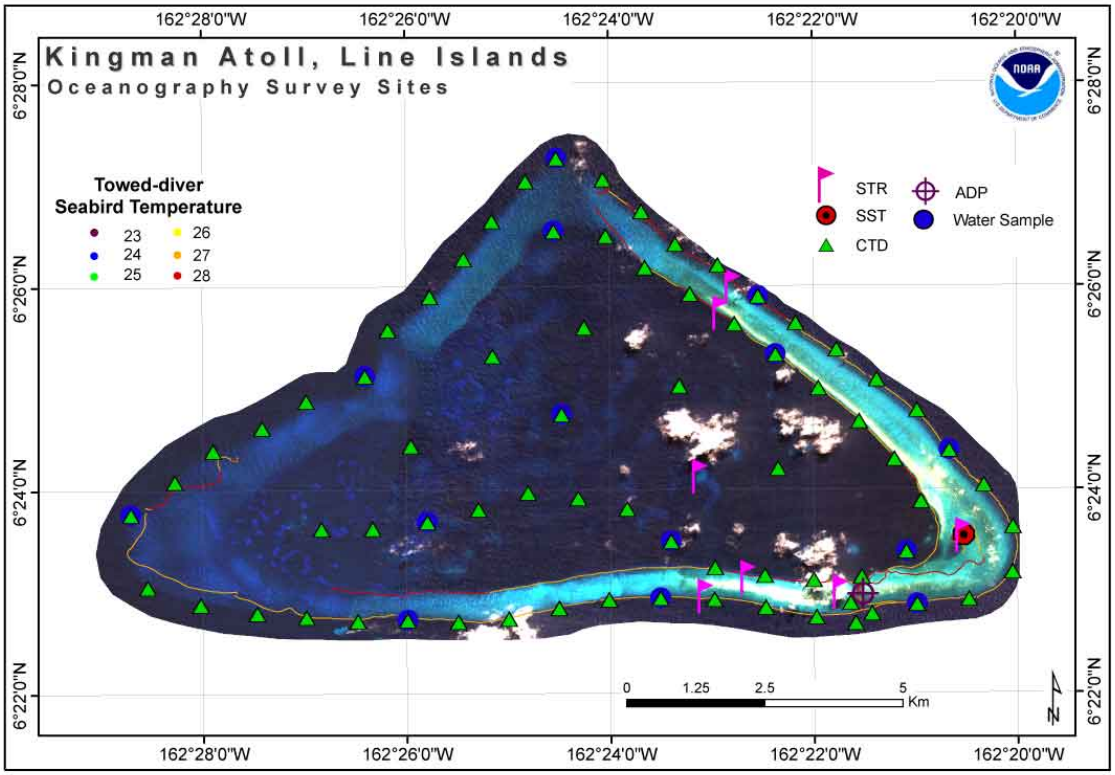


Figure D.2-1: Oceanography sites at Kingman Reef

D.2.1. CTD Casts and Water Samples

Seventy-three CTD casts to 33 meters were conducted around the periphery and inside the atoll at a 1-km interval in as close to 35 meters of depth as possible considering the slope of the island and surf conditions. Water quality profiles were conducted at 14 of these sites from which 80 chlorophyll and 80 nutrient samples were collected. In sampling the east and south sides of the atoll, a particular effort was made to follow the ~35-meter contour both inside and outside the emergent reef to facilitate a comparative analysis. Moving westward across the atoll, cast sites were evenly spaced with the 1-km interval often stretched, and the western side of the atoll was only covered on the outside of the submerged reef crest.

Four 500-meter CTD/water quality profile casts were conducted off of the *Hi'ialakai* during night operations concurrently with the running of an acoustic Doppler current profiler (ADCP) box transect around the atoll collecting 24 chlorophyll and 24 nutrient samples. The completed shipboard CTD sampling plan is shown in Figure D.2.1-1.

Five CTD casts were conducted from the *AHI* to 200 m, and three CTD casts were conducted to 500 meters in support of the mapping effort.

Shipboard CTD, ADCP, and Water Sampling Plan
Kingman Atoll - HI0604

Transect 1: 03/31/06 (CTD/Water Sampling/ADCP)

This will be a 75-km box transect around the atoll that will hit four of Coral Reef Ecosystem Division's (CRED's) historical CTD stations. Begin the ADCP transect at pt "CTD001" (the south-central point). Either begin CTD casts or the ADCP transect at this point depending on the 'druthers' of the Survey Tech. Proceed around the transect in a clockwise direction conducting CTD casts with water samples at the mid point of each side of the box. The closest that the transect comes to any shoal area is over 2 km at its closest approach so that proximity is within vessel safety protocols. All casts will be to 500 meters presuming seafloor depth is > 600; if not, cast depth will be reduced (though this should not be an issue). Water samples will be collected according to CRED protocols on all casts.

Transect Positions:

ID	LAT_DEG	LAT_MIN	LAT_H	LONG_DEG	LONG_MIN	LONG_H
CTD001	6	21.77200	N	162	24.49400	W
CNR001	6	21.80380	N	162	30.97090	W
CTD002	6	24.91570	N	162	30.95590	W
CNR002	6	28.57680	N	162	30.93800	W
CTD003	6	28.54410	N	162	24.40480	W
CNR003	6	28.51400	N	162	18.62230	W
CTD004	6	24.83520	N	162	18.64170	W
CNR004	6	21.76040	N	162	18.65780	W

Figure D.2.1-1: Shipboard oceanographic sampling plan

D.2.2. Oceanographic Instrumentation Deployments

One sea surface temperature (SST) buoy was recovered and replaced at its established site, and one recruitment plate array was recovered and replaced on the old Coral Reef Early Warning System (CREWS) anchor nearby. Five subsurface temperature recorders

(STRs) were recovered and replaced, one on the old CREWS anchor and the rest at reef sites, while two new STRs were installed. One installation was accomplished outside of the fringing reef from the northernmost established STR site to duplicate a similar arrangement along the southern fringing reef, while the other was installed on a patch reef in the eastern lagoon. This spread of STRs is intended to study thermal dynamics in the shallowest part of the atoll with the most restricted flow.

In addition to these standard deployments, one Nortek Auadopp acoustic Doppler profiler (ADP) was installed in the pass of the southeast corner of the lagoon to test its utility and study the movement of heated water from the shallow portion of the lagoon out of the pass during the full range of tidal cycles. The ADP was deployed at the midpoint of the pass in 8 meters of depth to monitor temperature, direction, and intensity of the current and tide level. It was deployed on the first and retrieved on the last day of operations collecting 6 days of data.

D.2.3. Towed-diver Temperature Profiles

Twenty-two towed-diver surveys were conducted at Kingman Reef totaling 52.35 km in length. Temperature data was recorded at 5-second intervals along each tow survey.

D.2.4. Kingman Channel Experiment

The eastern end of Kingman Reef is characterized by nearly one-hundred percent coral, algae, and mollusk cover. The area is enclosed by reef crests running along the south side, around the east end of the reef, and continuing to the northwest. The western section is open to a deeper, more exposed section of the reef. The southern end of this section has one small break deep enough for small boats to pass. This channel is approximately 7 to 9 m deep and about 30 m wide.

In order to determine the exchange through this small channel opening, a 5-day experiment was performed using a Nortek Aquadopp 2 MHz ADP which was deployed in approximately 7.5 meters of water (low tide) in the center of the channel (Fig. D.2-1). The Aquadopp is capable of measuring flow velocities throughout the water column as well as pressure to approximate the tides and water temperature at the instrument. The Aquadopp was set up with a 20-cm blanking distance and 50-cm bins.

The instrument was deployed between March 29, 2006 at 2200 (UTC) and April 3, 2006 at 1800 (UTC). During this time, there was nearly zero net flow in or out of the channel. Exchange is loosely tied to tidal forcing but further analysis is necessary (see Figs. D.2.4-1 and D.2.4-2). The small net west current is thought to be attributed to high velocity eastern winds during the test period.

Table 1. Net flow through Kingman Channel between March 29, 2006 at 2000 and April 3, 2006 at 1800. Negative velocity values refer to west, south, or down flow, respectively.

Direction	Flow Velocity (m/s)
Net East Flow	-0.092
Net North Flow	0.000
Net Up Flow	-0.006

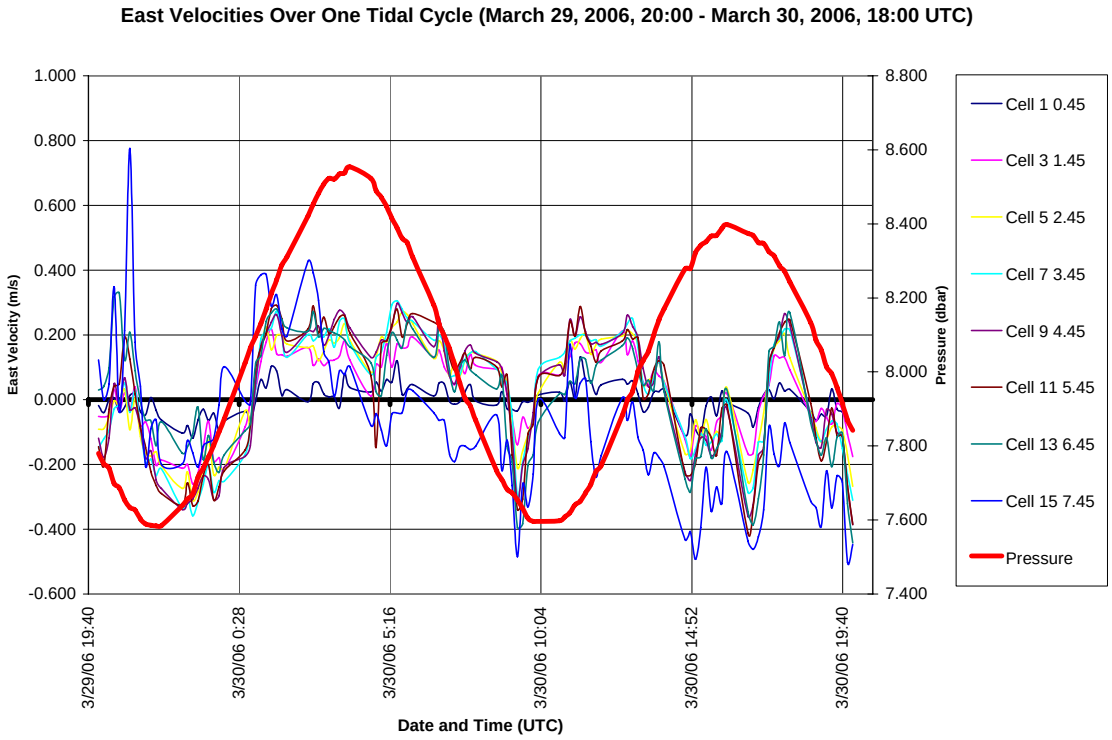


Figure D.2.4-1: East velocities in channel at Kingman

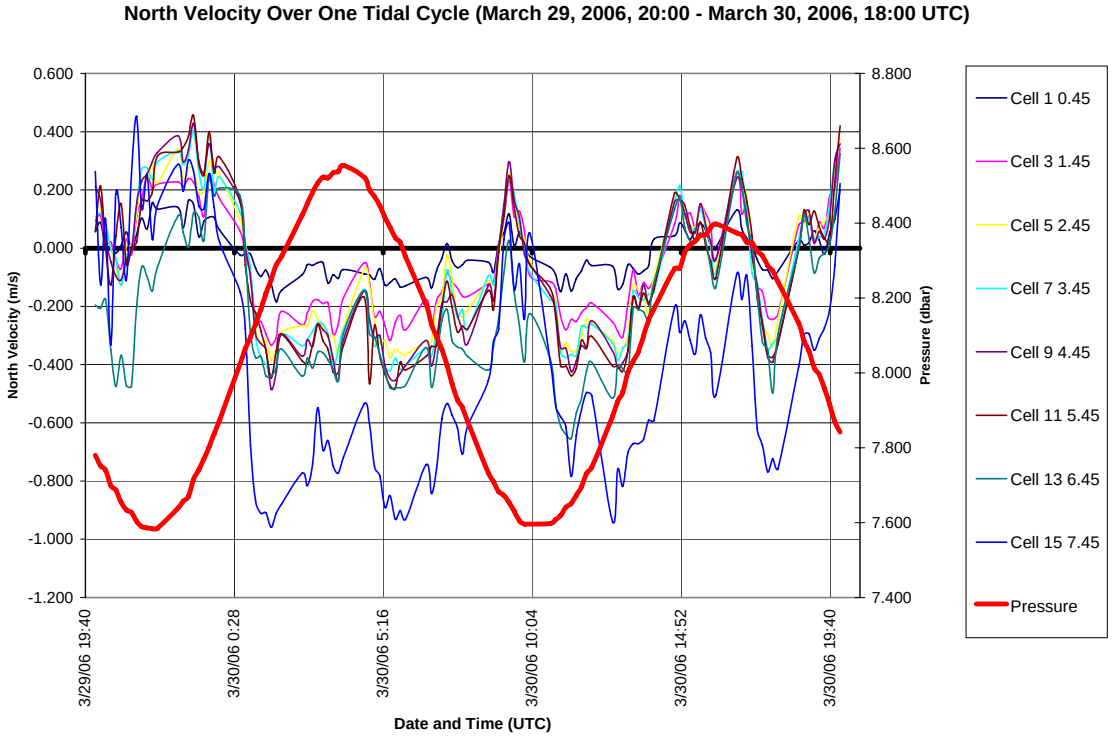


Figure D.2.4-1: North velocities in channel at Kingman

D.3. Benthic Environment

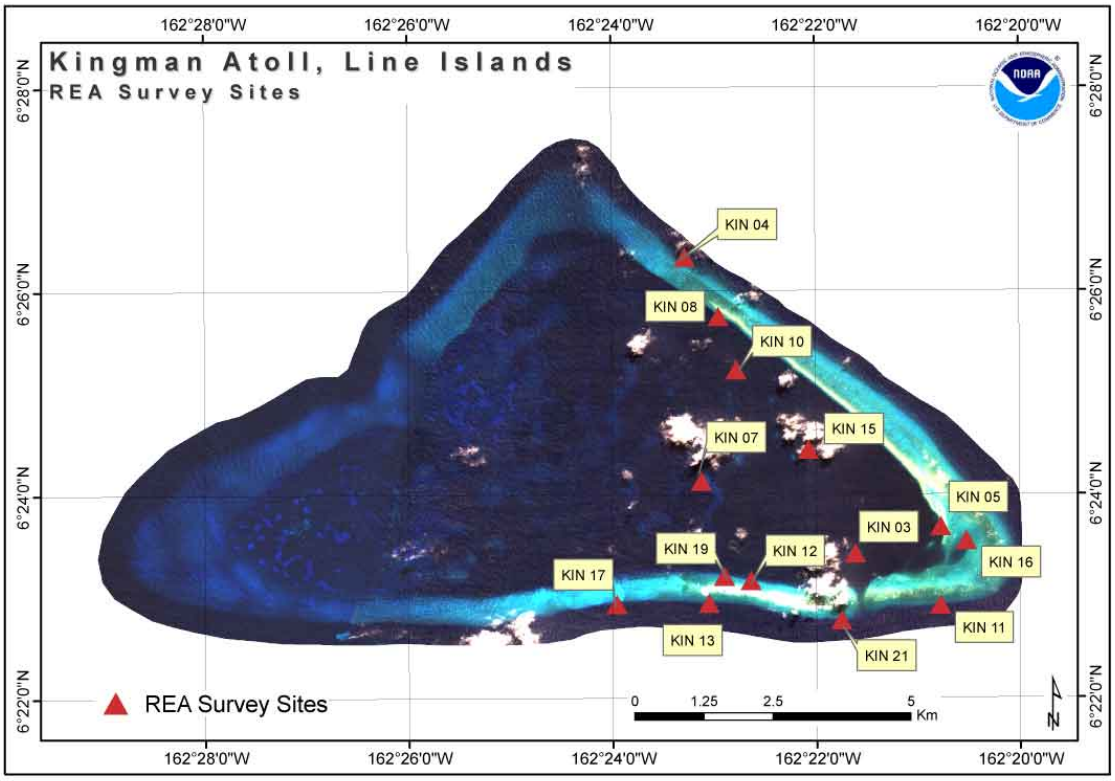


Figure D.3-1: REA survey sites at Kingman Reef

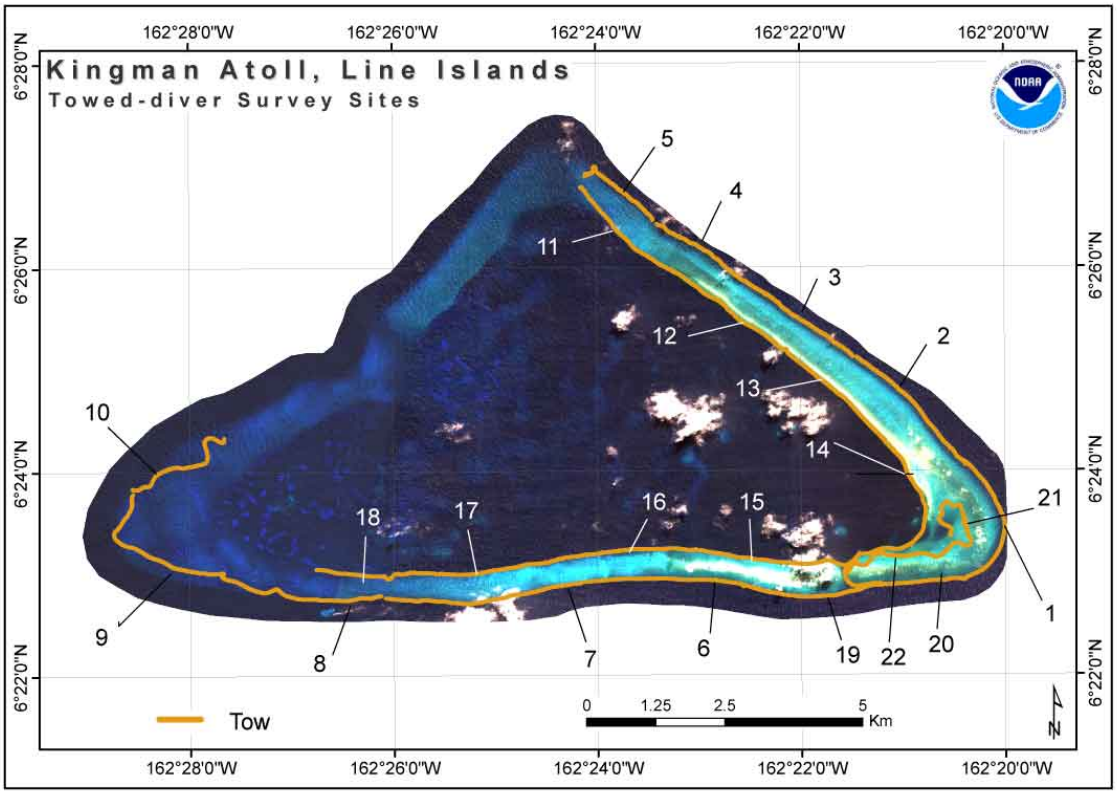


Figure D.3-2: Towed-diver survey transects at Kingman Reef

The purpose of the rapid ecological assessment (REA) activities onboard the HI-06-04 was to select sites surveyed during previous rapid ecological assessments for long-term monitoring. Selection of sites was based on their year-round accessibility and their representation of the different types of habitats present at each location. Between March 29 and April 3, 2006, quantitative surveys were conducted at 14 sites around Kingman Reef. Site KIN21 was a new site, not visited during prior visits in 2002 or 2004. In addition, two qualitative surveys were conducted at sites KIN22, on the western perimeter, and site KIN23 on the outer eastern shore and eastern point of Kingman Reef. Most of the sites visited were located on the inner and outer eastern and southern perimeters, as well as the western terrace. Only one site KIN04 surveyed the outer perimeter on the north. Other sites on the outer northern perimeter were inaccessible because of increased wave action, swell, and strong currents. Survey depths ranged from 3.6 and 17.6 m. A total of 22 towed-diver habitat surveys totaling 52.35 km were conducted around Kingman Reef. Surveys were conducted in three principle locales: forereef, backreef, and reef pool.

All visited sites at Kingman were dominated by green turfs and crustose coralline algae, *Halimeda* and *Microdictyon*. Algal richness and abundance were relatively homogenous among sites. A total of 21 genera of macroalgae and 4 functional groups were recorded in 2006, while only 11 genera and 5 functional groups were recorded in 2004.

Elevated percent live coral cover was observed along the east side. Salient characteristics of these sites were the presence of elevated numbers of the giant clam *Tridacna maxima* and a diverse assemblage of acroporid corals. For the most part, all the patch reefs in the western terrace as well as the backreef communities on the north and south perimeter exhibited live coral cover <30%, and there was a strong predominance of the lobe coral, *Porites*. In addition, within the survey areas, 56 cases of coral disease and 44 cases of predation were detected on scleractinian corals, as well as 20 cases of disease on crustose coralline algae. Coral collection efforts were made at several sites for taxonomic purposes, as well as at two more sites for coral health and disease characterization.

Each habitat at Kingman Reef exhibits a great abundance and variety of macroinvertebrates. Most sites had high coral cover combined with abundant macroinvertebrate fauna. The abundance of cnidarians, mollusks, and echinoderms recorded at the majority of sites was impressive. Tridacnid clam populations were the most unique attribute, with relative abundances reaching as high as 4.76/m^2 in some locations.

D.3.1. Algae

- Algal diversity is higher in 2006 than in 2004. Eleven genera of green algae, eight of red algae, and two of brown algae were found in 2006, while only nine genera of green algae and two of red algae were found in 2004. The number of functional groups is relatively similar between the 2 years (five in 2004 and four in 2006).
- Turf algae and crustose corallines, *Halimeda* and *Microdictyon,* were the dominant macroalgae at Kingman.
- *Boodlea*, *Neomeris*, *Laurencia*, *Dictyota* and *Lobophora* were relatively abundant (4^{th}-6^{th} rank and 30-48% of occurrence in photoquadrats).
- Microdictyon was less abundant in 2004 (34% of occurrence) than in 2006 (67%).

D.3.1.1. Algal REA Sites Description

Each site description includes observations of the oceanographic and weather conditions, coral diversity and abundance, and algal diversity and relative abundance in photoquadrats. Details concerning algal richness and abundance are given in Table D.3.1.1-1

KIN11 (3-29-2006: 06°22.911'N, 162°20.781'W)

This reef slope was located southeast of Kingman. Weather conditions in the morning were rainy and windy. A significant current was noticed underwater. Visibility was higher than 40 m. Coral cover was very high. Coral communities were dominated by *Porites* and *Favia*. Algal diversity was relatively low. Algal communities were dominated by turf algae, crustose corallines, and *Halimeda*. Additionally, *Boodlea*, *Cladophora*, *Phyllodictyon* (reported as *Microdictyon* in the table to be consistent with Palmyra ranking), *Laurencia,* and *Caulerpa* were observed in the photoquadrats. Blue-green algae were also abundant.

KIN17 (3-29-2006: 06°22.921'N, 162°20.960'W)
This reef slope was located south of Kingman. Weather conditions were sunny. Visibility was higher than 40 m. Coral cover was important along the first transect and moderate along the second transect. This latter one was dominated by coral rubbles. Coral communities were dominated by *Porites*, *Pocillopora*, *Favia,* and *Acropora*. Algal diversity was moderate. The principal macroalgae in photoquadrats were *Halimeda*, crustose corallines, turf algae, *Neomeris,* and *Phyllodictyon* (*Microdictyon* in the Table). Additionally, *Peyssonellia*, *Lobophora*, *Boodlea*, *Laurencia,* and *Caulerpa* were found in relative abundance. Blue-green algae were also present in the photoquadrats and were more or less abundant.

KIN13 (3-29-2006: 06°22.931'N, 162°23.054'W)
This reef slope was located southwest of Kingman. Weather conditions were cloudy. A significant current was noticed underwater. Visibility was higher than 40 m. Coral cover was important. Coral communities were dominated by *Porites*, *Acropora,* and *Favia*. Algal diversity was moderate. Algal communities were dominated by crustose corallines, turf algae, *Laurencia*, and *Halimeda*. Moreover, *Neomeris*, *Phyllodictyon*, and *Valonia* were often seen in the photoquadrats. Blue-green algae were relatively abundant at this site.

KIN10P (3-30-2006: 06°25.221'N, 162°22.778'W)
This reef slope was located north of Kingman. Weather conditions were good. The swell was strong and visibility was higher than 40 m. Coral cover was moderate. Coral communities were dominated by *Porites*. Lots of coral rubbles were seen on the floor. Algal communities were dominated by crustose corallines, turf algae, *Halimeda*, *Boodlea,* and *Phyllodictyon* (could be *Microdictyon*?). Moreover, *Valonia*, *Dictyosphaeria*, *Jania*, *Cladophora* (or *Chaetomorpha*?), and *Avrainvillea* were recorded in the photoquadrats. Blue-green algae were rare.

KIN04 (3-30-2006: 06°26.330'N, 162°23.285'W)
This patch reef was located in the 'lagoon' of Kingman, on the north side. Weather and oceanographic conditions were good (no swell, no current). Visibility was higher than 50 m. Coral cover was very high. Coral communities were dominated by colonies of *Porites* and *Fungia*. Algal diversity was relatively moderate. The predominant macroalgae were crustose corallines, turf algae, *Heterosiphonia* (called *Laurencia* during ranking; need to be IDed in the lab), and *Halimeda*. *Boodlea* and *Cladophora* (or *Chaetomorpha*) as well as *Neomeris* were also very abundant in the photoquadrats. *Dictyosphaeria* and *Jania* were present but were not very abundant. Blue-green algae were rare.

KIN08 (3-30-2006: 06°25.749'N, 162°22.953'W)
This reef was located in the northern side of the 'lagoon' at Kingman. Weather conditions were good, as well as oceanographic conditions. Lots of plankton were observed in the water (snow), but the visibility was still higher than 40 m. Coral cover was relatively high. Coral communities were dominated by *Porites*. However, those colonies of massive *Porites* experienced a lot of damages because of crown-of-thorns starfish (COTS). At

least 10 *Acanthaster planci* were seen along both transects. Algal communities were dominated by turf algae, crustose corallines, *Phyllodictyon* (or Microdictyon) and *Halimeda*. *Heterosiphonia*, *Boodlea*, *Cladophora* (or *Chaetomorpha*), *Jania,* and *Neomeris* were also seen in relative abundance in the photoquadrats. Very few blue-green algae were seen along transects.

KIN07 3-31-3006: (06°24.131'N, 162°23.123'W)
This patch reef was located in the middle of the lagoon of Kingman. Weather conditions were good and there was no current. Visibility was about 30 m. Sedimentation was important. The reef floor was covered by a layer of sandy particles. Coral cover along the first transect was moderate, while it was low along the second transect. Coral rubbles dominated along the second transect. Coral communities were dominated by colonies of massive *Porites* and colonies of *Pocillopora*. Algal diversity was moderate. Communities were dominated by turf algae, crustose corallines, *Halimeda*, *Phyllodictyon* (or *Microdictyon*), and *Neomeris*. Other macroalgae such as *Boodlea*, *Lobophora,* and *Jania* were also found in the photoquadrats. *Caulerpa* were seen abundant along transects but not in the photoquadrats.

KIN19 (3-31-2006: 06°23.195'N, 162°22.903'W)
This patch reef or backreef was located south of Kingman, in the lagoon. Weather conditions were good (a bit cloudy) and there was no current. Visibility was around 25-30 m. Coral cover was moderate. Coral communities were dominated by *Porites*. COTS were observed along transects. Algal diversity was moderate. Algal communities were dominated by turf algae, crustose corallines, *Halimeda,* and *Neomeris*. *Phyllodictyon*, *Boodlea*, red turf, and *Avrainvillea* were also recorded in the photoquadrats and in relative abundance. Blue-green algae were present.

KIN12 (3-31-2006: 06°23.150'N, 162°22.642'W)
This backreef was located south of Kingman Lagoon. Weather conditions were a bit cloudy but still sunny. Visibility was around 25 m. Sedimentation was important (lots of particles in suspension and lot of sand on the reef floor covering organisms). Coral cover was moderate. Coral communities were dominated by heads of massive *Porites*. COTS were abundant at this site. Algal diversity was relatively low. Algal communities were dominated by turf algae, red turf algae, crustose corallines, and *Halimeda*. *Phyllodictyon*, *Boodlea,* and *Neomeris* were relatively abundant too. Blue-green algae were present.

KIN15 (4-01-2006: 06°24.440'N, 162°22.073'W)
This patch reef was located northeast of Kingman Lagoon. Weather conditions were cloudy, windy, and rainy. Visibility was about 25 m. Coral cover was low/moderate. Coral communities were dominated by colonies of massive *Porites*. Lots of coral rubbles and dead colonies of *Acropora* and *Porites* were present along both transects. Algal diversity and cover were high. Algal communities were dominated by turf algae, crustose corallines, *Halimeda*, *Phyllodictyon* (called *Microdictyon* in the Table), and *Boodlea*. Additionally, *Heterosiphonia* (called *Laurencia* in the Table), *Avrainvillea*, *Peyssonellia,* and *Grateloupia* were observed. Blue-green algae were also present in the photoquadrats.

KIN03 (4-02-2006: 06°23.420'N, 162°21.61'W)
This reef was a backreef located in the southeast corner of Kingman Lagoon. Weather conditions were good although some wind was noticeable. Visibility was around 25 m. Coral cover was moderate. Coral communities were dominated by massive *Porites* and soft corals. The dominant macroalgae were turf algae, crustose corallines, *Peyssonellia*, *Halimeda*, *Neomeris*, *Phyllodictyon* (or *Microdictyon*), and *Boodlea*. *Valonia*, *Caulerpa*, red 2, and blue-green algae were also observed in the photoquadrats. *Ventricaria* and *Grateloupia* were recorded during the random swim.

KIN05P (4-02-2006: 06°23.683'N, 162°20.779'W)
This backreef was located southeast of Kingman Lagoon. Weather conditions were good. Visibility was about 30 m. Coral cover was moderate/high. Coral communities were dominated by massive colonies of *Porites* and corals from the family Fungiidae. Algae were dominated by turf algae, crustose corallines, *Halimeda*, *Phyllodictyon* (or *Microdictyon*), and *Boodlea*. Red 2, *Grateloupia,* and *Dictyosphaeria* as well as blue-green algae were also recorded in the photoquadrats.

KIN16P (4-03-2006: 06°23.544'N, 162°20.526'W)
This backreef was located southeast of Kingman Lagoon. Weather conditions were good. This reef is in shallow water (15 m maximum). Visibility was higher than 50 m. Coral cover was maximal. Coral diversity was very important. Coral communities were, however, dominated by massive *Porites* and *Fungia*. Algal cover as well as algal diversity was limited. Macroalgal communities were dominated by turf algae, crustose corallines, *Boodlea*, *Phyllodictyon* (or *Microdictyon*), *Neomeris*, *Halimeda*. *Avrainvillea*, *Jania,* and *Dictyosphaeria versluysii* were also present in photoquadrats but were less abundant. Blue-green algae were present but rare. *Caulerpa* and *Bryopsis* were found during the random swim. Some red algal filaments were found within branches of dead colonies of *Pocillopora* along both transects, possibly red 2 or *Chondria*.

KIN21 (4-04-2006: 06°22.764'N, 162°21.755'W)
This reef was located east of Kingman (in front the sandy area). Weather conditions were sunny but windy. Visibility was about 30 m. Coral cover was very low. The reef floor was mostly composed of coral rubbles and dead colonies. Algal diversity and abundance were important. Algal communities were dominated by green and red turfs, crustose corallines, *Halimeda,* and *Lobophora*. Additionally, *Dictyota* was found very abundant at this location (>90%).

Table D.3.1.1-1 Algae of Kingman Island. Bold numbers indicate the number of photoquadrats in which an alga occurred, below which is the alga's relative abundance (rank) in relation to other algae occurring in the same photoquadrat. Standard deviations of the island averages are given in parentheses. Asterisks indicate algae found during the random swim that were not present in sampled photoquadrats.

	KIN11	KIN17	KIN13	KIN04	KIN10P	KIN08	KIN07	KIN19	KIN12	KIN15	KIN03	KIN05P	KIN16P	KIN21	Island	
Green algae																
Avrainvillea	*			**8.3**		**25.0**	**8.3**	**16.7**	**33.3**	**16.7**	**8.3**	**16.7**		**8.3**		**15.7**	(9.9)
				5.0		3.3	4.0	7.0	7.0	7.0	5.0	7.0		4.0		5.5	(1.5)
Boodlea	**8.3**	**8.3**	**8.3**			**66.7**	**50.0**	**41.7**	**33.3**	**25.0**	**91.7**	**33.3**	**83.3**	**66.7**		**43.1**	(31.7)
	6.0	5.0	7.0			5.5	4.5	5.6	7.0	6.7	6.3	5.5	4.6	4.0		5.6	(1.0)
Bryopsis														*	*	*	
Caulerpa	**8.3**	**25.0**	**8.3**	*				**16.7**	**8.3**		**16.7**	**8.3**		*	**16.7**	**13.5**	(7.3)
	2.0	5.0	6.0					6.5	3.0		4.5	4.0			7.5	4.8	(1.8)
Cladophora	**8.3**	**16.7**		**41.7**	**75.0**	**8.3**		**16.7**						**25.0**		**27.4**	(24.2)
	5.0	7.0		6.2	4.9	7.0		7.5						3.7		5.9	(1.4)
Dictyosphaeria	**16.7**	**8.3**	**16.7**	**16.7**	**50.0**		**8.3**	**16.7**		**8.3**	**8.3**	**8.3**		**33.3**		**17.4**	(13.5)
	6.0	6.0	6.0	8.0	4.7		8.0	8.0		7.0	5.0	6.0		5.3		6.4	(1.2)
Halimeda	**58.3**	**100.0**	**91.7**	**66.7**	**41.7**	**75.0**	**58.3**	**75.0**	**66.7**	**100.0**	**75.0**	**75.0**		**33.3**	**50.0**	**69.0**	(30.7)
	2.0	2.7	3.4	4.0	3.4	3.3	2.7	3.0	4.3	2.8	4.2	3.6		2.8	5.8	3.4	(0.9)
Microdictyon	**75.0**	**41.7**	**50.0**	**58.3**	**75.0**	**66.7**	**91.7**	**58.3**	**83.3**	**100.0**	**58.3**	**75.0**		**41.7**		**67.3**	(28.0)
	5.1	6.2	7.0	5.6	6.0	4.5	4.0	5.3	5.1	5.5	5.0	4.3		4.6		5.2	(0.8)
Neomeris		**75.0**	**8.3**	**8.3**		**41.7**	**58.3**	**66.7**	**58.3**		**83.3**			**16.7**		**46.3**	(32.2)
		4.8	7.0	9.0		5.6	6.0	5.3	5.6		4.4			6.5		6.0	(1.4)
Valonia	**16.7**		**50.0**	**25.0**	**33.3**	**8.3**	**16.7**	**16.7**		**8.3**	**8.3**	**8.3**				**19.2**	(14.6)
	5.0		6.0	6.7	6.3	6.0	5.5	7.0		7.0	8.0	5.0				6.2	(1.0)
Ventricaria	*				**8.3**						*					**8.3**	(5.9)
					6.0											6.0	(1.6)
Red algae																	
Unknown red alga 1	**8.3**		**8.3**	**8.3**	**16.7**											**10.4**	(5.9)
	5.0		6.0	7.0	3.5											5.4	(1.5)
Chondria								**25.0**	**8.3**		**8.3**	**25.0**				**16.7**	(11.2)
								7.3	4.0		9.0	7.3				6.9	(2.1)
Galaxaura														*?	*		
Grateloupia										**8.3**	*	**8.3**				**8.3**	(4.8)
										4.0		5.0				4.5	(0.7)
unknown red alga 2	**16.7**		**16.7**							**8.3**	**8.3**	**33.3**	**25.0**	**8.3**		**16.7**	(10.7)
	4.0		6.0							9.0	6.0	6.5	3.3	6.0		5.8	(1.8)
Jania			**8.3**	**33.3**	**25.0**	**41.7**	**50.0**						**25.0**	**8.3**		**27.4**	(14.7)
			8.0	7.0	5.0	5.8	7.2						7.0	6.0		6.6	(1.0)
Laurencia/ Chondrophycus	**50.0**	**50.0**	**75.0**	**91.7**		**50.0**	**25.0**	**8.3**		**75.0**			**8.3**			**48.1**	(33.6)

	2.8	4.3	3.7	3.9		4.2	6.3	7.0		6.1			6.0		4.9	(1.4)
Peyssonnelia	**8.3**	**8.3**			**8.3**	**16.7**	**8.3**	**8.3**	**33.3**	**50.0**	**58.3**	**33.3**	**25.0**	**8.3**	**22.2**	(18.3)
	3.0	3.0			3.0	3.0	6.0	3.0	4.5	3.8	3.3	4.5	4.0	4.0	3.8	(0.9)
red turf	**8.3**		**50.0**	**75.0**	**16.7**			**16.7**	**75.0**		**16.7**	**16.7**	**8.3**	**100.0**	**38.3**	(34.1)
	4.0		3.0	2.2	5.0			4.5	2.3		5.0	3.5	1.0	3.0	3.4	(1.3)
crustose coralline	**100.0**	**100.0**	**91.7**	**100.0**	**83.3**	**91.7**	**100.0**	**83.3**	**91.7**	**100.0**	**100.0**	**100.0**	**66.7**	**100.0**	**93.5**	(33.7)
	1.9	2.4	1.1	1.3	1.2	1.8	2.2	2.3	2.7	2.0	1.9	2.2	1.0	2.0	1.9	(0.5)
Brown algae																
Dictyota			**8.3**	**8.3**										**91.7**	**36.1**	(43.2)
			9.0	7.0										4.4	6.8	(2.3)
Lobophora	**8.3**	**16.7**	**58.3**	**8.3**		**16.7**	**58.3**	**41.7**	**25.0**	**16.7**			**16.7**	**58.3**	**29.5**	(19.8)
	3.0	6.5	4.1	6.0		5.5	5.0	3.4	4.3	6.5			4.5	4.7	4.9	(1.2)
Others																
Blue-green	**41.7**	**66.7**	**58.3**	**50.0**	**8.3**	**25.0**	**58.3**	**50.0**	**33.3**	**41.7**	**33.3**	**33.3**	**25.0**	**33.3**	**39.9**	(18.9)
	4.6	4.9	4.3	4.7	4.0	6.7	6.4	5.2	4.0	5.8	7.8	6.0	6.3	6.0	5.5	(1.1)
turf	**83.3**	**100.0**	**58.3**	**58.3**	**91.7**	**91.7**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**66.7**	**100.0**	**89.3**	(34.4)
	1.8	1.3	3.3	1.9	1.8	1.2	1.6	1.2	1.2	1.5	1.1	1.0	2.3	1.1	1.6	(0.6)

D.3.1.2. Benthic Towed-diver Survey—Algae

Macroalgae was observed to have the highest abundance on the southern forereef around the channel with estimates of up to 20% coverage. Coralline algae was recorded to be highest on average in the southeastern reef pool with an estimated coverage of up to 70% in selected locales and along the eastern forereef where estimates reached up to 50% of the total benthic cover.

D.3.2. Corals

D.3.2.1. Coral diversity and population dynamics

Although Kingman has now been surveyed for corals on six separate trips since 2000, there has been very little coverage of the western half of the atoll reef and ocean reefs off the east tip and northeast ocean side of the reef. Despite these impediments, more than 180 species and 54 genera of corals and other cnidarians have been reported at the atoll, including new records of the genera *Pachyseris* and *Subergorgia* at the far western end of the reef at a depth of 30-35 m in 2006 (new site KIN22). Deeper surveys and better coverage of the atoll reef, especially in the west will likely yield additional records. Moreover, several species of corals at Kingman belonging to *Porites* and *Acropora* are new to science and undescribed. The transect surveys accounted 38 genera at Kingman in 2006 and a few more were cited close by the transects at sites KIN11 and 23. The genus *Porites* accounted for 34% of the corals, with the mushroom coral *Fungia* a distant second at 12%. In descending order, the remaining numerous genera accounting for at least 1% of the corals were: *Favia, Pavona, Lobophytum, Turbinaria, Montipora, Favites,* and *Acropora.* The most abundant soft corals were *Lobophytum* and *Pachyclavularia.*

The coral fauna at both Kingman and neighboring Palmyra is unusual in being high in diversity compared to all of the other Line Islands surveyed for corals during the past several decades. The lack of habitable land at Kingman has helped to keep it one of the most pristine reefs in the Pacific. Another possible reason for higher diversity at Kingman is its large open lagoon providing a greater variety of habitats for corals compared to Palmyra, Tabuaeran, and Kiritimati Atolls. Another possible reason is that Kingman and Palmyra are often in the path of the eastward flowing Equatorial Countercurrent which may be transporting larvae of additional species of corals from the more diverse western Pacific.

Generic richness was very high (23–28 genera) on the REA transects on ocean reefs along the southeast ocean reefs (KIN11, 13, 23) and lagoon pinnacle near the south pass (KIN 3). Generic richness was high (20-21 genera) at adjacent south lagoon and ocean sites (KIN17, 12, 21). Generic diversity was moderately high (15-19 genera) on northern ocean facing sites (KIN04, 08, 15). All remaining sites had generic richness levels of 11 or more, still high in comparison to other islands. Crown-of-thorns sea star (*Acanthaster planci*) predation affects coral diversity at many lagoon and exposed ocean sites. The highest diversity levels were reported where evidence of sea star predation was low, although a large aggregation of the sea stars may be closing in on site KIN11, where the highest levels (28 genera) were reported (Molly Timmers pers. comm.). Observations

indicate that the sea stars prefer *Acropora, Montipora, Pocillopora, Pavona,* and several genera of brain corals (*Montastrea, Favia, Favites*) over the dominant lobe coral, *Porites.* A recent period of heavy sea star feeding on preferred prey species would reduce the proportion of targeted species and lower coral diversity levels.

Table D.3.2.1-1 and Figure D.3.2.1-1 summarize the characteristics of the coral populations at the 13 Kingman REA sites in 2006. Frequencies (no. of corals per m^2) were relatively high at sites in 2006. The lowest frequency (5.4 corals per m^2) was reported at south ocean site (KIN21) which had appeared to suffer from a recent episode of sea star predation. The next lowest levels (9.4 to 10) were south lagoon sites near the pass (KIN03, 07, 19) and one north lagoon site (KIN08). The highest frequencies (30 to 32 corals per m^2) were reported at a north lagoon pinnacle (KIN10) and north ocean facing reef site (KIN04). Remaining sites showed frequencies of 11−18, all high in comparison to other islands and atolls. Kingman appears to be recruiting many corals at all size classes. Mean diameter values are highest (19–23 cm) at sites KIN11 (southeast ocean reef) and KIN05P (east lagoon). At both sites, there are many large *Porites* colonies with KIN11 also showing many large colonies of *Acropora* off the transects in shallower water. A nearby exploratory site (KIN23) was very similar in showing many large colonies and high biodiversity. These sites have not recently experienced heavy sea star predation, although KIN05P experienced heavy predation between 2000 and 2004. The timing and degree of sea star predation at Kingman REA sites may be influencing frequencies, mean diameter, diversity, and other coral population measures at the sites.

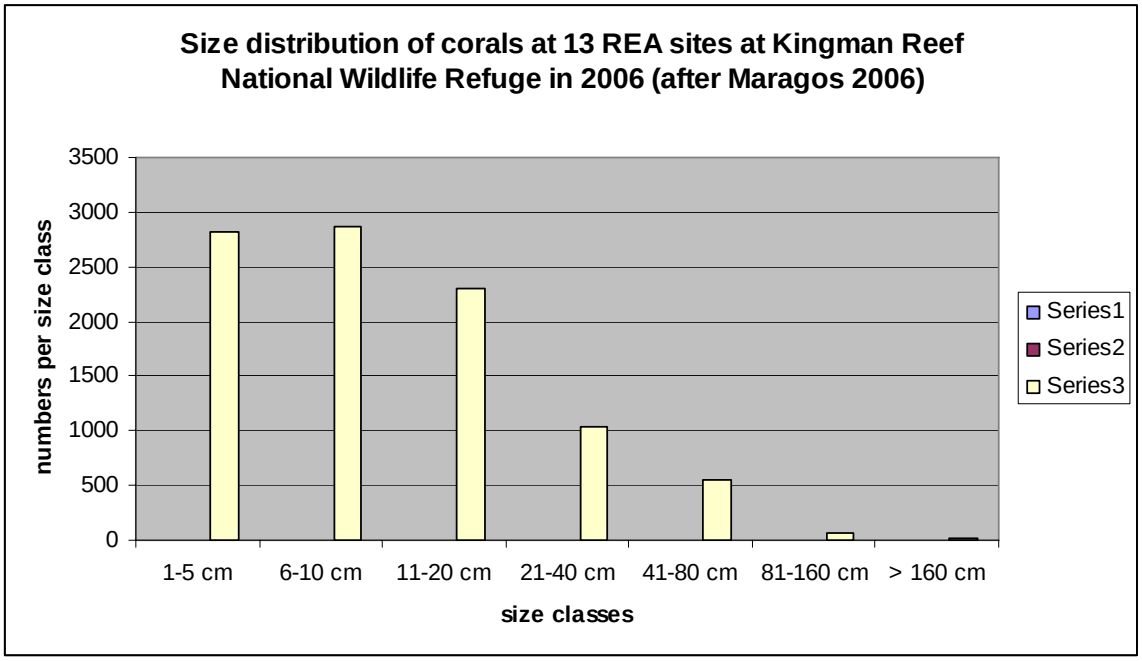


Figure D.3.2.1-1 Size class distribution for corals at 13 REA sites, Kingman Reef 2006

Table D.3.2.1-1 Coral generic diversity, frequency, and mean diameter at 13 REA sites, Kingman Reef National Wildlife Refuge, April 2006 (after Maragos 2006).

KIN REA site #	**11**	**17**	**13**	**4**	**10P**	**8**	**7**	**19A**	**12**	**15**	**3**	**5P**	**21**		
mean diam.	23	14	14	12.1	14.3	17	14	11	12	12	17	19	13		
Frequency	15	17	18	30.3	32.2	9.4	9.9	10	13	11	9.4	18	5.4		
# of genera	28	20	23	19	16	15	19	14	20	18	23	11	21	total	
Locale	SE	SW	S	N	NC	N	C	S	S	C	SE	E	SE	per	**% of**
coral genera														gen.	**total**
Acropora	16	21	34	71	9		3			2	1		6	**163**	1.7
Alveopora											4		3	**7**	0.1
Astreopora						2	3		2		18			**25**	0.3
Cladiella	66		1	9									1	**77**	0.8
Cryptodendrum	1							1						**2**	0
Cycloseris								3	1	4				**8**	0.1
Distichopora	2													**2**	0
Echinophyllia														**17**	0.2
Favia	58	85	87	292	148	18	28	6	9	8	20	42	3	**804**	8.2
Favites	24	13	15	132	73		13		5		3	1	8	**287**	2.9
Fungia	79	30	220	167	479	11	6	1	4	29	20	636	5	**1687**	17
Gardineroseris	1			8									2	**11**	0.1
Goniastrea					1				2	1	3			**7**	0.1
Halomitra	4			1										**5**	0.1
Herpolitha	4					1		3	6		5	2		**21**	0.2
Heteractis		1	1		3					1	2			**8**	0.1
Hydnophora	11	6	14	9			4		1	1	2		2	**51**	0.5
Leptastrea	18	12	3		1	4	5		10		4	3	2	**62**	0.6
Leptoseris	3		4	3										**10**	0.1
Lobophyllia	20		23											**43**	0.4
Lobophytum		12	72	96	3	87	71	94	107	21	55	6	7	**631**	6.5
Millepora			1							1				**2**	0
Montastrea	1	14	1	4	4		26		3		1		1	**55**	0.6
Montipora	15	45	35	78	56		25	7	41	11	18	20	9	**360**	3.7
Pachyclavularia	30		33	5		1	12				8			**89**	0.9
Palythoa	8	15		9			1						3	**36**	0.4
Pavona	31	75	60	451	7	2	6	1	1	1	9	2	21	**666**	6.8
Platygyra	12	3		7	1	3	2				2		1	**31**	0.3
Pocillopora	47	180	124	78	18		13	1	1	4	4		108	**578**	5.9
Porites	228	294	174	75	631	238	240	224	296	383	244	176	74	**3277**	34
Psammocora	2	8			22	2	9	2	1	6	25		2	**59**	0.6
Rhodactis								10	2					**12**	0.1
Sandalolitha			2										1	**3**	0
Stylaster	1									2				**3**	0
Stylophora	2	1	24											**27**	0.3
Turbinaria	28	8	7			61	18	134	110	68	15	6	7	**462**	4.7
Sarcophyton	1	27		1		33	8		2	4	6			**82**	0.8
Sinularia						3		2	6		4	1		**16**	0.2
totals per site	**727**	**848**	**920**	**1513**	**1453**	**471**	**495**	**514**	**644**	**548**	**471**	**878**	**279**	**9761**	99

Changes in coral populations over time

The permanent transect data at sites KIN05P, 10P, and 16P could not be processed in time for this report. However, six REA sites, four in the lagoon (KIN03, 07, 08, 12) and two off the south ocean reef (KIN11, 13) from the 2004 REA surveys were resurveyed in 2006 and offer some comparisons over the 2-year period. The mean diameters for all six 2004 sites were substantially higher (ranging from 17 to 47 cm) than at the same sites in 2006 (ranging from 11 to 22 cm). However, the frequency levels at all six 2006 sites (ranging from 9.4 to 32.2 corals/m^2) were two to three times higher than the counterpart 2004 frequencies (4.4 to 6.8 corals/m^2). Large numbers of smaller corals recruited to all six sites during the 2-year period, helping to explain these trends. The lowest size class numbers were substantially more abundant in 2006 compared to their 2004 counterparts. In fact, there were higher levels for four or more of the size classes for four of the 2006 sites. Only at the two oceanic sites (KIN11, 13) did any of the 2004 show higher levels and only for the two largest size classes. Out of the 38 coral genera reported during 2006 surveys, 14 showed substantial net increases during the 2-year period, 24 genera showed no clear changes, and none showed declines between 2004 and 2006. The increasing genera are: *Astreopora, Favites, Hydnophora, Leptastrea, Lobophyllia, Lobophytum, Montastrea, Pachyclavularia, Palythoa, Pavona, Pocillopora,* and *Porites.* The large influx of corals of many types and most size classes during the 2-year period may be a positive indicator of the healthy present status of coral populations at Kingman Reef National Wildlife Refuge.

D.3.2.2. General assessment of percent live coral cover

Coral community REA surveys indicated that the mean percent live coral cover on reefs around Kingman Reef for all sites combined was close to 33% and crustose coralline algae represented nearly 17.9%. Other benthic components, including rubble, algae, soft corals, and non-scleractinian sessile invertebrates accounted for close to 24% of the bottom cover. A summary table of benthic parameters is presented in D.3.2.1-1. Mean percent coral cover was the highest on the east side; sites KIN05, 11, 16P and 23 all exhibited percent live cover in excess of 45% and elevated generic diversity. Salient characteristics of these sites were the presence of elevated numbers of the giant clam *Tridacna maxima* at KIN16P and a diverse assemblage of acroporid corals in shallower waters at KIN23. For the most part, all the patch reefs on the western terrace as well as the back-reef communities on the north and south perimeter exhibited live coral cover <30% and strong predominance of the lobe coral *Porites* sp., except for sites KIN10, 13, and 22. These three sites, located on the western terrace, and the southern and western perimeters, respectively, also exhibited higher live coral cover (>40%). A salient characteristic of the patch reefs on western terrace was the presence of the corallivore starfish, *Acanthaster planci*. Predation scars were particularly abundant at site KIN08 where they reached 11/10 m^2, mainly on colonies of the coral *Porites*, but they were also observed on other species such as *Favia stelligera*, *Astreopora*, *Montipora*, *Turbinaria*, and *Fungia*. Observations along shallower substrata, outside the REA survey plots, where the abundance of Porites colonies was lower, indicated that crown-of-thorns feeding scars were abundant on Favia, Astreopora, and Montipora.

D.3.2.2-1 Summary statistics of percent benthic cover parameters at Kingman Reef. CCA: Crustose coralline algae; Other: Other benthic elements including: fleshy macroalgae, rubble, rock, soft corals, etc).

	Coral cover	Dead	Pavement	Sand	CCA	Other
KIN11	50.0	6.9	7.8	0.0	13.7	21.6
KIN17	22.5	0.0	28.4	2.9	13.7	32.4
KIN13	44.1	3.9	6.9	1.0	22.5	21.6
KIN04	29.4	2.0	2.9	0.0	42.2	23.5
KIN10	60.8	0.0	11.8	0.0	20.6	6.9
KIN08	18.6	2.9	23.5	11.8	13.7	29.4
KIN07	13.9	0.0	20.8	5.0	14.9	45.5
KIN19A	14.7	13.7	6.9	11.8	15.7	37.3
KIN12	23.5	18.6	9.8	8.8	9.8	29.4
KIN15	20.6	28.4	7.8	0.0	17.6	25.5
KIN03	29.4	11.8	10.8	7.8	16.7	23.5
KIN05	46.1	8.8	23.5	0.0	3.9	17.6
KIN16P	67.6	3.9	11.8	0.0	10.8	5.9
KIN21	19.6	0.0	31.4	0.0	34.3	14.7
Mean	32.9	7.2	14.6	3.5	17.9	23.9
Std Err	5.4	2.5	3.1	1.5	3.1	3.8

D.3.2.3. Coral health and disease assessment

At Kingman Reef, a total reef area of approx. 6050 m^2 was surveyed to assess coral health condition and occurrence of disease. Within this area, 56 cases of disease and 44 cases of predation were detected on scleractinian corals, as well as 20 cases of disease on crustose coralline algae. Figures D.3.2.3-1, D.3.2.3-2, and D.3.2.3-3 illustrate the relative abundance per site of coral and coralline algae disease, as well as the prevalence of disease. The disease REA surveys, indicated that the most common affliction to corals at Kingman Reef was *Acanthaster* predation. Crown-of-thorns starfish (COTS) predation was more common at the western lagoon patch reefs than at the inner and outer perimeter reef slopes. Although COTS predation was noted at 50% of the sites, scars only occurred within the survey transects at five sites. At site KIN08, abundance of scars were as high as 11/10 m^2, mainly on colonies of the coral *Porites*, but also observed on other species such as *Favia stelligera*, *Astreopora*, *Montipora*, *Turbinaria*, and *Fungia*. The second most abundant coral affliction was tissue loss on colonies of *Pocillopora spp*. This condition was observed at 9 out of 14 sites quantitatively surveyed. As at Palmyra Atoll, this affliction was generally associated with paling of the branches where tissue loss was observed. In addition, territorial damselfish as well as discrete algal lawns were commonly observed among or in association with the areas of exposed skeleton. The size and appearance of these tissue loss marks may be suggestive predation; however, no specific corallivores were observed associated with these blemishes. These blemishes may also be a result of algal lawn expansion by territorial damselfish. More detailed assessment of this condition is needed. Growth anomalies were also quantified at Kingman. Seventy-five percent of these cases occurred on *Porites*, but were also observed on two colonies of *Acropora* cf. *clathrata* and one colony of *Herpolitha limax*. Discoloration was also observed, mostly affecting colonies of *Pocillopora* spp., but also *Porites*. On *Pocillopora* spp. it generally occurred on a few peripheral branches and on one side of the colony only. On *Porites*, discoloration occurred mottled or streaked on the

upper surface of the colony. Paling and discoloration also occurred associated with growth anomalies, as well as irritations and necrotic lesions, respectively. Representative tissue samples of this latter type were procured for histological characterization. Finally, one case of necrosis and one case of irritation were observed on colonies of *Porites*. Representative tissue samples of the latter type were procured for histological characterization. As for afflictions to coralline algae, 20 cases of fungal disease were detected; 90% of these occurred at KIN03, just off La Paloma channel, and KIN11 on the southeastern outer perimeter. The estimated relative abundance of coralline algal disease was ~33 cases per 1000 m^2. Figure D.3.2.3-4 illustrates some examples of the main types of afflictions affecting scleractinian corals at Kingman Reef.

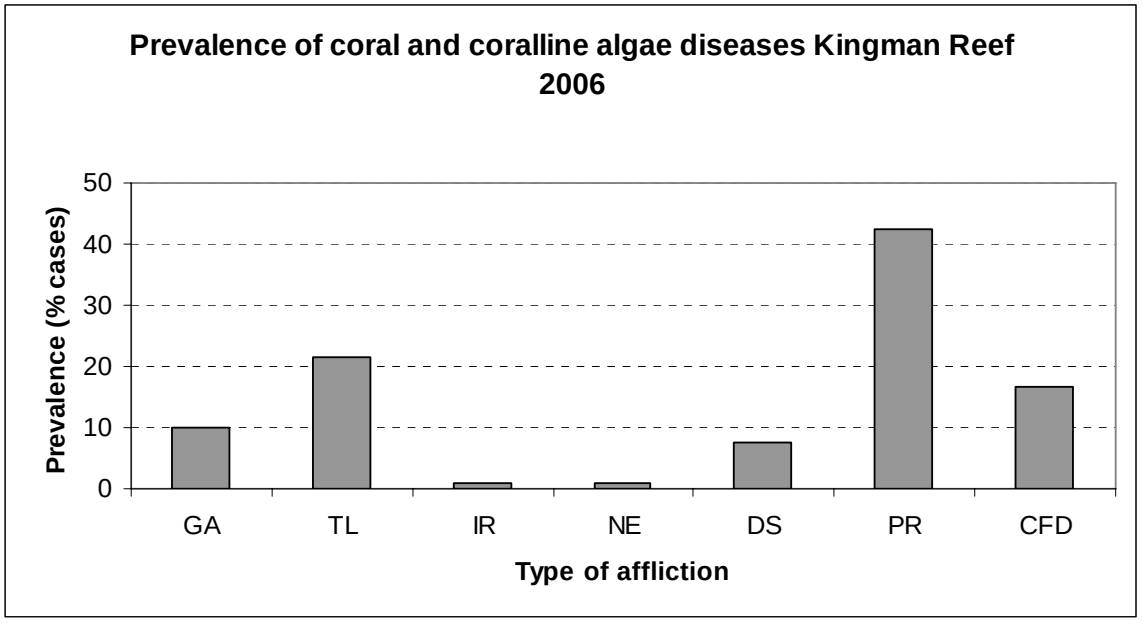


Figure D.3.2.3-1 Prevalence (% cases) of disease and afflictions on scleractinian corals and coralline algae at Kingman Reef, 2006. GA: growth anomalies; TL: tissue loss; IR: irritation; NE: necrosis; DS: discoloration; PR: predation; CFD: crustose coralline fungal disease.

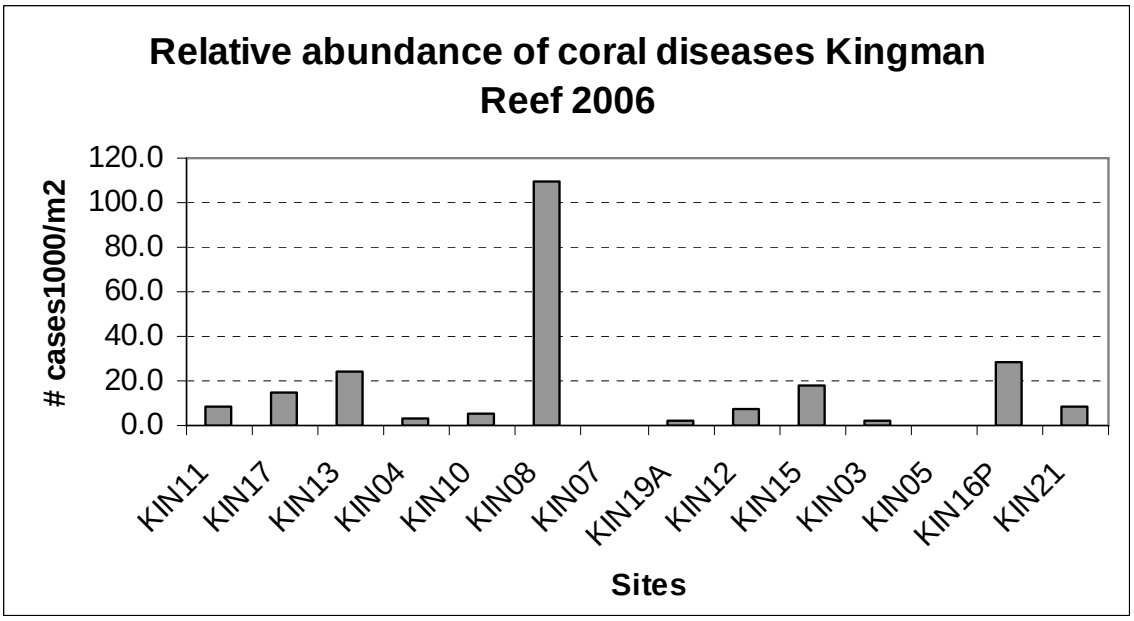


Figure D.3.2.3-2 Estimated relative abundance of coral disease per site Kingman Reef, 2006

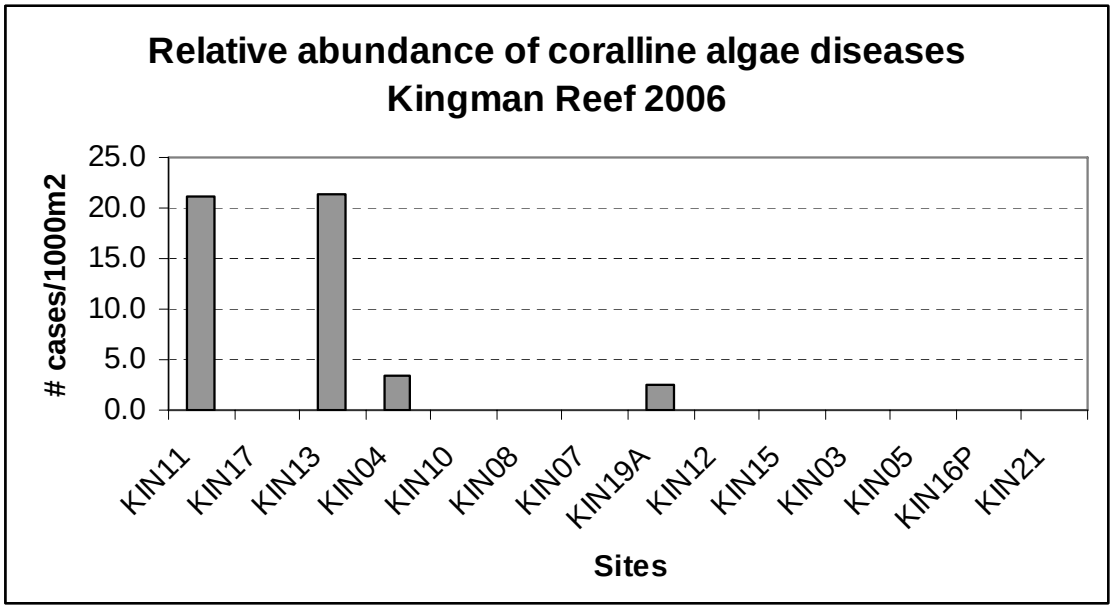


Figure D.3.2.3-3 Estimated relative abundance of coralline fungal disease per site at Kingman Reef, 2006

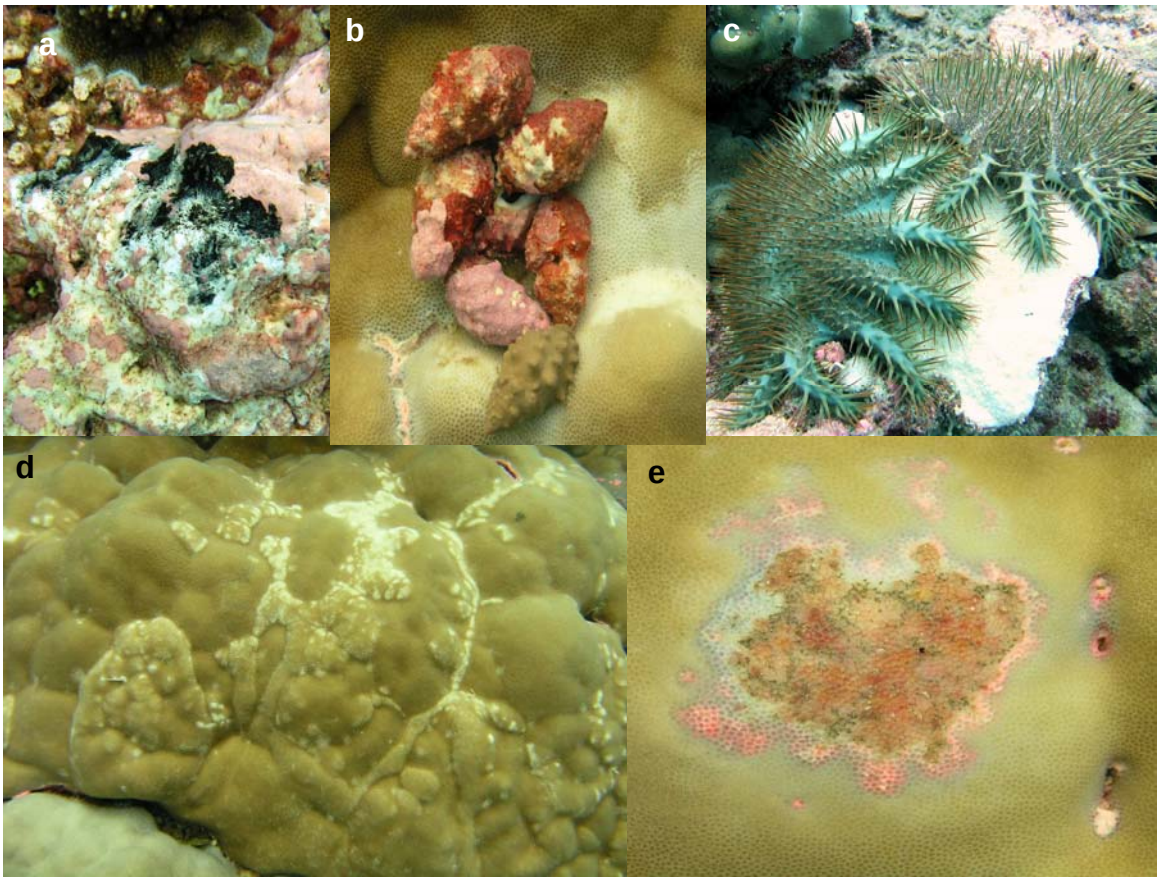


Fig.D.3.2.3-4 Field appearance of selected types of diseases, syndromes, and other afflictions affecting scleractinian corals, soft corals and coralline algae at Kingman Reef, 2006. a. Crustose coralline algae fungal disease; b. *Drupella* predation on Porites; c. *Acanthaster* predation; d. Growth anomaly and discoloration on *Porites*; e. Necrosis and discoloration on *Porites*.

D.3.2.4. Coral REA sites description

KIN11 (3-29-2006: 06°22.911' N; 162°20.781' W)
Southeast, ocean fringing reef slope; gentle slope, approx. 5–10 degrees. Depth range: 12–15 m. Mean coral cover was 50%. Relative high coral diversity and topographic complexity dominated by *Porites* spp, *Montipora*, and *Pocillopora verrucosa/meandrina/eydouxi*. Other corals observed in the survey area included: *Turbinaria reniformis*, *Favia stelligera*, *Fungia*, *Herpolitha*, *Pavona duerdeni*, *Pavona* cf. *chiriquiensis*, *Pavona varians*, *Pavona explanulata*, *Hydnophora microconos*, *Lobophyllia,* and *Psammocora*. Coral health and disease assessment indicated that within the total area surveyed (~475 m^2), two cases of tissue loss were observed on *Pocillopora* cf. *verrucosa*. Additionally, two cases of growth anomalies were observed on tabular *Acropora*. The estimated relative abundance of coral diseases for this site was 8.4 cases/1000 m^2. Additionally, 10 cases of coralline fungal disease were observed (~21 cases/1000 m^2).

KIN17 (3-29-2006: GPS: 06°22.921' N; 162°23.960' W)
South, ocean fringing reef slope; gentle slope, approx. 5–10 degrees. Depth range:

13−15 m. Mean coral cover was 22%. Relative high coral diversity dominated by *Porites* spp. and *Pocillopora verrucosa/meandrina/eydouxi*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), six cases of tissue loss were detected on colonies of *Pocillopora* cf. *verrucosa*. The estimated relative abundance of coral diseases for this site was 15 cases/1000 m^2.

KIN13 (3-29-2006: 06°22.931'N; 162°23.054'W)
South–Southwest, ocean fringing reef slope; gentle slope, approx. 5–10 degrees. Depth range: 14 m. Mean coral cover was relatively high, 44%. Relative high coral diversity dominated by *Porites* spp. and *Pocillopora verrucosa/meandrina/eydouxi*. Other corals observed in the survey area included: *Turbinaria*, *Favia stelligera*, *Pavona duerdeni*, *Pavona* cf. *chiriquiensis*, *Pavona varians*, *Pavona explanulata*, *Hydnophora microconos*, *Lobophyllia*, *Montastrea*, and *Psammocora*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), seven cases of tissue loss were observed on *Pocillopora* cf. *verrucosa*. Additionally, one case of growth anomaly on *Herpolitha*, and one case of discoloration on *Pocillopora* were observed. The estimated relative abundance of coral diseases for this site was 24 cases/1000 m^2. Additionally, eight cases of coralline fungal disease were observed (~21 cases/1000 m^2).

KIN04 (3-30-2006: 06°26.330' N; 162°23.285' W)
Northwest ocean fringing reef. Depth range: 45−60. Relatively high species richness. Mean coral cover was close to 30%. *Porites* spp. was the dominant scleractinian. Other corals present included: *Favia stelligera*, *Montipora*, *Pavona duerdeni*, *Pavona varians*, *Pocillopora*, *Hydnophora*, and *Fungia*. Coral health and disease assessment indicated that within the total area surveyed (~300 m^2), one case of tissue loss was observed on *Pocillopora* cf. *verrucosa*. The estimated relative abundance of coral diseases for this site was 3.3 cases/1000 m^2. Additionally, one case of coralline fungal disease was observed (~3.3 cases/1000 m^2).

KIN10 (3-3-2006: 06°26.221'N; 162°22.778' W)
Northwest internal lagoon patch reef. Depth range: 8–12 m. Mean coral cover was high, 60.7%. Site dominated by dome-shaped colonies of *Porties* sp. Other scleractinian corals present included: *Favia stelligera*, *Montipora*, *Acropora*, *Pavona duerdeni*, *Psammocora*, *Turbinaria*, *Pavona varians*, *Pocillopora*, *Hydnophora*, and *Fungia*. Coral health and disease assessment indicated that within the total area surveyed (~350 m^2), one case of tissue loss was observed on *Pocillopora* cf. *verrucosa*. The estimated relative abundance of coral diseases for this site was 5.7 cases/1000 m^2. Additionally, several *Acanthaster* predation scars were noted on *Favia stelligera*, *Porites*, *Fungia*, and *Montipora*.

KIN08 (3-30-2006: 06°25.749' N; 162°22.953'W)
Northwest internal lagoon fringing reef. Depth range: 13–18 m. Mean coral cover was low; 18.6%. Low species richness, composed of a mixture of *Porites*, *Turbinaria*, and *Favia*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2) no coral diseases were observed. However, 10 crown-of-thorns starfish (*Acanthaster planci*) were observed, as well as numerous predation scars; approx. 11

scar/100 m^2. Over 95% scars occurred on colonies of *Porties*; however, some colonies of *Turbinaria* and *Astreopora* also exhibited predation damage.

KIN07 (3-31-2006: 06°24.131' N; 162°23.123' W)
Central lagoon patch reef. Depth range: 11–14 m. Mean coral cover was 13%. Relative low coral diversity dominated by *Porites* spp. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), no coral diseases were observed.

KIN19A (3-31-2006: 06°23.195' N; 162°22.903' W)
Central lagoon backreef. Depth range: 11–15 m. Mean coral cover was 14.7%. Relative low coral diversity dominated by *Porites* spp. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), one case of tissue loss was observed on *Pocillopora* cf. *verrucosa* (2.5 cases/1000 m^2). Additionally, 10 individuals of *Acanthaster* were observed.

KIN12 (3-31-2006: 06°23.150' N; 162°22.643' W)
Central lagoon backreef. Depth range: 11–15 m. Mean coral cover was 23.5%. Relative low coral diversity dominated by *Porites* spp. Other corals in order of importance included: *Turbinaria*, and *Montipora*. Coral health and disease assessment indicated that within the total area surveyed (~400 m^2), no coral diseases were observed. Outside the survey area, two cases of discoloration were observe on *Porties* cf. *lutea.*

KIN15 (4-1-2006: 06°24.440' N; 162°22.073' W)
Central lagoon, patch reef. Depth range: 6–14 m. Mean coral cover was 20.5 %. Relative low coral diversity dominated by massive *Porites* spp. Other corals in order of importance included: *Turbinaria*, and *Fungia*. There was a clear difference in zonation between the shallow *Porites*-*Fungia*-crustose coralline algae dominated areas versus the deep *Porites*-rubble dominated ones. *Acanthaster* predation scars and partial mortality on *Porites* sp., were noted, particularly between 9 and 13 m depth. Coral health and disease assessment indicated that within the total area surveyed (~600 m^2), two cases of growth anomalies were detected on *Porites*; one of these cases also exhibited discoloration. In addition, one case of tissue necrosis and discoloration were observed on *Porites*. Finally, within the survey area, predation scars by *Acanthaster* (n = 3) and Drupella (n = 1) were also observed on colonies of *Porties*. The estimated relative abundance of coral diseases for this site was
18.3 cases/1000 m^2.

KIN03 (4-2-2006: 06°23.420' N; 162°22.614' W)
East central lagoon patch reef. Depth range: 14–17 m. Mean coral cover was 29.4%. Relative low coral diversity dominated by *Porites* spp. and *Turbinaria*. Clear zonation difference between the shallow (6–11 m) and the deeper reef. Other corals in order of importance included: *Pavona*, *Favia stelligera,* and *Montipora*. Coral health and disease assessment indicated that within the total area surveyed (~500 m^2), one case of growth anomaly was detected on *Porites*. Additionally, 29 *Acanthaster* feeding scars were enumerated. The estimated relative abundance of coral diseases for this site was two cases/1000 m^2; the estimated occurrence of *Acanthaster* feeding was 58 scars/1000 m^2).

KIN05P (4-2-2006: 06°23.683' N; 162°20.779' W)
East backreef. Depth range: 9–12 m. Mean coral cover was 46%. Relative low coral diversity dominated by *Porites* spp. and *Fungia*. Coral health and disease assessment indicated that within the total area surveyed (~450 m^2), no diseases were observed.

KIN16P (4-2-2006: 06°23.543' N; 162°20.526' W)
East central lagoon patch reef. Depth range: 5–8 m. Mean coral cover was 66.7%. Relatively high coral diversity; dominant corals in order of importance: *Porites* spp. *Fungia*, *Montipora*, *Pocillopora*. Elevated numbers of the giant clam *Tridacna* maxima. Coral health and disease assessment indicated that within the total area surveyed (~500 m^2), five cases of growth anomalies were detected on *Porites* and one on *Montipora*. Additionally, four cases of tissue loss/necrosis were observed on *Porites*. Finally three cases of discoloration were also noted on *Porites*. Two of these cases involved a pink irritation; the other case involved paling. The estimated relative abundance of coral diseases for this site was 28 cases/1000m^2.

KIN21 (3-4-2006: 06°22.764'N; 162°21.755'W)
Southeast, just west of La Paloma channel. Depth range: 11–15 m. Mean coral cover was close to 20%. Salient characteristic of this site was the presence of a sizeable thicket of *Porites rus*. However, considerable expanses as this site were composed of bioeroded and coralline algae-encrusted table and staghorn *Acropora* rubble. Most common corals at this site were *Pocillopora* cf. *verrrucosa* and *P. eydouxi*. Nonetheless scleractinian generia richness was relatively high and included: *Alveopora*, *Leptastrea*, *Turbinaria*, *Gardineroseris*, *Favia*, *Herpolitha*, *Pavona*, *Montipora*, *Psammocora*, *Acropora*, *Echinophyllia*, and *Astreopora*. The hydrocoral, *Millepora,* was also observed at this site. Coral health and disease assessment indicated that within the total area surveyed (~500 m^2), two cases of discoloration were noted on *Pocillopora* cf. *verrucosa* and *Pocillopora eydouxi*. In addition, one case of tissue loss on *Pocillopora* cf. *verrucosa* and one case involving a pink irritation on *Porites* sp. were observed. The estimated relative abundance of coral diseases for this site was 8 cases/1000 m^2.

KIN22 (3-4-2006: 06°25.532'N; 162°26.159'W)
West terrace. Depth range: 21–24 m. Qualitative survey. Estimated coral cover: 65%. High coral richness and diversity. Site dominated by platy ecomorphs of *Porites*. Other scleractinians observed included: *Favia*, *Lobophyllia*, *Turbinaria*, *Alveopora*, *Fungia*, *Herpolitha*, *Sandalolitha*, and *Oxypora*. One case of growth anomaly was observed on *Porites*.

KIN23 (3-4-2006: 06°22.939'N; 162°20.476'W)
East corner, ocean fringing reef. Depth range: 9–15 m. Qualitative survey. Estimated coral cover: 60%. High coral richness and diversity. Significant stands of *Acropora* cf. *nobilis* and *A. formosa* were present at this site. Other acroporids particularly *A. cytherea*, *A. hyacinthus*, as well as *A.* cf. *humilis*, and *A.* cf. *valida* also occurred at this site. Other scleractinians observed included: *Favia*, *Lobophyllia*, *Leptoseris*, *Turbinaria*, *Platygyra*, *Fungia*, *Herpolitha*, *Sandalolitha*, and *Stylophora*. Two cases of growth anomalies were

observed on colonies of *Acropora cytherea* and *A. hyacinthus*, respectively. Also, one case of coralline algae fungal disease was observed.

D.3.2.5. Benthic Towed-diver Survey—Corals

The forereef and the southeastern reef pool areas contained the highest estimates of total hard coral habitat cover; averaging between 20and 30%. Surveys along the backreef lagoon area had live hard coral cover estimates averaging between 10 and 20%. Overall, coral richness appeared to be greater in the forereef than in the backreef, which was dominated by *Porites* and *Fungia.* Along the eastern forereef, recruits from the genera *Pocillopora* and *Acropora* were prevalent. Soft coral cover is similarly highest in both the eastern and southern forereef locales measuring between 20 and 30% and much lower in backreef and reef pool survey sites averaging <5%. Stressed corals were prevalent along the eastern backreef slope, southeastern backreef, and within the vicinity of the forereef area around the channel. The stresses on these corals appeared to be caused by predation from the starfish, *Acanthaster planci.* Areas along the eastern backreef slope had estimates of >40% of the corals being stressed, and the southeastern backreef and channel areas had estimates up to 20%.

D.3.3. Invertebrates

The purpose of the REA activities for HI-06-04 was to select sites surveyed during previous rapid ecological assessments for long-term monitoring. Selection of sites was based on their year-round accessibility and their representation of the habitats present at each site. Surveys focusing on marine invertebrates other than corals were performed in conjunction with surveys of coral and macroalgae, collectively termed the benthic survey. This benthic survey was conducted collaboratively with fish surveys. This report will cover the non-coral invertebrates encountered and from this point forward any mention of marine invertebrates refers to this particular group.

D.3.3.1. Invertebrate REA Site Descriptions

KIN11 (3-29-2006: 06°22.911'N, 162°20.781'W)

South shore forereef with high coral cover. The soft coral *Sinularia* was common, as were the urchins, *Echinothrix calamaris* and *Echinothrix diadema*. Tridacnid clams were rare, as were the holothuroids, *Bohadschia graeffii* and *Bohadschia argus*. The hydrozoans, *Distichopora* and *Stylaster* were common throughout the site. The anemones, *Heteractis magnifica* and *Cryptodendrum adhaesivum*, were rare occurrences.

KIN17 (3-29-2006: 06°22.921'N, 162°20.960'W)

South shore forereef with high coral cover. The site was characterized by high abundance and diversity of echionoderms. The holothuroids *Holothuria atra*, *Holothuria whitmaei*, *Thelenota ananas* and *Actinopyga obesa*, and the echinoid *Echinothrix diadema* were the most common, while there was a rare occurrence of *Bohadschia argus*. *Tridacna maxima* was considered to be occasional at this site.

KIN13 (3-29-2006: 06°22.931'N, 162°23.054'W)
South shore forereef with moderate coral cover. This site had less numerous echinoderms compared to the two previous sites. The dominant species was the echinoid, *Echinothrix diadema* with moderate numbers of the holothuroids, *Holothuria atra* and *Bohadschia graeffii*.

KIN04 (3-30-2006: 06°26.330'N, 162°23.285'W)
North shore forereef with low coral cover and high coralline algae coverage. This site had the appearance of being victim to an *Acanthaster* predation outbreak and is in the early stages of recovery. The soft corals *Sinularia* and *Lobophyton* were dominant over the hard corals present. *Tridacna maxima* clams were moderately abundant and the anemones, *Heteractis magnifica* and *Cryptodendrum adhaesivum,* were common and rare, respectively. The urchin, *Echinothrix calamaris,* was abundant throughout the site.

KIN10P (3-30-2006: 06°25.221'N, 162°22.778'W)
Shallow central lagoon patch reef with high coral cover. This site was dominated by the giant clam *Tridacna maxima*, with a rare occurrence of *Tridacna squamosa*. The urchin, *Echinothrix diadema* was abundant, while another echinoid, *Heterocentrotus* was rare in the depth zone being surveyed. A single crown-of-thorns sea star was recorded at the site. The anemone, *Heteractis magnifica,* was common above 10 m.

KIN08 (3-30-2006: 06°25.749'N, 162°22.953'W)
Backreef site located on the northern side of the atoll with high coral cover. The site had abundant giant clams and echinoderms throughout. Both *Tridacna maxima* and *Tridacna squamosa* were present, and there was a solitary sighting of an octopus. The holothuroids *Holothuria atra*, *Actinopyga obesa*, *Bohadschia argus*, *Bohadschia graeffii,* and *Thelenota ananas* were common throughout the site. The crown-of-thorns starfish *Acanthaster planci* was quite abundant in both shallow and deep areas.

KIN07 3-31-3006: (06°24.131'N, 162°23.123'W)
Lagoon patch reef in the central part of atoll. This site was characterized by low coral cover with high abundance of holothuroid echinoderms. The holothuroids represented were primarily *Holothuria atra* and *Actinopyga obesa* but *Bohadschia argus* and *Bohadschia graeffii* were also present. The urchin *Echinothrix calamaris* was present in moderate numbers, while the sea star *Acanthaster planci* was uncommon. There was a rare occurrence of the helmet shell *Cassis cornuta,* and *Tridacna maxima* was occasional.

KIN19 (3-31-2006: 06°23.195'N, 162°22.903'W)
South shore backreef site located 500 meters north of the solitary sand spit island. Holothuroid echinoderms were the most abundant and diverse groups of macroinvertebrates. The holothuroid species present were *Holothuria atra*, *Holothuria whitmaei*, *Bohadschia argus*, *Bohadschia graffei*, *Holothuria edulis*, *Actinopyga obesa* and the synaptid holothuroid *Euapta*. The echinoid urchins *Echinothrix calamaris* and *Toxopneustes pileolus* were present in depths 8 m and greater, and the species *Echinothrix diadema* and *Diadema setosum* were found in combination with *E. calamaris* in shallow depths (< 7 m). The presence of two corallimorpharia, *Rhodactis* and

Discosoma, was recorded in cryptic locations, while the anemone *Heteractis magnifica* was common. The predatory gastropods *Charonia* and *Lambis* were recorded from this site in depths greater than 15 m. *Tridacna maxima* was very abundant throughout the site.

KIN12 (3-31-2006: 06°23.150'N, 162°22.642'W)
This site was a short distance due east of KIN19. Essentially, the fauna was identical except for the absence of the urchin, *Toxopneustes pileolus* and the predatory gastropod, *Lambis*.

KIN15 (4-01-2006: 06°24.440'N, 162°22.073'W)
Central east lagoon patchreef. The site was low in coral cover and was dominated by rubble composed of *Fungia* and *Porites*. *Tridacna maxima* was very abundant, as were holothuroids and echinoids. The holothuroids were *Bohadschia graeffii*, *Bohadschia argus*, *Actinopyga obesa*, *Euapta* and an unknown species from the genus *Holothuria*. The bivalve *Spondylus* was common and the predatory gastropod *Cassis cornuta* was rare. The anemones *Heteractis magnifica* and *Phymanthus* were present, with the former being common and the latter being rare.

KIN03 (4-02-2006: 06°23.420'N, 162°21.61'W)
Southeast lagoon patch reef with high coral cover, especially large colonies of *Porites*. The area surveyed was made up of coral rubble from *Porites* and *Fungia*. Holothuroid echinoderms and tridacnid clams were the dominant macroinvertebrates. The holothuroids present were *Holothuria atra*, *Holothuria edulis*, *Holothuria hilla*, *Holothuria whitmaei*, *Bohadschia paradoxa*, *Bohadschia argus*, *Bohadschia graeffii*, *Thelenota ananas*, *Stichopus chloronotus,* and *Euaptia*. The asteroid echinoderms *Fromia millepora*, *Linckia guildingi* and *Acanthaster planci* were present. Only *Tridacna maxima* was present in above average abundances, while the large predatory gastropod, *Lambis lambis* was rare. The anemones *Heteractis magnifica*, *Heteractis* sp., *Cryptodendrum adhaesivum* and *Phymanthus* were all present, with the first two being the most abundant.

KIN05P (4-02-2006: 06°23.683'N, 162°20.779'W)
Southeast lagoon ribbon reef structure composed of high coral cover at the crest and above average cover combined with rubble on the slopes. The giant clam *Tridacna maxima* was very abundant throughout depths from 5 to 15 m deep. The urchins, *Diadema setosum* and *Echinothrix calamaris* were the next most dominant macroinvertebrates at the site. The predatory sea star *Acanthaster planci* was common at the 10–15-m depth range. The anemones, *Heteractis magnifica* and *Heteractis* sp., were common throughout the depth range of 5–15 m. The cryptic anemone, *Phymanthus,* was rare at the site.

KIN16P (4-03-2006: 06°23.544'N, 162°20.526'W)
Eastern end of southeastern lagoon. The dominant macroinvertebrate was the giant clam *Tridacna maxima*, which had amazingly high densities throughout the site. The urchins, *Diadema setosum* and *Echinothrix calamaris,* were common throughtout the site but were mostly cryptic.

KIN21 (4-04-2006: 06°22.764'N, 162°21.755'W)
New site surveyed on the south shore west of the La Paloma channel. Coral cover was low but macroinvertebrate abundance was quite high. The dominant organisms were holothuroids and urchins. The most numerous holothuroid was *Actinopyga obesa* but *Holothuria atra*, *Holothuria whitmaei,* and *Thelenota ananas* were also present. The urchin present exclusively was *Echinothrix calamaris*. There were rare occurrences of the predatory gastropod, *Lambis lambis* and *Octopus cyanea*.

D.3.3.2. Specific Findings for Invertebrates

Table D.3.3.2-1 summarizes the relative abundance data for most common species enumerated during REA surveys and percent cover for cnidarians.

Table D.3.3-1. Relative abundances of various taxa and percent cover for Cnidaria

Island	Kingman	Kingman	Kingman	Kingman	Kingman	Kingman	Kingman	Kingman	Kingman	Kingman	Kingman	Kingman	Kingman	Kingman
Date	3/29/2006	3/29/2006	3/29/2006	3/30/2006	3/30/2006	3/30/2006	3/31/2006	3/31/2006	3/31/2006	4/1/2006	4/2/2006	4/2/2006	4/2/2006	4/3/2006
Site	KIN-11	KIN-17	KIN-13	KIN-4	KIN-10	KIN-08	KIN-07	KIN-19	KIN-12	KIN-15	KIN-03	KIN-05P	KIN-16P	KIN-21
Depth(feet)	60	50	57	56	40	64	45	40	55	55	52	40	20	50
Habitat	South Shore Forereef	South Shore Forereef	South Shore Forereef	North Shore Forereef	Patchreef	North Backreef	Lagoon Patchreef	South Shore backreef	South Shore backreef	Central east Lagoon	SE Lagoon	SE Lagoon	SE Lagoon	South Shore W of Channel
Cnidaria	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**	**Avg%Cover/m2**
Zoanthid	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroidea	1.280	2.000	0	0	0	0	0	0	0	0	0	0	0	1.040
Sinularia	4.320	0	0.600	3.800	0	0	0	0	0	0	0	0	0	0
Sarcophyton	0	0	0	0	0	1.520	0	0	0	0	0	0	0	0
Lobophyton	0	0	0.920	0	0	0.560	1.360	0.880	1.720	0	0	0	0	0
	Avg#/m2	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**	**Avg#/m2**
Mollusca														
Spondylus	0	0	0.0010	0	0.0030	0	0	0	0	0.0040	0	0.007	0	0
Tridacna sp	0.0020	0.0050	0	0.0090	3.0800	0.0400	0.3800	0.0290	0.1350	0.2800	0.1350	1.15	4.76	0
Pinctada	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Charonia sp.	0	0	0	0	0.0010	0	0	0	0	0	0	0	0	0
Cassis sp	0	0	0	0	0	0	0.0010	0	0	0	0	0	0	0
Coralliophilidae	1.0000	0	0.0800	0	0.1200	0	0	0	0	0	0.0400	0	0	0.16
Octopus	0	0	0	0	0	0.0010	0	0	0	0	0	0	0	0.001
Lambis	0	0	0	0	0	0	0	0	0	0	0.0010	0.001	0	0.001
Echinoids														
Echinothrix sp.	0.0220	0.0490	0.0400	0.0350	0.1075	0	0.0170	0.0460	0.0310	0.0340	0.0130	0.015	0.007	0.085
Heterocentrotus	0	0	0	0	0.0050	0	0	0	0	0	0	0.001	0	0
Tripneustes	0	0	0	0.0025	0	0	0	0	0	0	0	0	0	0
Diadema	0	0	0	0	0	0	0	0.0040	0	0	0	0.021	0.013	0
Toxopneustes	0	0	0	0	0	0	0	0.0010	0	0	0	0	0	0
Holothuroids														
Holothuria atra	0	0.0050	0.0020	0	0	0.0050	0.0750	0.0070	0.0010	0	0.0010	0	0	0.002
Holothuria whitmaei	0	0.0050	0	0	0	0	0	0.0020	0.0020	0	0.0060	0	0	0
Actinopyga obesa	0	0.0060	0	0	0	0.0090	0.0090	0.0100	0.0320	0.0080	0.0510	0	0	0.016
Other Holothuroid	0.0050	0.0040	0.0040	0	0	0.0090	0.0040	0.0160	0.0140	0.0080	0.0100	0	0	0.005
Asteroidea														
Linckia guildingi	0	0	0	0	0	0	0	0.0010	0	0	0	0.001	0	0
Acanthaster planci	0	0	0	0	0	0.0170	0.0020	0.0140	0.0150	0.0020	0.0030	0.006	0	0
Other Asteroid	0	0	0	0	0	0	0	0	0	0	0.0040	0	0	0
Crustacean														
Trapezid crabs	0.2400	0.2400	0.4400	0.1200	0	0	0	0	0	0	0	0	0	0.16
Hermit Crabs	0.0400	0	0.2400	0.0400	0	0	0	0.0400	0	0	0	0	0	0.68
Large Brachyuran	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001

D.3.3.3. Benthic Towed-diver Survey – Macroinvertebrates

Overall, there was an abundance of conspicuous macroinvertebrates. Seven hundred twenty-eight non-cryptic crown-of-thorns starfish (*Acanthaster planci)* were observed throughout the reef, with the majority counted on the southern forereef outside of the channel and along the eastern backreef. There were no *A. planci* observed on the eastern

forereef. Over 2,000 sea urchins were observed, with the majority being recorded along the southern forereef. Over 1,000 sea cucumbers were recorded, 63% of which were observed along the eastern backreef. Giant clams (*Tridacna sp.)* were the most abundant macroinvertebrate observed, with over 25,000 individuals recorded. Over 70% were observed in the southeastern reef pool where they appeared to be the dominant substrate component. Approximately 24% were observed in the eastern backreef, and less than 5% were recorded on the entire forereef and the southern backreef.

D.3.3.4. Invertebrates Discussion

Each habitat at Kingman Reef (forereef, backreef, lagoon) exhibits a great abundance and variety of macroinvertebrates. Most sites had high coral cover combined with abundant macroinvertebrate fauna. The abundance of cnidarians, mollusks and echinoderms recorded at the majority of sites was impressive. The cnidarian fauna was represented by soft corals, zoanthids, anemones, and corallimorpharians. The soft coral genera were *Sarcophyton*, *Lobophytum*, and *Sinularia*, and were found only at moderate levels when present. Zoanthids of the genus *Zoanthus* and Corallimorpharians (Fig. D. 3.3-3) of the genus *Rhodactis* and *Discosoma* were present in lagoon locations but were not abundant. Anemones represented the most numerous taxa and were most numerous in lagoon patch reef habitats. The representative anemone genera were two species of *Heteractis* and a species of *Phymanthus (*Fig. D.3.3-3). The mollusk fauna was represented strongly by sessile species of bivalves of the genus *Tridacna* and *Spondylus,* but also by coralliophilid snails associated with *Porites* coral and by the large predatory species *Lambis lambis, Cassis cornuta* and *Charonia tritonis*. The giant clams, *Tridacna maxima* and *Tridacna squamosa,* were both present but *T. maxima* was the most numerous. The abundances of *T. maxima* were greatest at lagoon patch reef sites (Table D.3.3-1 and Fig..3.3-1) with uniquely abundant populations at sites KIN-10 (avg#/m^2=3.08), KIN-05P (avg#/m^2=1.15), and KIN-16P (avg#/m^2=4.76). The presence of *Tridacna squamosa* (Fig. D.3.3-3) would represent its northernmost record. Echinoderm fauna was less abundant than molluscan fauna but more diverse. Holothuroid fauna was the most abundant and diverse, followed by echinoids and asteroids. Holothuroids were the dominant fauna at patchreef locations and integral at other habitats. The fauna was made up of *Holothuria atra, Holothuria edulis, Holothuria hilla, Holothuria whitmaei, Bohadschia paradoxa, Bohadschia argus, Bohadschia graeffii, Thelonota ananas, Stichopus chloronotus, Euapta* sp., and an unknown species of *Holothuria*. The urchins *Echinothrix calamaris*, *Echinothrix diadema,* and *Diadema setosum* were the most common, while the species *Toxopneustes pileolus* was rare. The asteroid fauna was represented by *Linckia guildingi*, *Fromia milleporella,* and *Acanthaster planci*. *Acanthaster planci* has a patchy distribution and abundance spread across all habitats (Fig. D.3.3-2) but appears to be the main driver of disturbance within the Kingman Reef atoll system. This is especially true in backreef and lagoon patchreef habitats. Most of these sites were either experiencing impacts by the sea stars or showed signs of historical impacts. There was obvious evidence of incremental predation beginning with favored prey (*Pocillopora*) and prey-switching to less favored species (*Fungia*, *Porites,* and Faviidae).

Overall, Kingman Reef is the most unique and intact coral reef resource within the U.S. Fish and Wildlife National Wildlife Reserve (NWR) system. The abundance of sessile

fauna, such as *Tridacna*, is quite remarkable but non-coral cnidarian, molluscan and echinoderm fauna also contribute to the uniqueness of this atoll. It represents a mostly intact system with species, such as *Tridacna squamosa*, at their northernmost ranges.

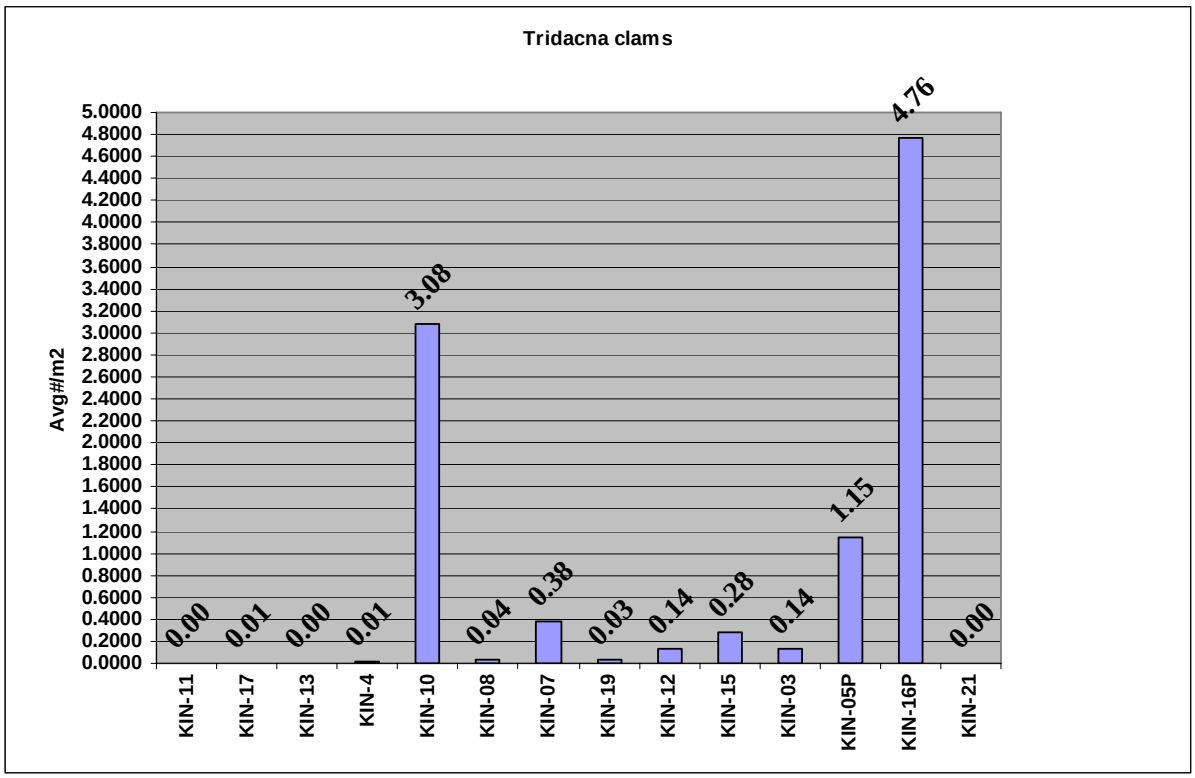


Figure D.3.3-1. The relative abundance of *Tridacna* for all survey sites.

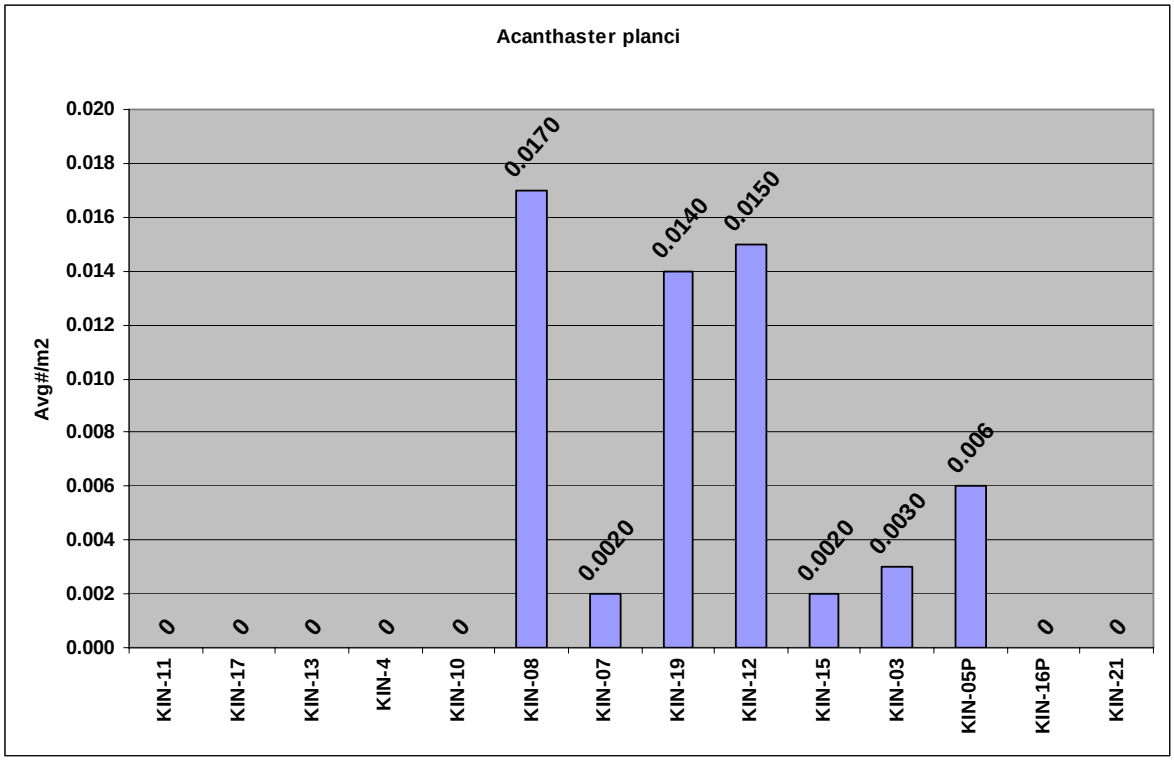


Figure D.3.3-2. Relative abundance of *Acanthaster planci* for all survey sites.

Figure D.3.3-3. L-R, *Discosoma* sp. (Cnidaria; Corallimorpharia; Actinodiscidae), *Phymanthus* sp. (Cnidaria; Actiniaria; Phymanthidae) and *Tridacna squamosa* (Mollusca; Bivalvia)

D.4. Fish

From March 29 to April 3, 2006, the fish REA team (Craig Musburger, Paula Ayotte, and Todd Wass) surveyed 16 sites around Kingman Reef while the towed-diver fish survey team (Stephane Charette, Amy Hall, and Edmund Coccagna) conducted 22 towed-diver fish surveys totaling 52.35 km in length.

All of the REA sites were monitoring sites previously visited by CRED teams except for three new sites (KIN21, KIN22, AND KIN23), two of which were only surveyed qualitatively. Quantitative belt transects (BLT), stationary point counts (SPC), and qualitative REA surveys (for species presence) were conducted at all other sites, using the same methodology as in previous years. Site KIN22 was a deep site along the submerged western boundary of the atoll and was too deep to allow for quantitative survey methods. Site KIN23 was located as far east along the Southern Reef Slope as weather conditions permitted the REA team to safely dive and was too rough for the laying of transects. The benthic team (corals, algae, invertebrates) followed the fish team at all survey sites.

Kingman Reef includes several habitat types that are not found at the two other islands surveyed during this cruise. The sunken atoll consists of exposed outer reef, extensive backreef, a series of small, scattered patch reefs, and a sunken western atoll rim. The REA team was able to survey at least one site in each of these habitat types. A preliminary total of 186 fish species was recorded by the fish REA divers at Kingman Reef. Numerically, damselfish (family Pomacentridae) dominated the fish fauna at Kingman, although the species composition varied more greatly from region to region at this island than at the other two islands surveyed during this cruise. Surgeonfish (family Acanthuridae) were also very abundant at most sites surveyed by the REA team. Among larger-bodied fishes surveyed by the REA team, twinspot snapper (*Lutjanus bohar)* were abundant at every site surveyed. Large aggregations of yellowback fusiliers (*Caesio teres),* blackfin barracuda (*Sphyraena qenie*), and rainbow runners (*Elagatis bipinnulata*) were observed at scattered sites. Sharks appeared to be more abundant here than at Palmyra, but less abundant than at Jarvis. No Napoleon wrasse (*Cheilinus undulatus*) or bumphead parrotfish (*Bolbometopon muricatum)* were observed by the REA team at Kingman Reef.

A total of 1,119 fishes were observed during the 22 tows conducted at Kingman Reef. The most abundant species observed was the twinspot snapper (*L. bohar*) with 477 individuals counted. The Pacific steephead parrotfish (*Chlorurus microrhinos*) was the second most frequently observed fish with a total of 260 individuals recorded. These were followed by the grey reef shark (*Carcharhinus amblyrhyncos*), which was the third most frequently observed species with 93 individuals recorded. Another notable observation was the sighting of a giant grouper (*Epinephelus lanceolatus*).

The most commonly observed family by the towed-diver surveyors was the snappers (family Lutjanidae) with 483 individual sightings. Parrotfish (family Scaridae) were the second most frequently observed family with 279 counts. Each of these families was largely represented by the two most frequently counted species, the twinspot snapper and the Pacific steephead parrotfish, respectively. Sharks (family Carcharhinidae) were the third most frequently observed family with 143 individual counts. The grey reef shark (*C. amblyrhynchos*) accounted for the majority of these sightings, followed by the whitetip reef shark (*Triaenodon obesus*) and the blacktip reef shark (*C. melanopterus*) with 47 and 2 observations, respectively.

D.4.1. Regional Summary

Kingman Reef can be divided into seven regions: A Southern Forereef, a Southern Backreef, a Northern Forereef, a Northern Backreef, Lagoon Patch Reefs, a submerged Western Atoll Boundary, and a shallow Southeastern Lagoon. Following are brief summaries of the fish observations of the fish REA team and the towed-diver fish observers by region. Please refer to the map of REA sites (Fig. D.3-1) and the map of towed-diver surveys (Fig. D.3-2) for specific site and tow track locations.

Southern Forereef:

REA sites KIN-17, KIN-13, KIN-21, KIN-11, and KIN-23; Towed-diver Surveys 6-10 and 19-20

The most abundant fish species recorded by SPC divers in this region was the yellowback fusilier (*Caesio teres)*; however, this number is inflated because of a single observation of a large school in excess of 2000 individuals at site KIN-13. On most SPC replicates, twinspot snapper (*Lutjanus bohar*) was the dominant species. This region was characterized by frequent observations of large schools of various fish species including blackfin barracuda (*Sphyraena barracuda*), rainbow runners (*Elegatis bipinnulata*), and sleek unicornfish (*Naso hexacanthus*). Grey reef sharks (*Carcharhinus amblyrhynchos*) and whitetip reef sharks (*Triaenodon obesus*) were common in this region as were Pacific steephead parrotfish (*Chlorurus microrhinos*).

Belt Transects in this region were dominated by dwarf chromis (*Chromis acares*), bicolor chromis (*C. margaritifer*), and Vanderbilt's chromis (*C. vanderbilti*). Surgeonfish (family Acanthuridae) and parrotfish (family Scaridae) were abundant and diverse in this region, especially at site KIN-21 where 10 species of parrotfish and 8 species of surgeonfish were recorded within the boundaries of quantitative surveys. Olive anthias (*Pseudanthias olivaceus*) were common along the Southern Forereef and were the only anthias recorded quantitatively in the region. Among wrasses (family Labridae) several species were common including blunthead wrasse (*Thalassoma amblycephalum*), fivelined wrasse (*T. quinquevittatum*), ornate wrasse (*Halichoeres ornatissimus*), and eightlined wrasse (*Pseudocheilinus octotaenia*). Angelfish (family Pomacanthide) and butterflyfish (family Chaetodontidae) were rare in this region and missing from many transects. Arceye hawkfish (*Paracirrhitus arcatus*) were very common at all sites along the Southern Forereef.

Seven complete towed-diver surveys were conducted in this region totaling 18.62 km. The twinspot snapper (*L. bohar*) was the most frequently recorded fish species in this region with 228 observations. The second most frequently recorded fish species was the Pacific steephead parrotfish (*C. microrhinos*) with 86 observations. Additionally, there was one sighting of a scalloped hammerhead (*Sphyrna lewini*). Out of 24 species, 510 individual fish were recorded in this region.

Southern Backreef
REA sites KIN-12 AND KIN- 19; Towed-diver Surveys 15-18

The two REA sites surveyed along the Southern Backreef were located in close proximity to each other, but differed in their proximity to the small emergent land area on the southern side of the atoll. SPCs at both sites revealed high abundances of twinspot snapper *(Lutjanus bohar*) and Pacific steephead parrotfish (*Chlorurus microrhinos*). Sharks were quite common here and consisted mainly of grey reef sharks (*Carcharhinus amblyrhynchos*). Unlike the Southern Forereef, there were no large schools of fish recorded on SPCs in this region.

The most abundant fish along BLTs in this region were bicolor chromis (*Chromis margaritifer*) and neon damselfish (*Pomacentrus coelestis*). Many outer reef species were entirely missing from transects here including dwarf chromis (*C. acares*), Vanderbilt's chromis (*C. vanderbilti*), and all species of hawkfish (family Cirrhitidae). Juvenile surgeonfish tentatively identified as bluespotted bristletooth (*Ctenochaetus marginatus*) were abundant here. Wrasses appeared to be less diverse here than in other regions with four to seven species recorded along each transect. No wrasse species was recorded as especially abundant. No anthias and few groupers (family Serranidae) were recorded on transects in this region.

Four complete towed-diver surveys were conducted in this region totaling 9.39 km. The Pacific steephead parrotfish (*C. microrhinos*) was the most frequently recorded fish species with 125 sightings. The second most commonly observed species was the twinspot snapper (*L. bohar*) with 94 individuals recorded. Two notable observations from this region were the sightings of a giant grouper (*E. lanceolatus*) and a scalloped hammerhead (*S. lewini*). Out of 12 species, 262 individual fish were recorded in this region.

Northern Forereef
REA site KIN-04; Towed-diver Surveys 1-5

Harsh weather conditions made working on the exposed Northern Forereef difficult for the REA team, and only a single REA site was visited here. This site had previously only been visited in 2000. The SPC here revealed twinspot snapper (*Lutjanus bohar*) to be the most abundant species, followed by bridled parrotfish (*Scarus frenatus*) and whitetip reef sharks (*Triaenodon obesus*). A single 85-cm TL giant trevally (*Caranx ignobilis*) was recorded here. Other common species included Pacific steephead parrotfish (*Chlorurus microrhinos*), bluefin trevally (*Caranx melampygus*), and Vlaming's unicornfish (*Naso vlamingii*).

The BLT divers here recorded dwarf chromis (*Chromis acares*), bicolor chromis (*C. margaritifer*), and Vanderbilt's chromis (*C. vanderbilti*) as abundant on each transect. Two species of parrotfish, bullethead parrotfish (*Chlorurus sordidus*) and bridled parrotfish (*S. frenatus*) were abundant as were two species of surgeonfish, goldrimmed

surgeonfish (*Acanthurus nigricans*) and bluelipped bristletooth (*Ctenochaetus cyanocheilus*). Overall species and family diversity were quite low at this site compared to most other regions.

Five complete towed-diver surveys were conducted in this region totaling 10.54 km. The twinspot snapper (*L. bohar*) was the most frequently recorded fish species with 117 observations. The second most frequently seen species was the Pacific steephead parrotfish (*C. microrhinos*) with 37 individuals recorded. Sharks (family Carcharhinidae) were the third most frequently recorded fish family with 33 observations. Out of 19 species, 234 individual fish were recorded in this region.

Northern Backreef
REA site KIN-08; Towed-diver Surveys 11-14

Similar to the Northern Forereef, this region proved difficult to work for the REA team. The northeast exposure of the atoll provided little lee from the prevailing wind and swell, and only a single REA site was surveyed in this region. The SPC here was characterized by overall low fish density. The most common species were twinspot snapper (*Lutjanus bohar*) and Pacific steephead parrotfish (*Chlorurus microrhinos*). Five grey reef sharks (*Carcharhinus amblyrhynchos*) were recorded as were two manta rays (*Manta birostris*). A single 50-cm TL lyretail grouper (*Variola louti*) was also recorded.

The most common fish within BLT boundaries at this site was the bicolor chromis (*Chromis margaritifer*). On one replicate, 60 neon damselfish (*Pomacentrus coelestis*) were recorded. No angelfish and very few butterflyfish were present. A single individual blackside hawkfish (*Paracirrhitus forsteri*) was the only hawkfish recorded by BLT divers here. Among surgeonfish (family Acanthuridae), bluespotted bristletooth (*Ctenochaetus marginatus*) and goldrimmed surgeonfish (*Acanthurus nigricans*) were most common, and the Hawaiian bristletooth (*C. hawaiiensis*) was also recorded. Wrasses were moderately diverse but not abundant. One species of damselfish, the scaly chromis (*Chromis lepidolepis*), was recorded here which was not recorded in other regions.

Four complete towed-diver surveys were conducted in this region totaling 9.13 km. The twinspot snapper (*L. bohar*) was the most frequently observed fish species with 28 observations. The second and third most commonly observed fish were both species of the shark family (family Carcharhinidae). The grey reef shark (*C. amblyrhynchos*) and the white tip reef shark (*Triaenodon obesus*) were counted 19 and 10 times, respectively. Out of 15 species, 91 individual fish were recorded in this region.

Lagoon Patch Reefs
REA sites KIN-03, KIN-07, KIN-10, and KIN-15

The lagoon of Kingman hosts a series of scattered, small patch reefs. Because of the size of these reefs, towed-diver surveys are impractical here. REA sites often consisted of running transects around the circumference of the circular patches.

SPC surveys on these reefs again revealed twinspot snapper (*Lutjanus bohar*) to be the most abundant fish over 25 cm TL. Grey reef sharks (*Carcharhinus amblyrhynchos*) were abundant with 23 individuals ranging from 120 to 160 cm TL recorded at site KIN-15 alone. Pacific steephead parrotfish (*Chlorurus microrhinos*) were abundant at most Lagoon Patch Reefs. Peacock grouper (*Cephalopholis argus*) were recorded at every site and were especially abundant at site KIN-03. Milkfish (*Chanos chanos*) up to 100 cm TL were recorded at two sites.

The most abundant fish along transects at most Lagoon Patch Reef sites were bicolor chromis (*Chromis margaritifer*) and neon damselfish (*Pomacentrus coelestis*). The regionally endemic goldfin dascyllus *(Dascyllus auripinnis)* was also common along many transects. Yellowback fusiliers (*Caesio teres*) were recorded in schools of up to 500 individuals along belt transects at three of the four REA sites in this region, and at one site they were observed in a mixed aggregation with 250 Marr's fusiliers *(Pterocaesio marri*). The lagoon patch reefs also hosted a large number of juvenile (2 to 3 cm TL) blunthead wrasse (*Thalassoma amblycephalum*), which were recorded in large groups of up to 50 individuals. Lemonpeel angelfish (*Centropyge flavissima*) were frequently observed and no other angelfish species were recorded quantitatively. Hawkfish (family Cirrhitidae) were rare in this region and consisted of a few scattered observations of blackside hawkfish (*Paracirrhitus forsteri*) and arceye hawkfish (*P. arcatus*).

Submerged Western Atoll Boundary
REA site KIN-22

REA site KIN-22 was surveyed only qualitatively. The western side of Kingman Reef consists of a sunken atoll boundary reef and is too deep to allow for quantitative survey methods used at other REA sites. This site had not been previously visited by CRED scientists. The fish REA team noted the presence of enormous schools of yellowback fusiliers (*Caesio teres*) here as well as large numbers of grey reef sharks (*Carcharhinus amblyrhynchos*). A large school of blackfin barracuda (*Sphyraena qenie*) was also observed. Twelve species of butterflyfish were recorded here including Thompson's butterflyfish (*Hemitaurichthys thompsoni*), which was not recorded at any other site at Kingman Reef. Parrotfish (family Scaridae) and surgeonfish (family Acanthuridae) were less diverse than at most other sites, while soldier/squirrelfish (family Holocentridae) were more diverse here.

Southeastern Lagoon
REA sites KIN-05 AND KIN-16; Towed-diver Surveys 21-22

Two REA sites were surveyed in the Southeastern Lagoon of Kingman Reef. They were both shallow (<9 m) and comprised of habitat that was quite different from other parts of the atoll. The most common species recorded on SPCs in this region were twinspot snapper *(Lutjanus bohar*) and Pacific steephead parrotfish (*Chlorurus microrhinos*), but fish over 25 cm TL were not abundant here. No sharks were recorded on SPCs at site KIN-16, but at site KIN-05 14 grey reef sharks (*Carcharhinus amblyrhynchos*) and one witetip reef shark (*Triaenodon obesus*) were recorded.

The BLT divers at both of these sites noted low diversity and abundance of fishes at both sites. This was somewhat surprising as the quality of available habitat appeared excellent. At site KIN-16 the two most abundant species were blunthead wrasse (*Thalassoma amblycephalum*) and bicolor chromis (*Chromis margaritifer*). At site KIN-05 the two most abundant species were goldrimmed surgeonfish (*Acanthurus nigricans*) and variable chromis (*Chromis xanthura*). Most of the wrasses observed in this region were juveniles and many were estimated to be 2 to 5 cm TL. Groupers were scarce and consisted only of the peacock grouper (*Cephalopholis argus*).

Two complete towed-diver surveys were conducted in this region totaling 4.67 km. The twinspot snapper (*L. bohar*) was the most frequently recorded fish species with 10 observations. The Pacific steephead parrotfish (*C. microrhinos*) was the second most frequently recorded species with 7 observations. Three white tip reef sharks (*Triaenodon obsesus*) were recorded as well. Out of 5 species, 22 individual fish were recorded in this region.

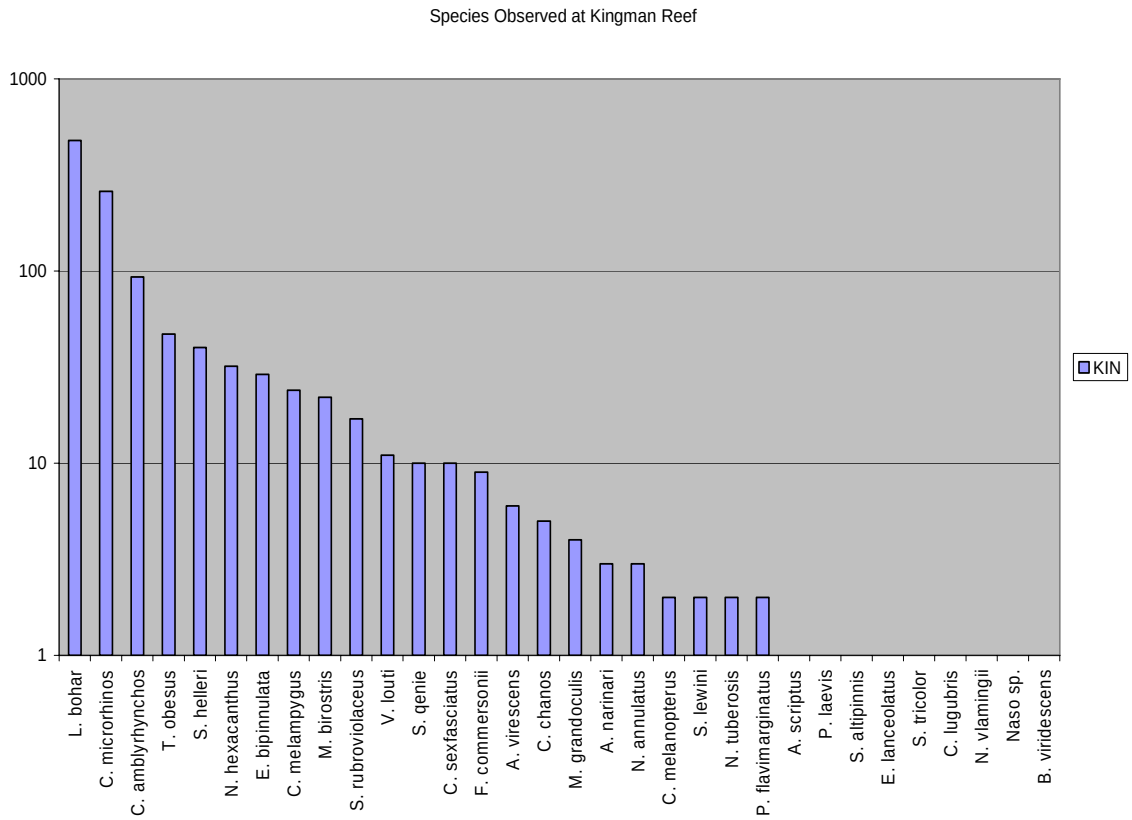


Figure D.4-1: Species observed during towed-diver surveys at Kingman Reef.

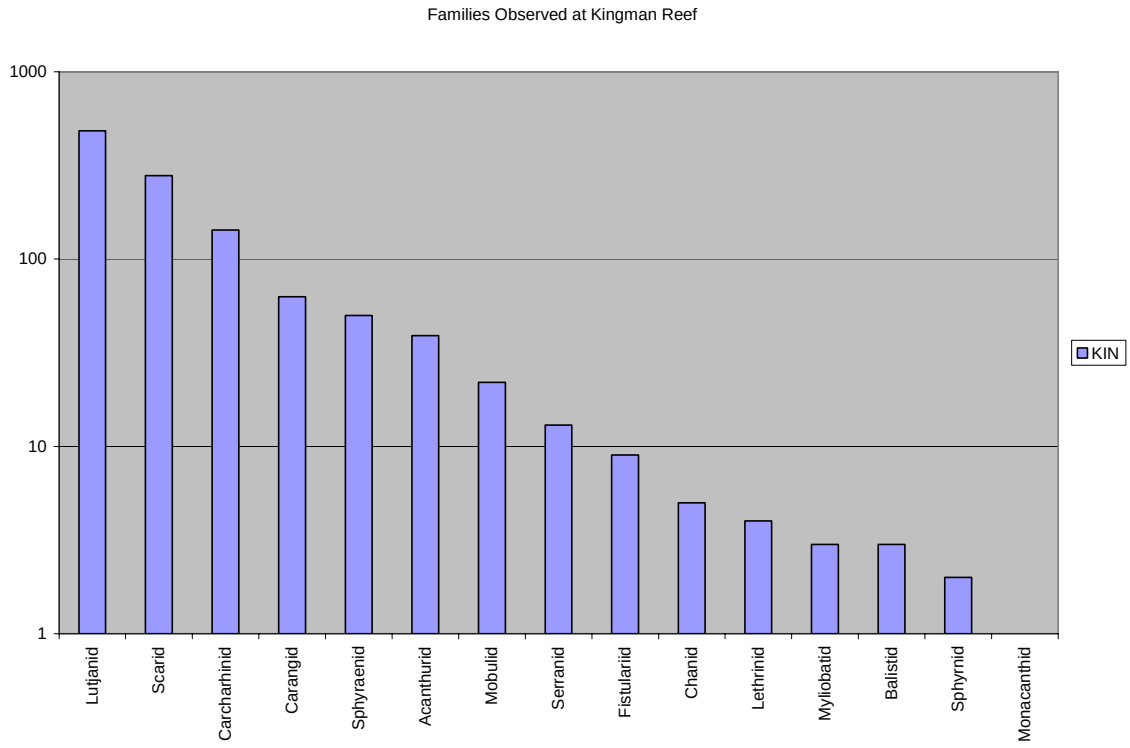


Figure D.4-2: Families observed during towed-diver surveys at Kingman Reef.

D.5. Terrestrial Studies

Terrestrial surveys were not conducted during HI-06-04.