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MARINE ECOLOGICAL ASSESSMENT OF PROPOSED WAVE ENERGY PROJECT AREA OFFSHORE MARINE CORPS BASE HAWAII

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The Office of Naval Research has been conducting tests of wave energy conversion buoys offshore Marine Corps Base Hawaii since 2003. Currently, the Naval Facilities Engineering Command (NAVFAC) is interested in deploying new buoy designs in the same (approved) project area, but at greater depths and further offshore.

NAVFAC Engineering Service Center's (ESC) Scientific Diving Services group conducted marine ecological monitoring of the wave energy facility from October 2003 through October 2004. No adverse impacts to any marine natural resources were detected during the first year of monitoring. Nevertheless, periodic monitoring was continued between 2005 and 2007 and an updated survey was performed in May 2011.

The key findings and conclusions of these investigations were: 1) no detectable adverse impacts to any threatened or endangered species, 2) no detectable adverse impacts to corals or coral reefs, 3) no detectable adverse impacts to fishery target species or to EFH, 4) no alien species have been detected on or adjacent to any of the equipment associated with the wave energy project, the equipment has not been an attractant to any alien species,5) the anchor base and associated equipment have increased habitat complexity and vertical relief, resulting in an increase in fin fish diversity and biomass, 6) the power cable supported greater densities of coral in May 2011 than the adjacent seafloor areas, 7) the findings from the Navy studies are compatible with the findings from two separate studies performed by personnel from USFWS, NOAA and other agencies.

The anchor base, power cable and associated equipment should be left in place and should not be removed. This equipment is benefiting marine natural resources and serving as a modest artificial reef. Removal of the equipment would result in adverse impacts.

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EXECUTIVE SUMMARY

The Office of Naval Research has been conducting tests of wave energy conversion buoys offshore Marine Corps Base Hawaii since 2003. Currently, the Naval Facilities Engineering Command (NAVFAC) is interested in deploying new buoy designs in the same (approved) project area, but at greater depths and further offshore.

NAVFAC Engineering Service Center's (ESC) Scientific Diving Service group conducted marine ecological monitoring of the wave energy facility from October 2003 through October 2004. No adverse impacts to any marine natural resources were detected during the first year of monitoring. Nevertheless, periodic monitoring was continued between 2005 and 2007 and an updated survey was performed in May 2011. All the surveys were focused upon the resources over which the regulatory agencies had expressed concern. These resources were: threatened and endangered species, corals and coral reefs, fishery target species and Essential Fish Habitat (EFH) and alien species.

In addition to the Navy's marine ecological surveys, multi-agency marine ecological surveys were performed at or near the project site in 2002, and 2004. This current report analyzed data from the 2005 to 2007 time period and the May 2011 surveys and then compared those findings with the initial first year monitoring effort and with the multi-agency surveys.

The key conclusions are as follows:

- The findings of the Navy surveys are fully compatible with the findings of the multi-agency surveys.
- There have been no detectable adverse impacts to any threatened or endangered species.
- There have been no detectable adverse impacts to corals or coral reefs. In fact, the power cable supported greater densities of coral in May 2011 than the adjacent seafloor areas.
- There have been no detectable adverse impacts to fishery target species or to EFH. The anchor base and associated equipment have increased habitat complexity and vertical relief, resulting in an increase in fin fish diversity and biomass.
- No alien species have been detected on or adjacent to any of the equipment associated with the wave energy project. The equipment has not been an attractant to any alien species.
- The anchor base, power cable and associated equipment should be left in place and should not be removed. This equipment is benefiting marine natural resources and serving as a modest artificial reef. Removal of the equipment would result in adverse impacts.

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ACRONYMS AND ABBREVIATIONS

COE	Corps of Engineers
COTS	Crown-of-thorns starfish
DLNR	Department of Land and Natural Resources
EA	Environmental Assessment
ESC	Engineering Service Center
EFH	Essential Fish Habitat
HAPC	Habitat Areas of Particular concern
LPI	Line Point Intercept
MCBH	Marine Corps Base Hawaii
MDSU-1	Mobile Diving Salvage Unit 1
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NAVFAC	Naval Facilities Engineering Command
ROV	Remotely Operated Vehicle
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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1.0 INTRODUCTION

1.1 General

The Office of Naval Research has been conducting tests of wave energy conversion buoys offshore Marine Corps Base Hawaii since 2003. Figures 1 and 2 depict the general project area. The Navy worked closely with the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), Hawaii Department of Land and Natural Resources (DLNR) and the U.S. Army Corps of Engineers (COE) to select an appropriate project location. The site chosen was approximately 1,190 m (3,900 ft) offshore North Beach at Marine Corps Base Hawaii (MCBH) at a water depth of 33 m (100 ft). The wave energy buoy was installed in the fall of 2003.

A marine biological monitoring program of the wave energy buoy, mooring equipment and power cable was initiated in October 2003. During the October 2003 to October 2004 timeframe, the first year of monitoring, the biological data collection was performed by S.H. Smith (Navy marine ecologist) using open circuit compressed air scuba. He completed 25 dives at the site. The results of the first year's monitoring program were presented in the *Wave Energy Technology Project, Offshore Marine Corps Base Hawaii Year 1 Biological Monitoring Report October 2003 Through October 2004* (Smith 2004). This report is included as Appendix A.

Between October 2004 and June 2007 an additional 27 dives were completed by Smith. The most recent assessment was completed by Smith and Donald Marx (Navy marine ecologist) in May 2011; they made 28 dives. All diving activities were supported by Mobile Diving Salvage Unit 1 (MDSU 1); the total number of person dives completed (2003 – 2011) was 151 dives. There were no accidents, injuries or incidents. Figures 3 and 4 show the anchor base.

Currently, the Naval Facilities Engineering Command (NAVFAC) is interested in deploying new buoy designs in the same (approved) project area, but in deeper water further offshore. The tentative water depths at the proposed new buoy locations would range from 46 to 83 m (150 to 270 ft) and would be located approximately 2,523 m (8,200 ft) from shore. The power transmission cable corridor would run from these deeper buoys to the existing sea floor equipment complex at 33 m (100 ft) and then parallel the existing cable route to shore.

The methods for assessing marine natural resources within the 33 to 83 m (100 to 270 ft) depth portion of the proposed project area are currently being determined. It is expected that they will involve multi-beam bathymetry, side scan sonar and ROV photography. This report is restricted to marine natural resource data collected at depths of 33 m (100 ft) or less. Note, initial side scan sonar surveys conducted in May 2011 indicate that the deeper portions of the project area appear to be predominantly flat, to gently sloping limestone, with a thin veneer of sand.

1.2 Biological Background and Regulatory Concerns

In April 2002 Marine Research Consultants, with the assistance of personnel from Sea

Engineering, NMFS and USFWS, completed a Rapid Ecological Assessment of the project area. The results of this assessment are presented in *Wave Energy Technology (WET) Marine Corps Base Hawaii Kaneohe Bay Marine Environmental Assessment* (U.S. Department of Navy 2003). As a result of the 2002 assessment, the marine community within the project area was divided into six basic habitat types or zones. These six zones have remained basically unchanged and the descriptions from 2002 were still accurate in May 2011. The following description of the six zones was taken directly from the EA.

1.2.1 Sand-Boulder Zone

"The ocean bottom just seaward of the beach, from a depth of zero to approximately 12 to 15 feet…, consists of a bed of coarse-grained carbonate sand that is kept in a state of continual re-suspension by wave energy. Interspersed on the sand bed are boulders that are continually swept by re-suspended sand. Some of the boulder riprap that was used to construct the revetment securing the end of the runway has separated from the structure and is submerged in the near shore area….As a result of the continuous re-suspension of sand with passing waves, the substrate from the shoreline through the sand-boulder zone contains little marine vegetation or coral…No fish or other marine vertebrates were observed residing in the sand-boulder zone during the underwater site assessment…"

1.2.2 Sand Channel Zone

"Farther offshore from the sand-boulder zone, the ocean bottom consists of consolidated limestone bisected by small channels, which vary in width and eventually end in ridge formations. These spur and groove formations are generally oriented perpendicular to the bottom contours and the shoreline. Generally 3 to 4 ft…of relief is present between the bottom of the channels and the adjacent ridges. While the channel bottoms typically consist of flat and scoured limestone with a thin veneer of sand, some live coral is present on the ridges. The sand channel zone transitions from the sand-boulder zone at approximately 12 to 18 feet…and extends to a depth of 30 to 35 feet…""The constant state of re-suspension in the sand channel zone restricts settlement of bottom dwelling organisms on both the sand and limestone surfaces. Macrobiota in this zone were scattered heads of the branching coral *Pocillopora meandrina,* which grow along the vertical sides of the reef channels…."

1.2.3 Reef Flat Zone

"Offshore from the sand channel zone, the emergent reef platform becomes more solid as sand cover decreases. The spur and groove formations end around the 30 to 35 ft…water depth, and the bottom from that point to approximately 50 feet is a wide plateau of relatively solid, flat limestone. Some scattered areas of vertical relief exist, generally due to potholing, coral growth or the presence of small limestone ridges and ledges."

"The surface of the limestone reef flat consists of a short algal turf that binds a thin layer of carbonate sediment. Macrobiota in this zone includes sporadic heads of coral *P. meandrina* and flat encrustations of *Porites lobata, Montipora capitata, Montipora patula, Montipora*

flabellata...The dominant algae on the platform are clumps of the genera *Porolithon.* Coral growth is greater along the edge of the ledges than in the flat areas, and fish are more likely to frequent the areas of coral growth…"

1.2.4 Escarpment Zone

"The escarpment zone can be defined from… the 50 ft…contour to approximately the 90 to 95 ft…depth contour…The primary macrobiota on the escarpment is the flat encrusting coral *M. capitata.* In some localized areas, this species covers up to 50% of the substrate…"

1.2.5 Deep Reef Platform Zone

"From the bottom of the escarpment zone, the bottom gradually slopes to a depth of approximately 100 ft….where it becomes almost featureless. There is a thin veneer of sand 1 to 2 in…thick bound to the pitted, flat limestone surface by a thin veneer of algal turf in some areas. The bottom topography remains relatively constant and barren through the depth range of the zone."

"The predominant macrobiota are scattered heads of the coral *P. meandrina* and flat encrustations of the coral *M. capitata.* Macrobiotic composition varies from relatively high coral cover above the 95 ft…depth contour to relatively little cover below this boundary. Other species known to transit the area at this depth include humpback whales, green sea turtles, and Hawaiian monk seals. Fish and turtle species tend to aggregate in areas of higher relief than that found in the proposed project area."

1.2.6 Undercut Ledge Zone

"At several locations at the eastern end of the deep reef platform, a system of small undercut ledges run parallel to the depth contours…Increased populations of fish and coral occur around the ledges…Undercut ledges can be designated as HAPC [Habitat Areas of Particular Concern]; however, based on the relatively small size of these ledges, they would not fall under this classification…"

1.2.7 Regulatory Concerns

It is important to note that after the initial 2002 surveys, the NMFS, USFWS and DLNR concluded that the project was not likely to adversely impact any of the resources under their jurisdiction. Nevertheless, some individuals, within those agencies expressed concern regarding the following issues:

1. Sea turtles might be attracted to the structure and become entangled or trapped.
2. Monk seals might be attracted to the structure and become entangled or trapped.
3. The structure might promote the growth and/or spread of alien species.

It has been the author's understanding that these three issues have continued to be the primary concern of the stakeholder agencies. Therefore, the surveys performed since 2004 have focused on those three issues while simultaneously gathering information of corals/coral reefs and EFH.

1.3 Review of Findings of 2003 to 2004 Monitoring Effort

The report of the first year monitoring effort is included as Appendix A. Fifty person dives (25 by Smith) were completed during the first year of monitoring. The six habitats described above remained unchanged between 2002 and 2004. In fact, the descriptions of those habitats were still accurate at the time of the May 2011 survey.

During the first year of monitoring seven important observations were made. These observations were:

1) No endangered hawksbill sea turtles (*Eretmochelys imbricata*) were sighted underwater or from the boat.

2) No threatened green sea turtles (*Chelonia mydas*) were sighted underwater. No significant quantities of preferred green sea turtle forage were sighted on any of the dives. No surface sightings (from the dive boat) of green sea turtles were made within approximately 500 m (1,625 ft) of either the buoy or the transmission cable. Four green sea turtle sightings were made from the dive boat during transits between the dive sites and Waterfront Operations at MCBH. The green sea turtles sighted all had a carapace length of approximately two feet.

3) No endangered Hawaiian monk seals (*Monachus schauinslandi*) were sighted underwater, or from the dive boat.

4) No endangered humpback whales (*Megaptera novaeangliae*) were seen underwater, or from the dive boat. No marine mammals sounds of any kind were heard during any of the dives.

5) No alien invertebrates were sighted on any of the dives.

6) No alien algae were sighted on any of the dives.

7) No changes in the behavior, distribution or concentration of mollusks, echinoderms or arthropods was observed along the transmission cable.

2.0 OBJECTIVES

The objectives of the present effort were to: 1) review the *Wave Energy Technology Project, Offshore Marine Corps Base Hawaii Year 1 Biological Monitoring Report October 2003 Through October 2004*; 2) review and present the findings of monitoring efforts conducted

between October 2004 and June 2007; 3) complete an updated assessment (diving survey) of selected marine natural resources at the existing mooring location (33 m [100 ft]) and along the power transmission cable corridor and 4) qualitatively compare present conditions with those found during the 2003 to 2007 time period. The marine natural resources assessed were:

- Threatened and endangered species
- Essential Fish Habitat (EFH)
- Corals / coral reefs
- Alien and invasive species

3.0 METHODS (2005 – 2007 AND 2011)

As previously noted, open circuit compressed air scuba dives were made to facilitate direct observations and data collection. In addition, all sea turtle and marine mammal sightings made from the dive boat were recorded. The methods used during the 2005 – 2007 time period were comparable to those used during the 2003 – 2004 period. Some of the methods used during the May 2011 survey were slightly different; all methods are described below.

3.1 Replicate Quadrats

These were performed at four points on the anchor base between 2003 – 2004 and during the 2005 – 2007 monitoring period. Guide pins had been welded onto the anchor base frame. A 50 X 50 cm (19.5 X 19.5 in) quadrat was place over the guide pins and the area within the quadrat was examined and photographed to determine what, if any, flora or fauna had settled there. At the time of the 2011 surveys, only the placement pin for quadrat number 2 remained. Figures 5 – 7 show representative photos of that quadrat taken in October 2006, June 2007 and May 2011. The areas at which the other three quadrats had been located appeared to have comparable fouling to the one quadrat that was precisely relocated.

3.2 Coral Recruitment in Chain Lockers

Two rectangular boxes filled with anchor chain provided additional ballast for the anchor base. Scleractinian coral recruitment to the chain and to the sides of the boxes was monitored by counting the number of colonies and photographing them. Zip ties were placed adjacent to selected coral recruits to facilitate re-locating them. Figures 3 and 4 and 8 – 13 depict the chain, chain lockers and coral recruitment.

3.3 Replicate Belt Transects

These were performed between the Escarpment Zone and the Reef Flat Zone. Two transects, each 50 m (165 ft) in length, were placed over the transmission cable. Zip tie tags on the rock bolt anchors and stainless steel pins driven into the sea floor, were used as the base point for the replicate transects. Each transect included an assessment of the transmission cable itself and flora

and fauna within 1 m (3.25 ft) on each side of the cable. Still photographs were taken at 5 m (16 ft) intervals along the transect. Figures 14 – 19 show representative cable sections in March 2005 and May 2011. By 2011, all the replicate transect markers had been lost or moved. Therefore, it was not possible to accurately relocate the previous transects.

3.4 Line Point Intercept

The previously established transects along and adjacent to the power cable could not be precisely relocated. All the zip ties marking power cable anchor bolts and all the steel transect pins were gone, or had become dislodged and rolled down slope. Instead, the transmission cable from the anchor base to a depth of 4.6 m (15 ft) was visually assessed and 16 Line Point Intercept (LPI) transects were completed on the power transmission cable, and parallel to the cable (at a distance of 5 m (16 ft) away on the eastern side of the cable). Each LPI transect was 10 m (33 ft) long and data was collected at intervals of 50 cm (19.5 in). The LPI transects were performed at three different depth zones 33 – 27.7 m (100 – 90 ft), 24.6 – 21.5 m (80 – 70 ft), 12.3 – 10.8 m (40 – 35 ft).

The categories of organisms recorded were: 1) turf algae, 2) crustose coralline algae, 3) other algae, 4) sponge, 5) scleractinian corals (identified to lowest taxa) and 6) all other organisms. Algae are classified into four major phyla: Cyanophyta/Cyanobacteria (Blue-green algae), Chlorophyta (Green algae), Phaeophyta (Brown algae) and Rhodophyta (Red algae). Tropical algae are also often placed into one of three functional groups: turf algae (also known as algal turf), crustose coralline algae and macro algae. Turf algae, as used in this report, are defined as the multi-species assemblage of diminutive, generally filamentous algal species with heights of less than 10 cm. The crustose coralline group contains species which are heavily calcified and have encrusting and/or hard lumpy growth patterns. Macro-algae includes all remaining species, including heavily calcified upright branching genera, like the Green algae *Halimeda sp.*

3.5 Invertebrate Assessment

This activity was primarily intended to record the condition of scleractinian (stony) corals. The observations of corals included visually evaluating the colonies for:

1.) Physical damage (e.g., cracks and broken branches)
2.) Complete or partial mortality of individual colonies
3.) Mucus production
4.) Disease
5.) Predation
6.) Bleaching

The physical damage component was intended to determine if movement of the power cable had occurred and damaged any corals. Partial mortality as used in these studies refers to surface lesions/dead areas on stony corals. Hughes and Jackson (1980), Riegl (1995) and others have shown partial mortality on the surface of stony corals can be effective indicators of stress. Stony coral mucus production is another indicator of stress from pollutants, sedimentation, etc (Stafford-Smith and Ormond, 1992; Stafford-Smith, 1993 and Wild et al. 2005). Bruno et al.

(2003) and Sutherland et al. (2004) have shown that corals are more susceptible to disease when they are stressed by changes in the environment. All apparent visual evidence of disease was recorded. The author's assessment of predation included action by Crown-of-thorns-starfish also known as COTS (*Acanthaster planci*), parrotfishes and macro-bioeroders (e.g., boring sponges). Cooper et al. (2008) have correlated high densities of macro-bioeroders with diminished water quality. Bleaching refers to the loss or reduction of symbiotic zooxanthellae which reside within the coral.

A semi-quantitative record was kept of the numbers of octopus, lobsters, COTS, and sea urchins. The presence/absence and/or numbers of individuals sighted on, under or within 10 m (33 ft) of any project equipment was recorded.

3.6 Fish Assessment

This activity involved recording every species of finfish, which could be identified in the field, or by photographs taken in the field. Photographs were also taken of the anchor base and used to estimate the total numbers of the numerically dominant fish species which frequent the anchor base. An effort was made to determine if any of the fishes exhibited unusual behavior and/or showed any signs of abnormalities, such as lesions. The fish assessments also included conducting meandering swims around the anchor base and estimating the total number of selected species within five numeric categories. The numeric categories used were: <10, >10 < 25, >25 <50, >50 <100, >100 <200. For some species, which were not abundant, like the moray eel *Gymnothorax meleagris* an exact number was recorded. Fish further than 10 m (33 ft) from the anchor base or associated equipment were not counted. Figures 20-22 illustrate fishes commonly sighted.

3.7 Alien Assessment

During the Marine Aliens Workshop at the University of Hawaii (May 18, 2001) five invasive alien algae, and 21 alien invertebrates were listed as being present within Kaneohe Bay. The *Marine Corps Base Hawaii Coral Reef Ecosystem Management Study* (December 2002) lists 1 alga, 47 invertebrates and 8 fishes. Some of these alien organisms can be quite confidently identified in the field, e.g., the snowflake coral *Carijoa riisei* and the sea frost worm *Salmacina dysteri.* Most, however, must be collected and identified in a laboratory. No sampling was conducted, but all field identifiable alien species were recorded.

3.8 Threatened and Endangered Species Assessment

The threatened green sea turtle *Chelonia mydas,* and the endangered hawksbill sea turtle (*Eretmochelys imbricata*), the endangered Hawaiian monk seal (*Monachus schauinslandi*) and the endangered humpback whale (*Megaptera novaeanglia*) have all been reported within the project area. Field identification of each of these animals is relatively easy. The MDSU 1 divers were instructed in how to identify each of these species and, in the case of the turtles, to also

estimate the size and sex. Whales can often be heard, but not seen. Care was taken during the dives to listen for whales and dolphins. All members of the team kept a lookout for these species during the dives and on the surface from the dive boat.

4.0 RESULTS

There were no detectable adverse changes to marine natural resources in any of the six habitat zones that could be reasonably attributed to the presence of the wave energy buoy or to the associated equipment. No threatened or endangered species or marine mammals were seen (or heard) within 500 m (1,625 ft) of the anchor base or power cable. There was no evidence that any sea turtles or monk seals had ever become entangled or entrapped in any of the equipment. Only one surface sighting of a green sea turtle was made within 500 m (1,625 ft) of the project sight. Sightings of green sea turtles and spinner dolphins (*Stenella longirostris*) were made during transits through Kaneohe Bay and the Main Channel to and from the project location. In fact at least one green sea turtle was sighted within Kaneohe Bay during every transit to the project site. The largest number of green sea turtles sighted on a single day, within Kaneohe Bay was six. Pods of Spinner dolphins were seen on five separate occasions during the transit, but none were ever seen or heard at the project site. Pod size was estimated to range from 10 to 15 individuals and included juveniles and adults. No alien or invasive species were observed.

Additional results and discussion are presented below. It is recommended that the reader review all the Figures included in this report

4.1 Replicate Quadrats

Prior to installation, the steel frame of the anchor base had been coated with an anti-fouling compound, at the direction of the stakeholder agencies. This coating proved to be very effective. At the end of 2004 only a thin film of bacteria was detectable within each quadrat. That condition did not change between 2004 and 2007. However, by 2011 the substrate under/adjacent to the four quadrats supported a mix of turf algae, crustose calcareous algae and some small encrusting sponges. No samples were taken, but the species observed appeared to be organisms commonly observed in the Main Hawaiian Islands. No scleractinian corals were observed in any of the quadrats.

4.2 Coral Recruitment in Chain Lockers and Adjacent Equipment

The first coral detected on the chains was (*Pocillopora meandrina*) sighted in February 2005 (see Table 1 for representative data). More coral recruitment has been observed on the anchor chains than on any other portion of the equipment complex. *Pocillopora meandrina* was the overwhelmingly dominant recruit (>90%) of all recruits observed. The other species which were observed recruiting to/growing on the anchor chains were *Pocillopora damicornis*, *Montipora capitata*, and *Porites lobata.* During the March 2005 survey, many of the corals were showing signs of predation by parrotfish. In spite of the parrotfish predation the number and size of the

colonies steadily increased through 2007. By 2011 the subjectively estimated biomass of corals growing on the anchor chains was greater than in 2007, but the total number of colonies was less. Note, that by May of 2011 several moderate sized colonies of *Pocillopora eydouxi* had successfully recruited to other portions of the anchor base complex and small (< 8 cm [3 inches]) specimens of *Leptastrea purpurea* were also sighted. Between 2003 and 2011 none of the corals observed on or immediately adjacent to the anchor base complex showed any signs of disease or stress (e.g., lesions, excessive mucus production, abnormal densities of macro-bioeroders or predation by COTS), with the exception of some moderate bleaching on *Pocillopora meandrina* and *Montipora capitata* (on the seafloor).

Table 1. Representative Coral Recruitment Data From Ballast Chains in Chain Lockers and Locker Walls*

Location & Date	*Pocillopora sp.* (sizes in cm)	*Porites lobata*(?)	*Montipora capitata***
W Locker Mar 05	0	0	0
W Locker June 05	1 @ 1.5 cm	0	0
W Locker Feb 06	3 w/largest spec 3.5 x 5.0 x 2.0 cm	0	0
W Chains Mar 05	2 both < 1 cm	0	3 ranging from 1 to 1.5 cm max dim.
W Chains June 05	4 ranging from 1.5- 3 cm max dim.	1@1cm	1 @ 1.5 cm
W Chains Feb 06	5 w/ largest spec 6.5 x 6.5 x 2.0 cm	0	0
E Locker Mar 05	1 @ 0.5	0	0
E Locker June 05	3 ranging from 1 to 2 cm max dim	0	0
E Locker Feb 06	1 @ 2 cm	0	0
E Chains Mar 05	0	0	0
E Chains June 05	7 ranging from 1 & 3 cm	0	0
E Chains Feb 06	7w/ largest spec 5.5 x 4.0 x 2.0	0	0

*In May 2011 no zip ties were detectable. Coral colony counts were not performed in the chain lockers or on the ballast chains due to time/weather constraints.
***Montipora capitata* colonies were only sighted during March 2005.

Coral bleaching is the phenomenon in which zooxanthellae (the symbiotic dinoflagellates which live within the coral tissue) either lose some of their pigments or when the zooxanthellae are actually expelled by the coral. The most common causes of bleaching are increased water temperatures and increased light levels. Between 2003 and 2011 mild bleaching has been present within various coral species around Oahu. No major bleaching events have occurred during that time period around Oahu. The bleaching observed on some of the corals within the study areas was not considered to be significant, based upon the low percentage of colonies exhibiting bleaching (< 10 percent) and the degree to which those colonies were bleached. Fewer than 10 colonies were observed to have been bleached to the point of complete colony mortality during the observation periods covered by this report.

There was no evidence that any portion of the power cable had moved since being installed in 2003. And, there was no evidence that any corals had been damaged due to movement of the power cable. None of the coral colonies sighted between 2003 and 2011 exhibited signs of increased mucus production, abnormal densities of macro-bioeroders, higher than normal degrees of algal overgrowth or predation by COTS.

4.3 Replicate Belt Transects and Line Point Intercept (LPI) Transects

Within less than 18 months of the cable's installation, the flora and fauna on the power transmission cable closely matched the flora and fauna adjacent to the cable and within 25 m (81 ft) of either side. At the time of the May 2011 survey, the cable supported a healthy cover of turf algae, crustose coralline algae, other algae, and scleractinian corals. Tables 2 and 3 summarize the LPI data.

Macroscopic biotic cover was greater on the power cable than on the seafloor at all depths. This was to be expected, because much of the seafloor is covered with unstable sand and rubble, while the power cable provides a stable, hard surface and one which is slightly elevated and thus less vulnerable to sand scour. While species such as the calcareous Green algae *Halimeda sp.* and the Brown algae *Padina sanctae-crucis* were well represented and abundant in some areas, the majority of the algal cover was contributed by turf algae. This was true of both the power cable and the seafloor.

It was not within the scope of this project to perform a rigorous statistical analysis of the data. However, the Chi-square test was used to evaluate what appeared (subjectively) to be significant differences in coral densities on and off the power cable. The null hypothesis was that the distribution of the two dominant species (*Pocillopora meandrina* and *Montipora capitata*) would be equal on and off the power cable after approximately eight years. Nine different comparisons were made with the following results:

- Pooling LPI points from all depth zones for all scleractinian coral species showed there was a significant difference (P = 0.0002) between coral on and off the power cable. That is, more coral was present on the cable vs. the seafloor than would be expected.
- Pooling LPI points from all depth zones for just *Pocillopora meandrina* also showed a significant difference (P=0.0001), with many more specimens on the power cable than on the seafloor.
- Pooling LPI points from all depth zones for *Montipora capitata* showed a significant difference (P=0.0046). However, in this case, the difference was opposite that for *Pocillopora meandrina;* significantly more *Montipora capitata* colonies were present on the seafloor than on the cable.
- Within the discrete LPI sampling depths, there were statistically significant differences for *Pocillopora meandrina* in the 24.6 – 21.5 m (80-70 ft) and 12.3 – 10.8 m (40-35ft) zones with P values of 0.0016 and 0.0001, respectively. In the 33 – 27.7 m (100 - 90 ft) zone the 'expected' value was only three; Chi-square calculations are only reliable when the expected values are five or higher. Therefore, the P value of 0.0143, which would normally be considered statistically significant, may not be a meaningful value due to the small expected value.
- The statistical significance was less dramatic for *Montipora capitata*; in the 33 – 27.7 m (100-90 ft) zone the P value was 0.0253. As in the preceding case the 'expected value' was less than five at this depth, so the previously described caveats also apply. In the 24.6 – 21.5 m (80-70 ft) and 12.3 – 10.8 m (40-30 ft) zones the differences in occurrence of *Montipora capitata* on and off the pipe were not statistically significant, with P values of 0.1655 and 0.0833, respectively.

It appears then, that *Pocillopora meandrina* either has a greater recruitment survival rate on the power cable versus the seafloor and/or the planula are preferentially attracted to the cable. In any case, the result is that the cable supports more *Pocillopora meandrina* than equivalent areas of adjacent seafloor. This coral species provides important micro habitat for many small invertebrate species and as well certain fin fish. Its presence, therefore, increased overall biomass and biodiversity.

Fenner (2005) notes that the taxonomy of *Pocillopora meandrina, Pocillopora verrucosa, Pocillopora elegans* and *Pocillopora ankeli* is unclear and that they may actually represent only a single species. *Pocillopora meandrina* is the most widely recognized. Based upon field level identifications only three Pocilloporid species were positively identified in the project area: *P. meandrina, P. eydouxi,* and *P. ligulata.* The Hawaiian members of this genus, particularly *Pocillopora meandrina* are regarded as pioneering species and would be expected to be among the first to colonize the cable as well as the mooring equipment. All the coral species observed on the cable were also observed on the seafloor adjacent to the cable.

Based upon the LPI surveys and upon our subjective evaluation, scleractinian coral cover was denser on the power cable, than on the adjacent sea floor and the greatest densities for both the power cable and the seafloor were between 13.8 – 26.1 m (45 - 85 ft) deep.

Table 2. Line Point Intercept Summary
(Points taken at 50 cm intervals on 10 m transects)

Species Category	Cable 100 to 90' Depth	Seafloor 100 to 90' Depth	Cable 80 to 70' Depth	Seafloor 80 to 70' Depth	Cable 40 to 35' Depth	Seafloor 40 to 35' Depth
	Total Points Taken-61	Total Points Taken-62	Total Points Taken-42	Total Points Taken-42	Total Points Taken-63	Total Points Taken-63
PM	6		10		18	
P sp.	3		1			
MC			4	16		3
M sp.	1	5	1			
PLO			6	1	5	4
Coral Other	8	1				
CCA		1	2		6	
A	43	29	18	19	34	50
SR		26		6		6
Other		1				
% Pts w/ coral	18/61 29.5%	6/62 9.7%	22/42 52.3%	17/42 40.5%	23/63 36.5%	7/63 11.1%
% Pts w/ CCA	0 0%	1/62 1.6%	2/42 4.8%	0 0%	6/63 9.5%	0 0%
% Pts w/ A	43/61 70.5%	29/62 46.8%	18/42 42.9%	19/42 45.2%	34/63 54.0%	50/63 79.4%
% Pts w/ SR	NA	26/62 41.9%	NA	6/42 14.3%	NA	6/63 9.5%

PM = Pocillopora meandrina
P sp. = other Pocillopora species
MC = Montipora capitata
M sp. = other Montipora species
PLO = Porites lobata
Coral Other = other species of scleractinian corals
CCA = crustose coralline algae
A = all other algal species
SR = sand and/or rubble

Table 3. Size Frequency Distribution of Selected Corals from Line Point Intercept Transects (Points taken at 50 cm intervals on 10 m transects)

Species Category	Cable 100 to 90' Depth	Seafloor 100 to 90' Depth	Cable 80 to 70' Depth	Seafloor 80 to 70' Depth	Cable 40 to 35' Depth	Seafloor 40 to 35' Depth
	Total Points Taken-61	Total Points Taken-62	Total Points Taken-42	Total Points Taken-42	Total Points Taken-63	Total Points Taken-63
PM < 5 cm	0	0	0	0	0	0
PM ≥5 cm < 10 cm	1	0	3	0	3	0
PM > 10 cm	5	0	7	0	15	0
P sp. < 5 cm	1	0	0	0	0	0
P sp. ≥5 < 10cm	1	0	0	0	0	0
P sp. >10 cm	1	0	1	0	0	0
MC < 5 cm	0	1	0	0	0	0
MC≥5 cm < 10 cm	0	1	1	0	0	1
MC > 10 cm	0	3	3	9	0	2
M sp. <5 cm	0	0	0	0	0	0
M sp. ≥5<10 cm	0	0	1	0	0	0
M sp. >10 cm	1	0	0	0	0	0
PLO<5 cm	0	0	3	0	0	2
PLO ≥5<10 cm	0	0	3	0	2	2
PLO >10 cm	0	0	0	1	3	0

PM = *Pocillopora meandrina*
MC = *Montipora capitata*
PLO = *Porites lobata*
P sp. = other Pocillopora species
M sp. = other Montipora species

4.4 Invertebrate Assessment

There were no subjectively detectable changes in the macro invertebrate population between 2003 and 2007. During the May 2011 survey there appeared to be substantial increase in the number of sea urchins (particularly *Echinothrix calamaris*). The increased number of urchins has also been observed by the author at other Oahu locations during 2011. No coral eating Crown-of-Thorns starfish have ever been sighted during the 2003 – 2011 surveys.

4.5 Fish Assessment

Table 4 summarizes selected fin fish sightings during the 2005 – 2007 and May 2011 surveys. No statistical comparisons were made. Between 2003 and 2007 the Bluestriped snapper – Ta'ape (*Lutjanus kasmira*), the Yellowfin goatfish – Weke a (*Mulloidichthys vanicolensis*) and the Threespot Chromis (*Chromis verater*) were the most abundant species during most survey periods; their numbers ranged from >50 < 500 and >50 <200 for the latter two species, respectively. During the May 2011 surveys the estimated number of individuals for first two species were the same and ranged from >25 < 50. The Threespot Chromis estimates ranged from >25 < 100. Estimates for schooling reef fish species vary dramatically both spatially and temporally. Changes in the number of fishes sighted are probably within the normal range of fluctuations that are typical of reef fishes, although they could also be related to fishing pressure from both spear and hook and line fishermen, both of which are known to utilize the site.

As noted in the first year monitoring report three species of intentionally introduced fish species (Peacock grouper – *Cephalopholis argus*, Blacktail snapper – *Lutjanus fulvus* and Bluestriped snapper - *Lutjanus kasmira*) were present. The later was the most numerically abundant species during the May 2011 surveys and ranked between first and third on all previous surveys.

Table 4. Summary of Fish Abundance Estimates for Selected Species and/or Groups

Species	Range 10/03- 9/04	Range 10/04-6/07	Range 5/11
Bigeyes-Priacanthidae *Priancanthus meeki*	<10<25	<10<50	<10
Butterflyfishes-Chaetodontidae All species	>25<50	>25<100	>25<50
Damselfishes-Pomacentridae *Chromis verater*	>25<200	>50<200	>25<100
Dameslfishes All other species	>25<100	>25<100	>25<50
Moray Eels-Muraenidae All species	0 - 1	0 - 4	1
Goatfishes-Mullidae *Mulloidichthys vanicolensis*	<25~100	>50<200	>25<50
Goatfishes All other species	<10<100	>25<200	>10<25
Groupers-Serranidae *Cephalopholis argus*	0 -3	0 - 6	0
Jacks, Trevallies, Mackerel Scad-Carangidae *Caranx melampygus*	0 - <10	0 - <25	<10
Jacks, Trevallies, Mackerel Scad *Decapterus macarellus &* *Selar crumenopthalmus*	0<100	0 - <200	<25
Jacks, Trevallies, Mackerel Scad All other Jacks & Trevallies	0-5	0-<25	0
Parrotfishes-Scaridae All species including juveniles	>25<50	>25<50	>25<50
Puffers & Porcupinefishes-Tetraodontidae & Diodontidae All Species	<10 to <10	<10	<10
Snappers-Lutjanidae *Lutjanus kasmira*	0~500	>50<500	>25<50
Snappers (Jobfish) Aprion virescens	0<10	0<10	0
Snapper All other species	<10<25	>10<100	>10<25
Emperors-Lethrinidae *Monotaxis grandoculis*	>10<25	>10<50	<10
Squirrelfishes-Holocentridae All species	>10<50	>10<50	>10<25
Soldierfishes-Holocentridae All species	>10<25	>10<25	>10<25
Surgeonfishes-Acanthuridae All Species	<10<25	>10<50	>10<25
Unicornfishes-Acanthuridae All Species	0<25	0<25	0
Triggerfishes-Balistidae All species	<10 to <10	<10 - <25	<10
Moorish Idol-Zanclidae *Zanclus cornutus*	>10<25	>10<25	>10<25

Notes: The signs > and < indicate that the number of fish present was estimated to be within that range. All counts represent fishes which were on, in, or within 30 feet of the anchor base or its associated equipment. In 2011 fish counts were made on two separate dives at the anchor base; however, "0s" indicate that no members of that group were seen on any of the May 2011 dives.

4.6 Alien Species

With the exception of the three fin fish species discussed above, no alien or invasive flora or fauna have been detected at the anchor base, on the power transmission cable or in any of the adjacent areas surveyed. During the multi-agency marine ecological assessment performed in 2004, no alien species were reported from their study sites closest to the project area. Concerns that the project equipment might attract alien or invasive species appear to be unwarranted.

4.7 Threatened and Endangered Species Assessment

No threatened or endangered species were observed directly on-site during this assessment. However, Green sea turtles (listed as threatened) were observed during transit to and from the survey site.

5.0 DISCUSSION

Between April and August 2004 a multi-agency effort headed by the USFWS and including personnel from the National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), Bishop Museum, University of Hawaii and Hawaii DLNR was completed. That survey team assessed marine natural resources at 11 Study Areas within the 461 m (500 yd) buffer zone around MCBH; that is, the surveys were conducted between the shoreline and the 461 m (500 yd) seaward boundary. Study Area 6 was located immediately to the west of the Wave Energy project location. Study Area 7 was located directly inshore from the project location. Note, one of the transects (7C) was located approximately 46 m (50 yd) seaward of the buffer line. Of course, the shoreward portion of the power transmission cable passes through Study Area 7.

USFWS et al. (2008) highlighted 16 survey findings and "…Related Conservation Recommendations." Four of those recommendations involved resources within Study Area 6 and 7. They are summarized below:

- Recommendation 8. This recommendation applied to Study Areas 1, 2, 5, 6 and 7. The marine algae *Dictyopteris australis*, also known as Limu Lipoa is an important cultural resource in native Hawaiian food gathering. The recommendation states: "Manage military and base activities in a manner that avoids degrading these algae beds."
- Recommendation 12. This recommendation applied to Study Areas 7, 9, 10 and 11. The recommendation is intended to help protect corals and macroinvertebrates from anchors and vessel groundings. It states: "Designate anchoring zones and/or moorings within the 500 yd security zone and in areas that would avoid impacts to coral reef resources."
- Recommendation 15. The recommendation was for Study Area 7, with an emphasis on Station 7C, and relates to coral disease. USFWS et al. (2008) suggest that a large number of bleached corals are present at MCBH. The recommendation states: "Monitor coral bleaching events and develop strategies for understanding bleaching-related impacts.

Cooperate with resource agencies to evaluate coral anomalies within the 500 yd security zone in a manner that is consistent with conservation plans."

- Recommendation 16. This general recommendation was applied to all 11 Study Areas and suggests additional future inventories; specifically "Continue to monitor coastal resources and coral health conditions in relation to base operations and continue to collect anecdotal observations of Hawaiian monk seal sightings." The specific recommendation states: "Repeat the inventory every 6 years to provide updated biological data and conservation recommendations. Also, evaluate shorelines at survey stations 2, 7 and 8 as potential haul-out sites for the Hawaiian monk seal."

As noted, the USFWS et al. (2008) Study Area 7 included the power transmission cable portion of the project area, and was inshore from the existing and proposed mooring sites and buoys. Three transects were completed by the USFWS team at depths of 7.7 m (25 ft) (7A), 10.8 m (35 ft) (7B) and 12.0 m (39 ft) (7C).

There were no discrepancies between the USFWS findings and those of the present study. Station 7C most closely matched the location of the Navy's mid-depth surveys. Notable similarities include, but are not limited to the following:

- Seafloor is a low relief carbonate pavement with occasional sand channels and overhangs and a thin veneer of sand and rubble.
- No invasive macroalgae were observed.
- No coral species rare to the Hawaiian Islands were sighted. The dominant coral (based upon percentage of the seafloor covered) was *Montipora capitata.* The USFWS team estimated coverage of this species was only 1percent (USFWS et al. 2008). The Navy team's subjective estimate of overall habitat cover by *Montipora capitata* in the 39 foot depth range was 2- 5 percent. For the LPI seafloor transects parallel to the cable at that depth range 11.1 percent of the points were coral of all species.
- Macroinvertebrates observed included many of the same species, such as octopus (*Octopus sp.*), cone shells (yellow cone - *Conus flavidus,* spiteful cone - *C. lividus,* marbled cone – *C.marmoreus*), and common sea urchins (banded sea urchin – *Echinothrix calamaris,* blue-black urchin – *E. diadema,* rock-boring urchin – *Echinometra mathaei*).

6.0 CONCLUSIONS

Algae, sessile and mobile invertebrates, fin fish, protected species and alien species have been evaluated by Navy marine ecologists as well as marine ecologists from NOAA, USFWS, Hawaii DLNR and the University of Hawaii over a period of nine years. The project location was originally chosen based upon the low probability that there would be any significant adverse impacts to marine natural resources. Based upon standard techniques and criteria there have been no significant changes to any of the marine natural resources assessed between 2002 and 2011.

The qualitative and quantitative data gathered by the Navy between 2003 and 2011 have shown no detectable adverse impacts to any marine natural resources, including any Threatened or Endangered species, Essential Fish Habitat or any fishery target species. Specifically, the survey data have shown the following:

- No endangered hawksbill sea turtles (*Eretmochelys imbricata*) have been sighted at or in the vicinity of the project site. This finding was expected.
- No threatened green sea turtles (*Chelonia mydas*) were sighted underwater and only one specimen was seen within 500 m (1,625 ft) of the project location.
- Installation of the wave energy equipment has not resulted in increased forage/food sources for hawksbill or green sea turtles. Therefore, the equipment has not served as an attractant for these protected species, based upon increased food sources.
- No endangered Hawaiian monk seals (*Monachus schauinslandia*) were sighted underwater or from the dive boat. This finding was expected.
- The wave energy equipment has not been an entanglement or entrapment hazard for any threatened or endangered species.
- The wave energy equipment has had a modest beneficial impact relative to Essential Fish Habitat and fishery target species. The equipment has provided stable hard substrate and increased habitat complexity and vertical relief. This has resulted in increased biomass and diversity of fin fish and invertebrates.
- No alien species have been attracted to or detected at the project site or on any of the project equipment.
- Scleractinian corals have successfully recruited to and grown on project equipment. The density of corals on the power cable is, in fact, greater than the density of corals on the adjacent seafloor areas. Those corals provide significant habitat for a variety of invertebrates and even some fin fish.
- There was no evidence that the project has resulted in increased disease, abnormalities or stress to any of the marine organisms present within the project area.
- The present wave energy conversion project and the proposed modifications to the project are compatible with all the recommendations made by the multi-agency survey team (USFWS, NOAA, USGS, Bishop Museum, University of Hawaii and Hawaii DLNR) for the marine natural resources offshore MCBH (USFWS et al. 2008).

7.0 RECOMMENDATIONS

The mooring base, power cable and associated equipment should be left in place and should not be removed. This equipment provides increased habitat complexity, vertical relief and stable hard substrate to which scleractinian corals have recruited and grown. The density of scleractinian corals on the power cable is greater than on the adjacent seafloor. Fin fish diversity and biomass were greater at the anchor base than in adjacent seafloor areas. The project components are, in fact, serving as a modest artificial reef which benefits a wide range of marine life. Removal of the equipment would not only eliminate those beneficial impacts, but would also introduce adverse impacts during the equipment recovery process.

Removal of the mooring equipment and power cable would require a lift barge and would necessitate the use of a multi-point mooring over the project site. Placement of the anchors and the re-positioning of the barge for multiple lifts would result in anchor/chain impacts to the seafloor. This equipment poses no risk to marine natural resources and its removal would have adverse impacts to the organisms associated with and growing on the equipment.

A post-construction survey should be completed after the new equipment is installed; to be followed by annual surveys for three years on the new and existing equipment.

Figure 1. Project location map

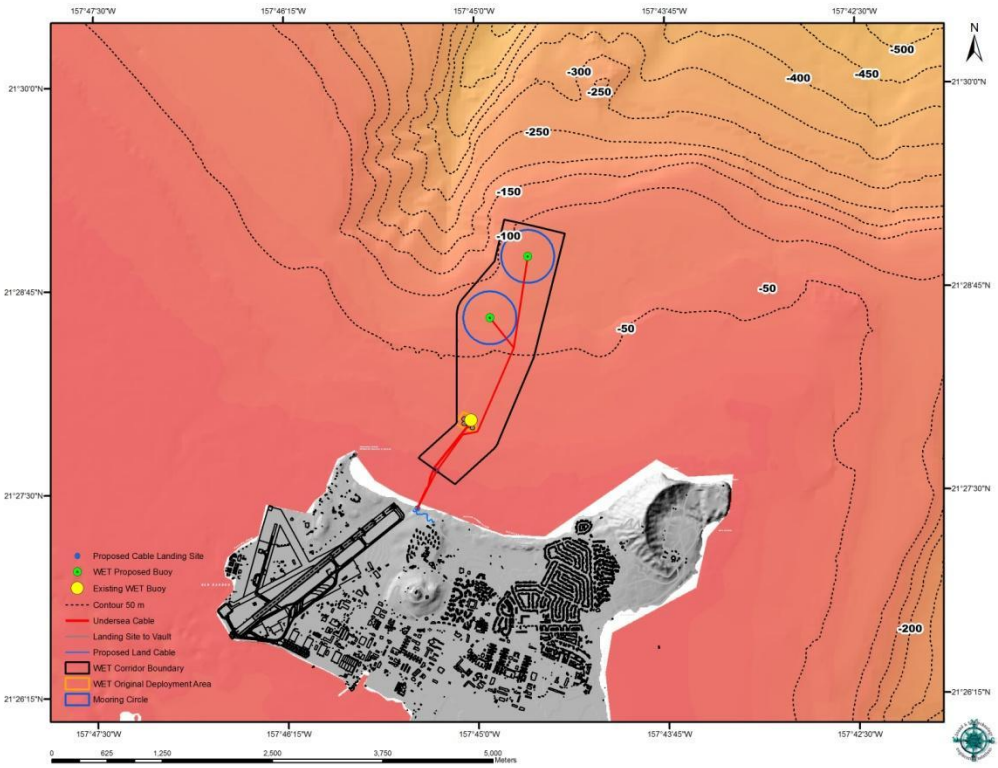

Figure 2. Existing and proposed buoy locations

Figure 3. Anchor/mooring base being installed (Fall 2003). Note ballast chain to the right

Figure 4. Anchoring/mooring base after installation (Winter 2004)

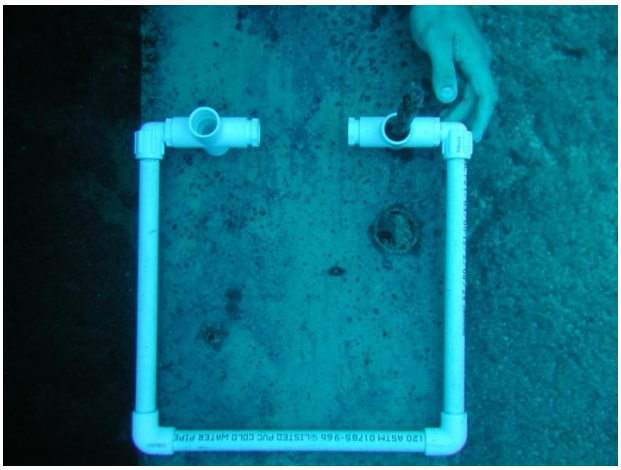

Figure 5. Quadrat No. 2 on anchor base Oct. 2006

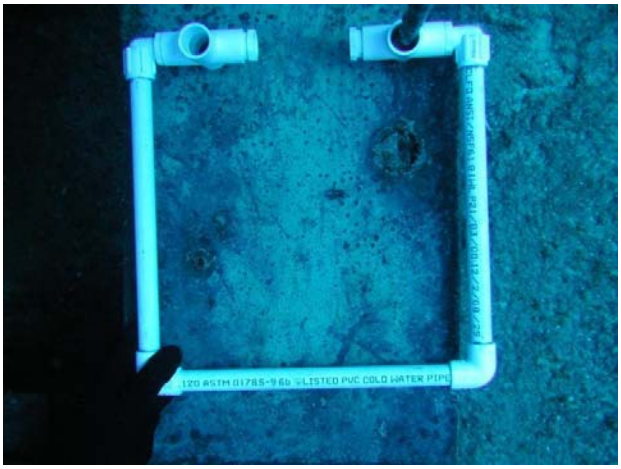

Figure 6. Quadrat No. 2 on anchor base June 2007. Note near complete absence of fouling organisms through June 2007

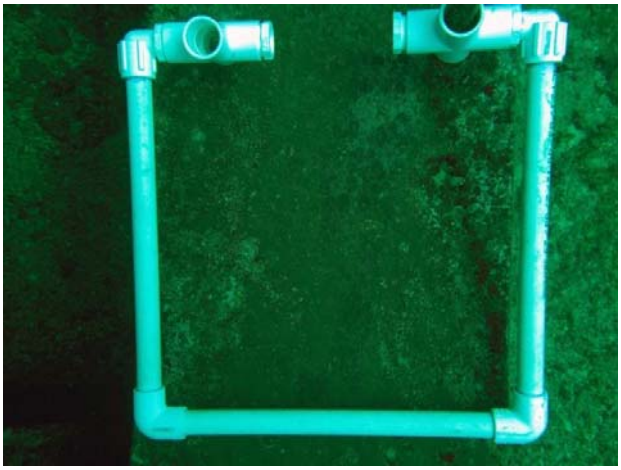

Figure 7. Quadrat No. 2 on anchor base May 2011. Fouling was still very limited

Figure 8. Ballast chain in chain locker in early 2004. Note the minimal fouling

Figure 9. Mooring base in early 2004. Note the minimal fouling

Figure 10. Coral recruitment (*Pocillopora sp.*) on ballast chain June 05. Note crustose calcareous algae and turf algae on chains

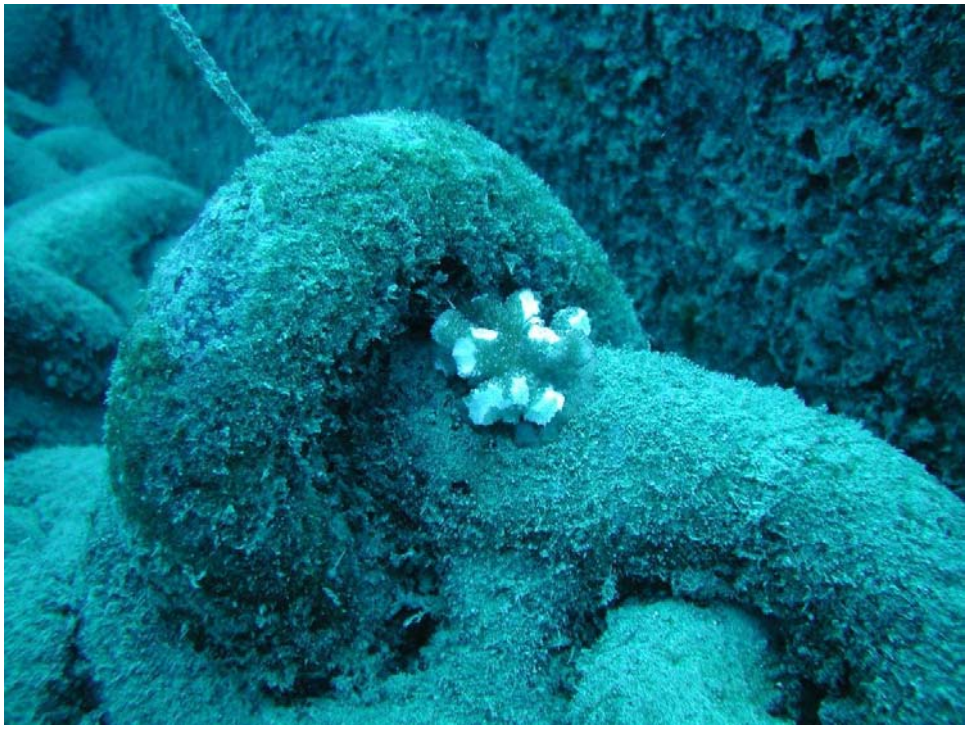

Figure 11. Same colony in Oct 06 showing considerable growth, but also predation by parrotfish (see bite scars)

Figure 12 May 2011 *Pocillopora meandrina* on ballast chain (knife = 32 cm). Note, dense cover of turf algae on chains vs. crustose calcareous algae in Figure 8

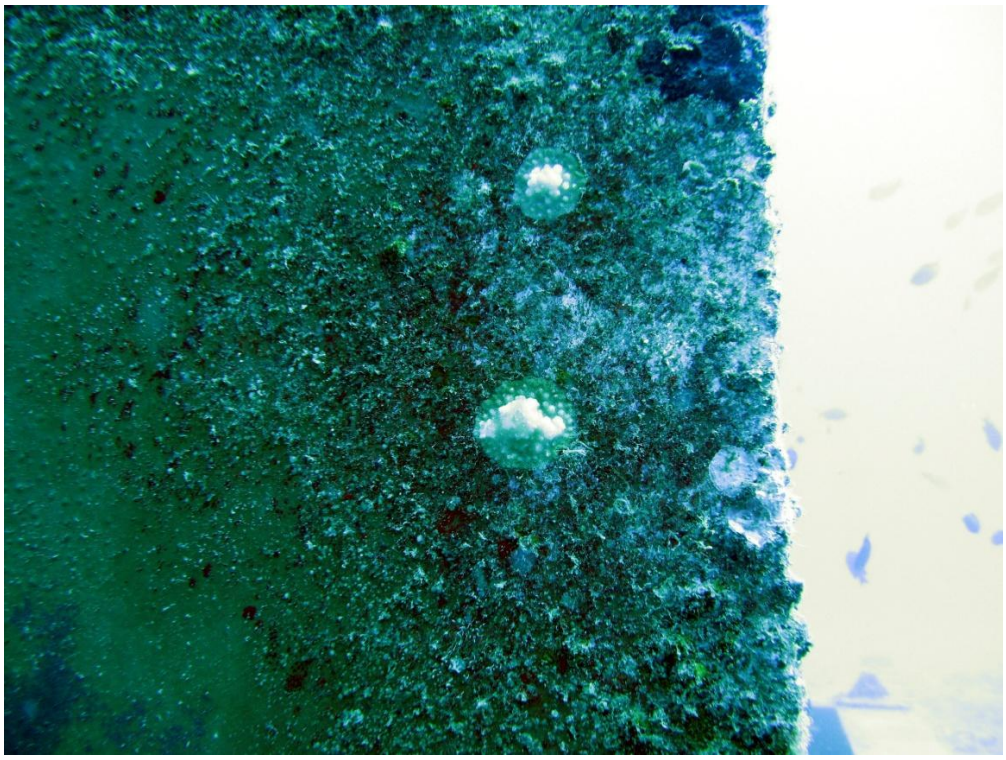

Figure 13. *Pocillopora sp.* recruit on side of chain locker

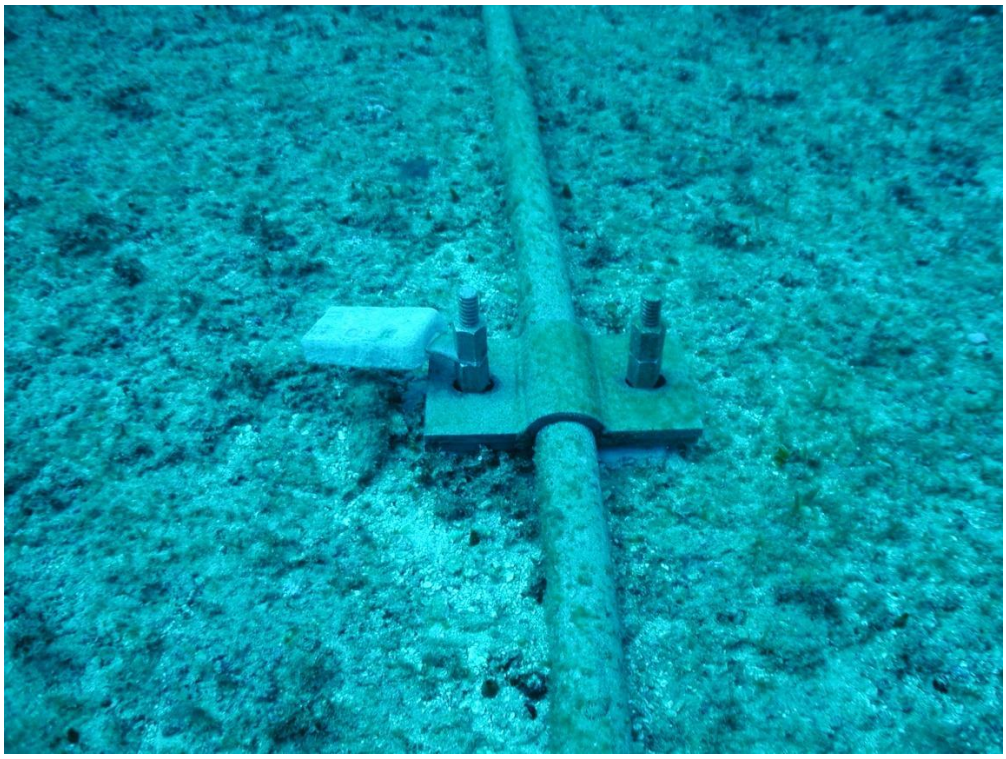

Figure 14. Power cable with anchor bolt at 50 ft in March 2005

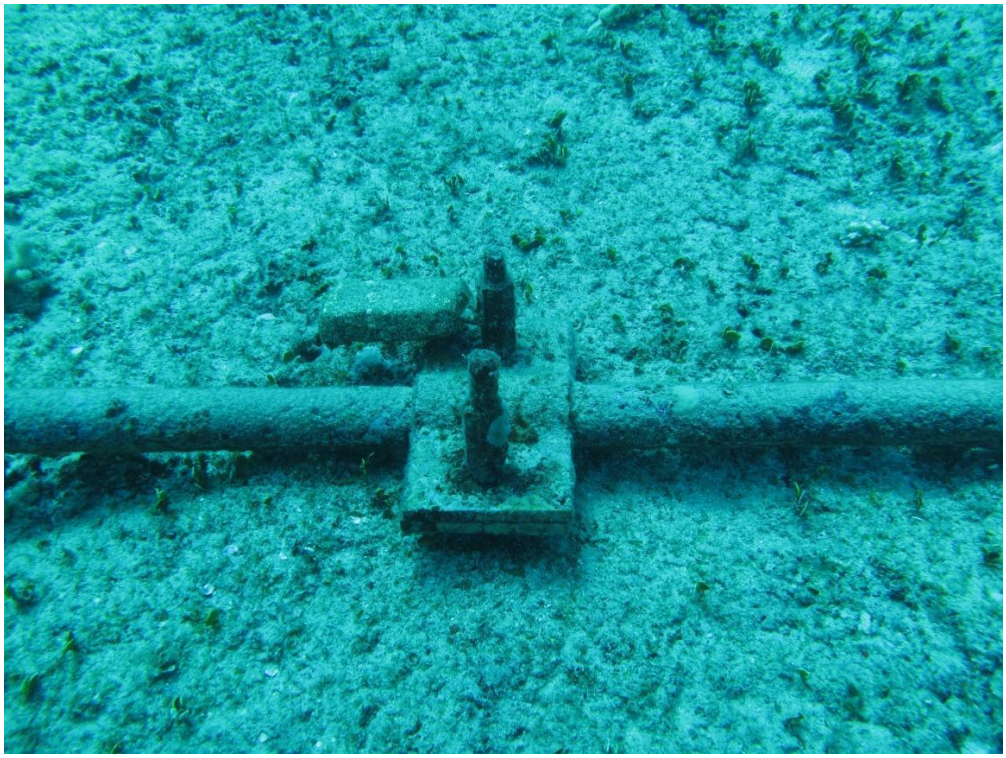

Figure 15. Power cable at approximately right angle in the same location in May 2011. Note, greater abundance of *Halimeda sp*. in 2011 and coral growing on anchor bolt

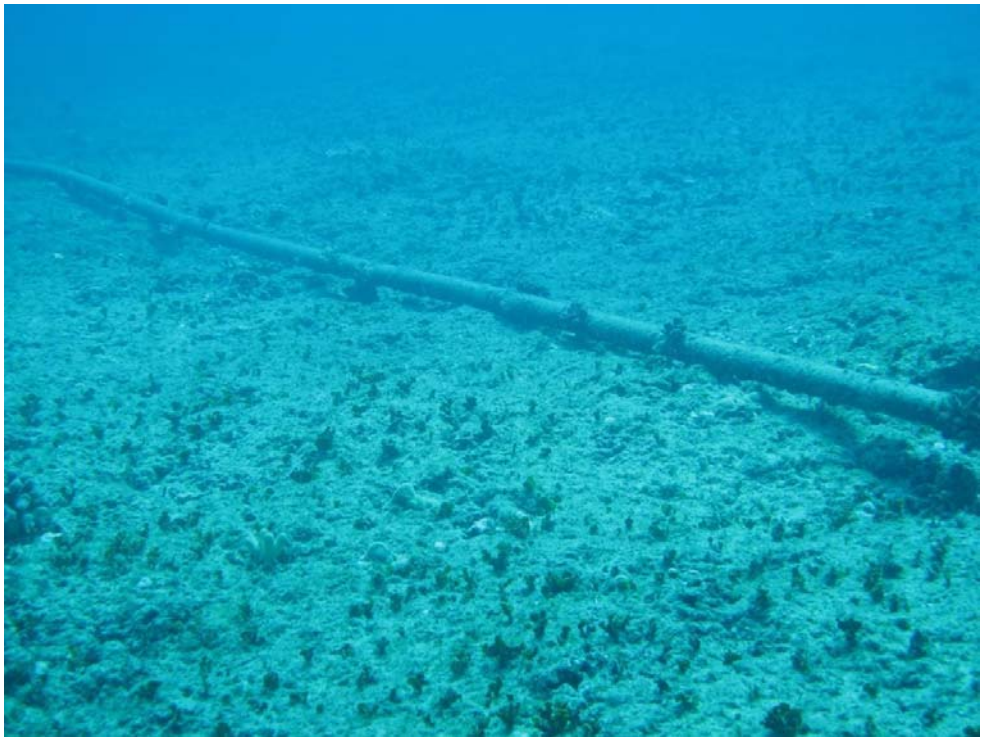

Figure 16. Power cable in 2011 at approximately 50 ft. Note, the large number of coral colonies on the cable

Figure 17. Power cable in 2011 at approximately 50 ft

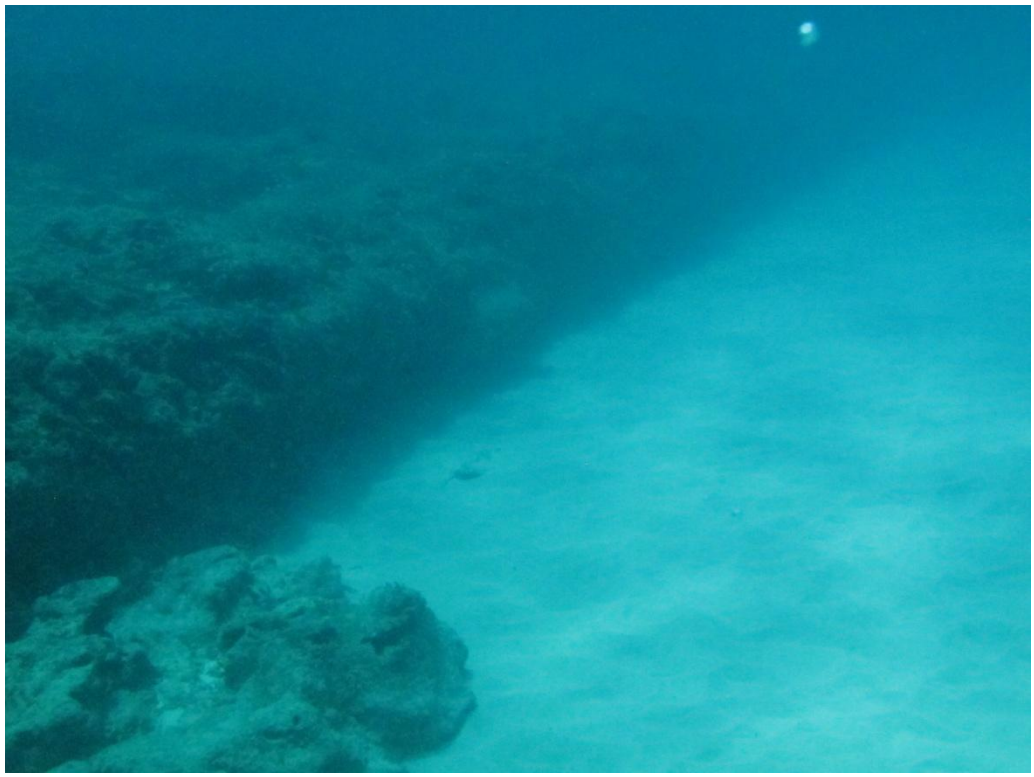

Figure 18. Sand-Channel Zone, note suspended sand in the water column due to surge and absence of coral on rock outcrops

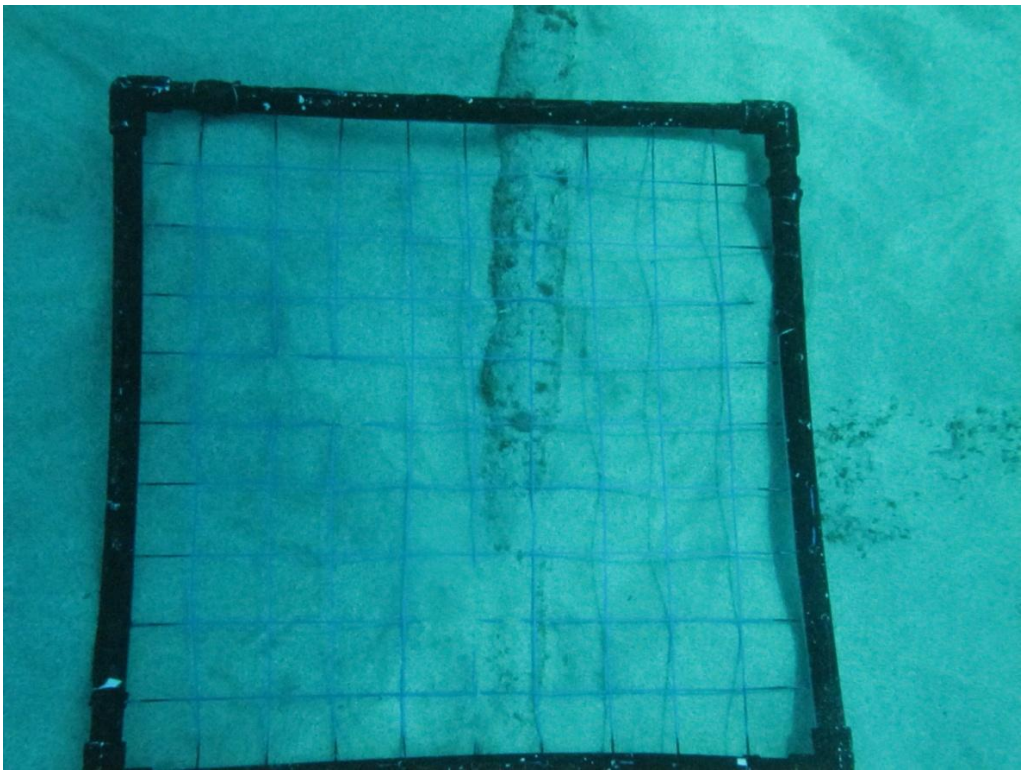

Figure 19. Power cable disappearing under the sand

Figure 20. Bluestriped snapper, one of the most common fishes from 2003 to 2011

Figure 21. Moorish Idols were common. Note 'barren' seafloor adjacent to anchor base.

Figure 22. Hawaiian Bigeye (Aweoweo) *Priacanthus meeki* with Bluestriped snapper (Ta'ape) *Lutjanus kasmira* in the background. Photo taken immediately adjacent to anchor base. Within project area, these species were closely associated with the anchor base

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SOURCES

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