

**Naval Information
Warfare Center**



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TECHNICAL REPORT 3561

October 2020

**Report for Dive Survey in Support of
Pearl Harbor Bulkhead 1461
Quay Wall Construction/Refurbishment Project**

Jessica E Carilli
Donald E. Marx Jr
Leslie Bolick
Stephen H. Smith

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ADMINISTRATIVE INFORMATION

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EXECUTIVE SUMMARY

Naval Information Warfare Center Pacific (NIWC Pacific), formerly Space and Naval Warfare Systems Center Pacific (SSC Pacific), Scientific Diving Services (SDS), conducted a marine resources survey of the Pearl Harbor Bulkhead 1461 Quay Wall in support of an upcoming construction/refurbishment project. Scientific dives were made to acquire quantitative and qualitative survey data to assess marine resources that may be adversely affected by the construction project.

THE DIVE SURVEY PRIMARY OBJECTIVE

The dive survey was conducted in March and April of 2018. The primary objective of the scientific dive survey was to provide a quantitative understanding of the marine resources located in and adjacent to the project area, and thus allow determination of whether construction plans will affect any of these resources. The authors also provide a current, site-specific, scientific basis for recommendations to minimize impacts to sensitive marine resources during in-water construction work to repair the quay wall.

The dive survey was comprised of three tasks:

(1) A roving survey aimed at reconnaissance of the site to acquire information on the general features and habitats, and to design the quantitative benthic habitat survey,

(2) Quantitative fish surveys, and

(3) A detailed benthic habitat survey aimed at collecting quantitative geospatial data.

SUPPORTING METRICS

Fine unconsolidated sediment was the dominant substrate and observed between 18 and 45 feet (5.5 and 13.7 meters). Other substrate types included rubble between 3 and 15 feet (0.9 and 4.6 meters) and natural limestone rock spurs creating walls and slopes at depths between 5 and 20 feet (1.5 and 6.1 meters) with the top of these spurs ranging from the surface to less than 5 feet (1.5 meters) to the surface. Anthropogenic material including portions of the quay wall, a cog rail vessel launching system, concrete blocks, pier pilings, and debris were also found throughout the site.

The unconsolidated sediment and rubble supported little to no habitat-building organisms. The rock wall substrate supported the most biological organisms of all the natural surfaces. The top of the rock spurs contained very little flora and fauna. The pier piles around the quay are heavily fouled with algal turf, sponges, bryozoans, tunicates, oysters, and barnacles. Only one coral colony was observed during the survey of the piles. There were a small number of widely scattered coral colonies on the quay wall; most were < 5 cm. Four coral species were observed at the site: *Leptastrea purpurea*, *Pocillopora damicornis*, *Montipora capitata* and *Porites compressa*. Compared to other areas around the project site, the cog rail supported relatively abundant corals.

Across the project site, live corals only covered an average of 2.8% of the surveyed substrate, with the highest concentration on the middle and shoreward sections of the cog rail. However, several large patches of coral were identified off of surveyed transects. At the seaward end of the eastern spur between 30 and 40 feet deep, a number of Rice Coral (*Montipora capitata*) colonies were grouped together. The four largest of these colonies each measured 30 cm in their maximum

dimension. The largest complex of *Montipora capitata* observed was located on a concrete block along the western edge of the western inlet and measured 2.5 m in its maximum dimension.

Additionally, one large *Porites compressa* patch with fused morphology was observed on the western spur, covering approximately 28.6 m². No macroalgae was present at the project site. Turf algae was recorded in low abundance on three transects (R1, T1, T7).

The habitat types observed were, as expected, comparable to those previously studied and documented throughout Pearl Harbor. This includes a small area in which mangrove roots from *Rhizophora mangle* overhung the western inlet. Like anthropogenic materials throughout the harbor, colonization was dominated by sponges and bivalves.

There were fewer species and a lower estimated biomass of fin fish compared to previous surveys in other areas of the Harbor. Acanthurids (surgeonfish and unicornfish) were the dominant fish at the site based upon number of species observed and estimated biomass. The fin fish population was estimated to be comparatively low, relative to fish surveys completed in other portions of Pearl Harbor. No portion of the proposed project area, nor of the immediately adjacent areas surveyed meet the criteria for designation as Habitat Area of Particular Concern. Strict adherence to standard Best Management Practices will reduce negative impacts to surrounding marine natural resources.

The proposed project area supports an array of sessile invertebrate species, including four species of scleractinian corals. All the species observed have been previously recorded throughout Pearl Harbor and the Main Hawaiian Islands, by numerous investigators. The only rare or unusual species sighted were three Pearl oysters. No sea grass was present, nor was any species of preferred green sea turtle forage.

In spite of routinely high levels of natural and anthropogenic turbidity, several species of coral and other organisms have been able to successfully recruit to and survive at the project site. The authors caution that placement of silt curtains, which requires the use of weighted chains to secure the lower edge, may inadvertently cause more damage to corals and other organisms that could be crushed or abraded by the equipment, compared with temporary turbidity increases associated with the required in-water work. If silt curtains are to be used, particular care should be taken to avoid the placement of any equipment at the three locations where moderate coral is present: the *Porites compressa* patch on the western spur, the *Montipora capitata* group at the tip of the eastern spur and the *Montipora capitata* complex along the western wall of the western inlet.

Real time turbidity monitoring could be conducted to monitor for turbidity curtain failure and/or to assess changes in turbidity from project activities. Concurrently, the health of corals at the site could be monitored, which may allow a better understanding of turbidity levels that corals in Pearl Harbor can withstand. This could be particularly useful for implementation of Best Management Practices in the harbor during future work.

ACRONYMS

AHRS	Attitude and Heading Reference System
BMP	Best Practices
cm	Centimeter
CNIC	Commander, Navy Installations Command
CSV	Comma Separated Values
EFH	Essential Fish Habitat
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
GPS	Global Positioning System
HAPC	Habitat Area of Particular Concern
IMF	Intermediate Maintenance Facility
JBPHH	Joint Base Pearl Harbor Hickam
KML	Keyhole Markup Language
ft	Feet
m	Meters
MMU	Minimum Mapping Unit
NAVFAC	Naval Facilities Engineering Command
NIWC	Naval Information Warfare Center
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
PAHs	Polycyclic Aromatic Hydrocarbons
PC	Personal Computer
PIFSC	Pacific Islands Fisheries Science Center
PHNSY & IMF	Pearl Harbor Naval Ship Yard and Intermediate Maintenance Facility
QIM	Quadrat Intercept Method
SDS	Scientific Diving Services
SSC Pacific	Space and Naval Warfare Systems Center Pacific
TL	Total Length
USBL	Ultra Short Baseline

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1. INTRODUCTION

The Pearl Harbor quay wall marine resources survey reported here was conducted by the Naval Information Warfare Center (NIWC) Pacific (formerly Space and Naval Warfare Systems Center Pacific (SSC Pacific)) Scientific Diving Services (SDS), and supported NAVFAC HI and the Pearl Harbor Bulkhead 1461 Quay Wall (hereafter referred to as the quay wall) Construction/Refurbishment Project. This project conducted scientific dives and collected quantitative and qualitative survey data to assess marine resources that may be adversely affected by the construction project. The primary objective of the scientific survey was to provide a quantitative understanding of the marine resources located in and adjacent to the project area, and thus allow determination of whether construction plans will affect any of these resources.

The authors also provided a current, site-specific, scientific basis for recommendations to minimize impacts to sensitive marine resources during in-water construction work to repair the quay wall.

This project consisted of three tasks, which are described in detail in the scope of work (SSCPAC, 2018) and summarized here:

Task 1. Dive survey of quay wall project site, consisting of four subtasks:

- Initial roving diver assessment to assess general conditions and refine full survey requirements based on presence of features of interest including essential fish habitat (EFH) that must be quantitatively assessed for regulatory approval.
- Quantitative mobile organism survey including dedicated fish data collection dives using methods adapted from NOAA's Rapid Ecological Assessment survey methodology, and qualitative observations of turtles, marine mammals and mobile invertebrates.
- Geospatial benthic habitat survey including: collection of quantitative benthic habitat cover estimates using transect and quadrat sampling, coral cover and size-frequency distribution assessment using belt transects and collection of scaled, georeferenced photographs of representative substrates, habitats, and features.
- Collection of geospatial (map) data including: survey locations, features of interest, approximate borders of substrate types and locations of quantitative benthic habitat cover estimates.

Task 2. Geospatial and photographic data processing and delivery

Task 3. Dive survey and assessment report

The report presented here completes Task 3 and includes the results from Tasks 1 and 2. Report sections include the site description and survey methods, detailed results of the survey and assessment, and a brief conclusion to support the biological consultation for the quay wall construction/refurbishment project.

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2. METHODS

2.1 SITE DESCRIPTION

2.1.1 Pearl Harbor estuary

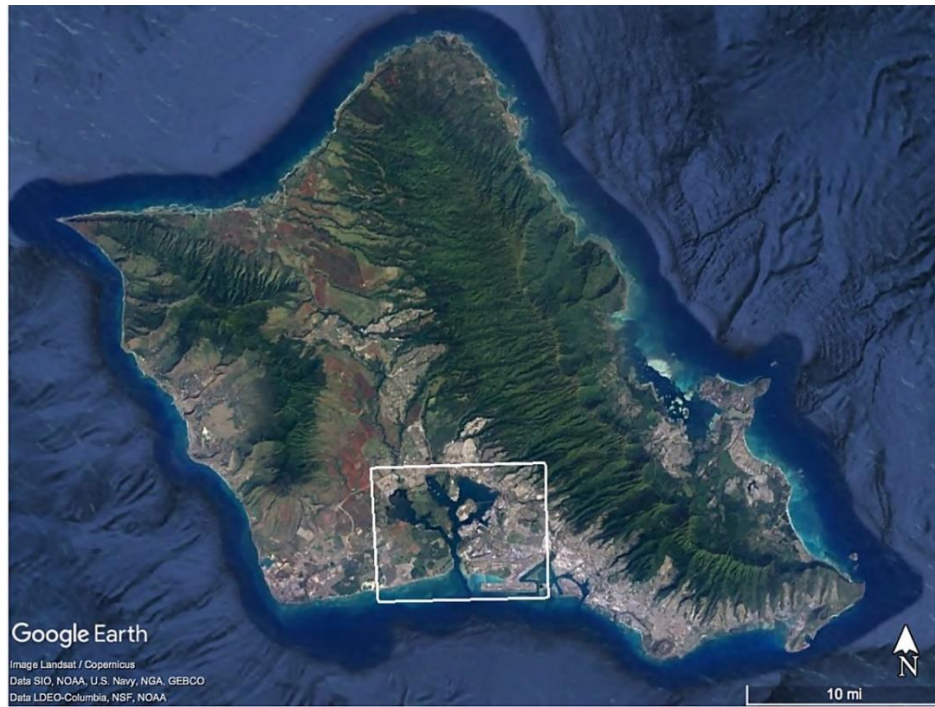
Pearl Harbor is a natural estuary covering approximately 5000 acres (8 square miles) on the south-central coast of Oahu, Hawaii (Figure 1). The Pearl Harbor basin is comprised of three main lochs (West, Middle, and East) formed when rising seas drowned former river valley systems (Wells et al., 2016). The harbor is relatively shallow, with an overall mean depth of 30 feet (ft; Grovhoug, 1992), though it is naturally deeper in some areas and is dredged to a maximum of 45ft in some areas. Tidal flow and circulation are weak and variable (Grovhoug, 1992). Mean tidal current velocity is 0.3 knots, with a narrow annual tidal range (mean 1.6 ft; U.S. Department of Commerce, 1989).

Much of the sea floor of Pearl Harbor is characterized by a thick layer of soft, unconsolidated sediment comprised of mud and silt from streams that drain into the harbor (Wells et al., 2016). Turbidity is persistent in the harbor as a result of ongoing siltation combined with nutrient loading, plankton abundance, and vertical mixing in the water column caused by northeasterly tradewind and vessel-driven sediment resuspension (Grovhoug, 1992; Wang et al., 2016). Although less common, rocks and hard substrates comprised primarily of limestone are also present (Wells et al., 2016).

Pearl Harbor estuary ecosystems are characterized by relatively high biological complexity and productivity (NAVFAC, 2016). Though they do not typically form true coral reefs in the harbor, coral colonies are beginning to recolonize patches of hard substrates inside the harbor following decades of decline (SSCPAC, 2016). The threatened green sea turtle is common in the outer portions of the Pearl Harbor entrance channel, and there are regular sightings within the inner reaches of Pearl Harbor (Smith et al., 2006; U.S. Department of the Navy, 2017).

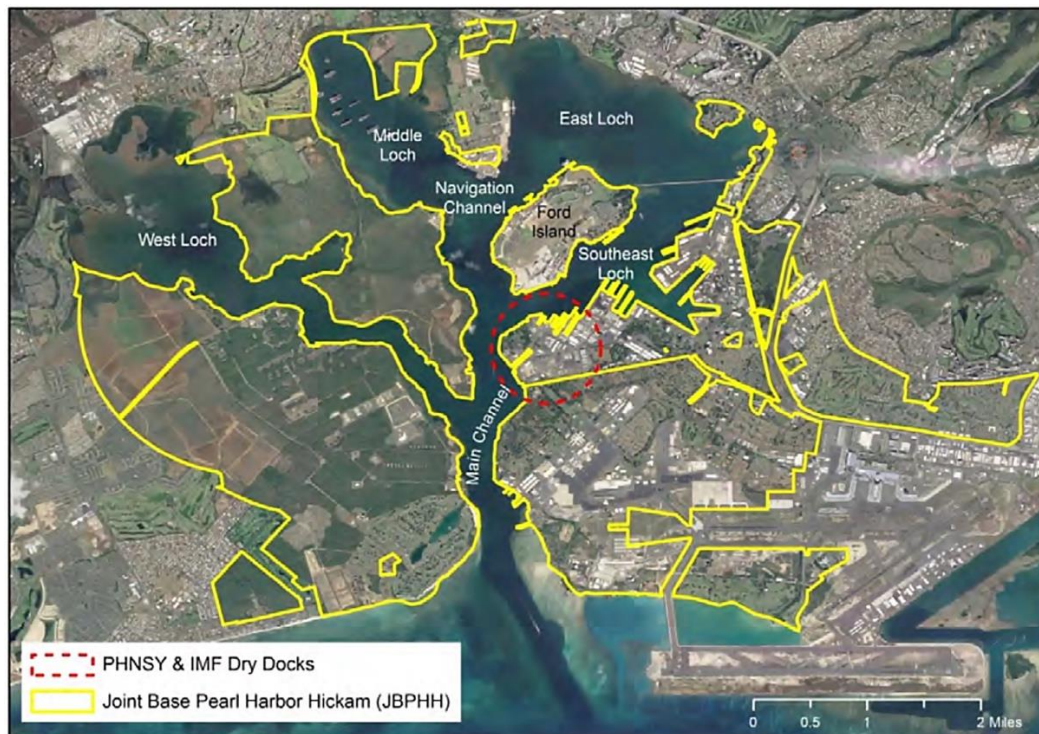
2.1.2 Pearl Harbor Naval Shipyard and project location

Pearl Harbor's submerged lands are under the jurisdiction of the U.S. Navy. Joint Base Pearl Harbor-Hickam (JBPHH), is comprised of the former Naval Station Pearl Harbor and Hickam Air Force Base, and supports both Air Force and Navy missions (CNIC, 2018). Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility (PHNSY & IMF) serves as the maintenance center for the Navy's surface ships and submarines in the central Pacific. The PHNSY & IMF dry docks serve a key role in this mission and are located between the Southeast Loch and the Main Channel of Pearl Harbor (Figure 2). The quay wall project site is located approximately 80 m west of dry dock #3 (Figure 2).



- Google Earth imagery date 12/15/2015.

Figure 1. Island of Oahu. Pearl Harbor region outlined in white.



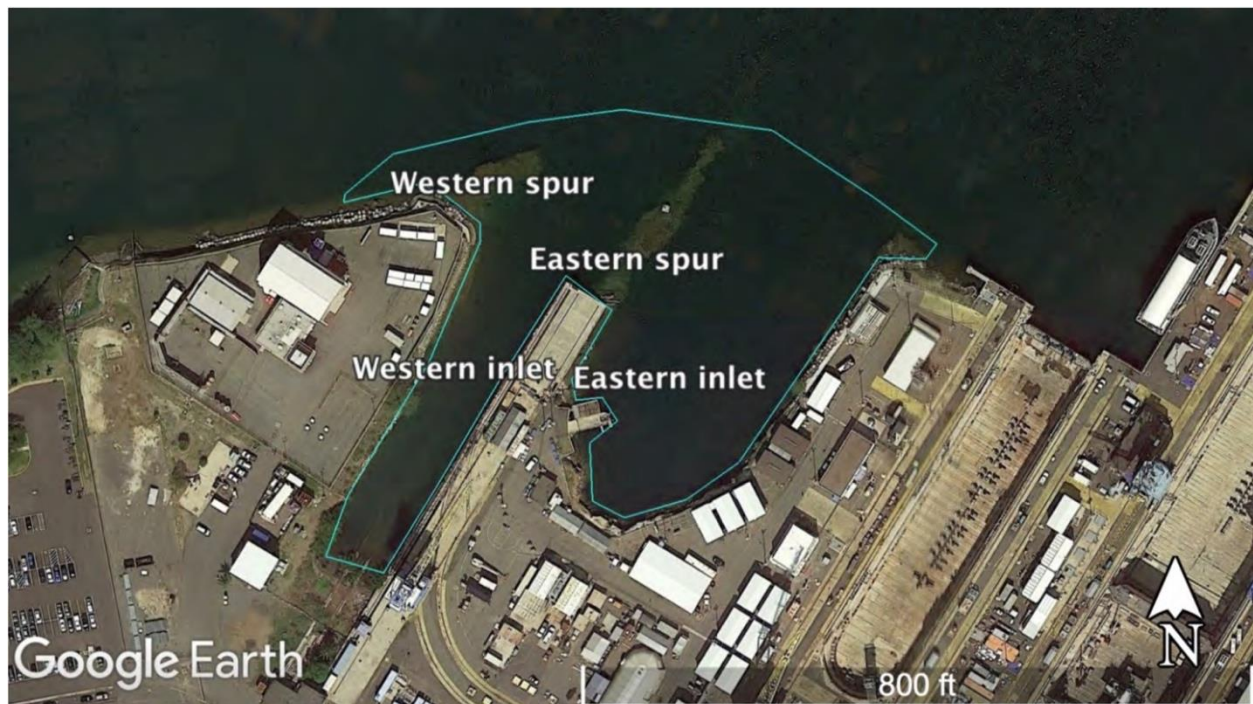
- Google Earth imagery date 12/15/2015.

Figure 2. Location of Joint Base Pearl Harbor Hickam (JBPHH) and Shipyard/Dry Docks.

2.1.3 Quay wall project site and survey areas

The Pearl Harbor Bulkhead 1461 Quay wall project area contains two natural limestone rock spurs and two inlets (hereafter referred to as the western and eastern spurs and inlets, respectively; Figure 3). Approximately in the middle of the western inlet is a submerged, narrow-gauge cog rail line originally used for launching and retrieving vessels, that is heavily fouled in some areas. This rail line surfaces and continues subaerially for approximately 50 meters (m) landward of the head of the inlet. The benthic habitat survey focused sampling on hard substrates including the areas around the rock spurs and the cog rail line. These areas were prioritized as they were expected to host a higher abundance and diversity of marine organisms, and this was confirmed during the initial reconnaissance surveys.

A concrete quay wall has been constructed over what is presumed to be the landward portion of the eastern spur. The west side of the quay wall contains wooden creosote pilings, most of which are dilapidated and broken. Many of the broken pilings are no longer securely attached to the quay. Observations on the west side of the quay wall were restricted to this outer row of wooden piles. Because the pier was classified as structurally compromised and unsafe, the Mobile Diving and Salvage Unit 1 Diving Supervisor would not allow NIWC Pacific marine ecologists to dive behind the piles and under the pier to assess that section of the project area. However, the area behind the piles had very low light levels, so it is unlikely that any macroalgae or coral was present, as both are photosynthetic.



- Google Earth imagery date 12/15/2015.
- Spurs and inlets are discussed in this report.

Figure 3. Pearl Harbor quay wall area with general project area (blue outline) and major features.

2.2 SURVEY OVERVIEW

The dive survey was comprised of three broad tasks: (1) a roving survey aimed at reconnaissance of the site to acquire information on the general features and habitats, and to design the quantitative benthic habitat survey, (2) quantitative fish surveys, and (3) a detailed benthic habitat survey aimed at collecting quantitative geospatial data. Some details of these survey efforts, including the numbers of photographs collected and provided to the study sponsor, are summarized in Table 1.

Table 1. Dive survey details.

Dive date	Dive tasks	Georeferenced photographs description	Photograph numbers collected	Transect numbers/ photograph focus
March 12, 2018	1. Reconnaissance survey	No, photos mostly from west spur/inlet	2364-2443	General features
March 13, 2018	1. Reconnaissance survey	No, photos mostly from east spur/inlet	2479-2527	General features
March 13, 2018	1. Reconnaissance survey	No, photos of western spur <i>Porites compressa</i> patch	2528-2540	General features, large coral patch
March 22, 2018	2. Fish surveys (4, 5, 6)	No	None	N/A
April 13, 2018	3. Benthic habitat survey (Cog rail transects, wooden pier piling assessment)	Yes, photos and in-situ sample data collection	4348-4411	R1, R2, R3
April 16, 2018	3. Benthic habitat survey Transects 4, 5, 6, boundary mapping	Yes, photos and in-situ sample data collection	3407-3416; 4418-4427; 3397-3398; 3399-3405; 3406-3419	T4, T5, T6, Boundary swim
April 17, 2018	3. Benthic habitat survey Transects 3, 9, 10, large <i>Montipora capitata</i> assessment	Yes, photos and in-situ sample data collection	4443-4457; 4462-4476; 4483-4501; 4433-4442	T3, T9, T10, Large coral photos

- Photographs provided separately to sponsor along with report.
- Note that photographs collected during the quantitative surveys were taken primarily to georeference in-situ data collection, and are often less clear than those taken during the reconnaissance survey.
- Additional photographs were collected to provide visual references for site features and conditions, but were not georeferenced.

2.3 GEOREFERENCING METHODS

2.3.1 Acoustic positioning system

Underwater locations of habitat survey locations, substrate boundaries and features of interest were georeferenced by time-stamp matching photographs and underwater notes to continuously recorded Global Positioning System (GPS) locations of each diver using a micro-ultra-short baseline (micro-USBL) acoustic positioning system. A SeaTrac micro-USBL system was used to simultaneously track diver positions using bi-directional data exchange. The system consists of one “local beacon” (X150 transponder beacon mounted to a rigid post on the dive support boat) and two “remote beacons” (X110 transponder beacons mounted on the tops of diver tanks). Each beacon is fitted with an onboard Attitude and Heading Reference System (AHRS), that collects pitch, roll and yaw information used to correct relative positions based on beacon range (distance between local and remote beacons). Positions are computed by the X150 beacon and transmitted to a rugged laptop Personal Computer (PC) running the SeaTrac PinPoint display and logging software. A GPS connected to the laptop provides georeferencing information, which is used in position computation. Before each dive, watches and cameras were synced with GPS clock time in order to match underwater data collected by the divers with positions recorded by the SeaTrac USBL system.

Diver positions were monitored on the laptop during recording to ensure the system was reporting positions. A line-and-buoy GPS backup system was on deck in stand by in case the SeaTrac system failed; however this required diver recall and survey restart so this backup was reserved for more serious system failures (e.g., problems with power or operating system that could not be corrected). Brief periods (several seconds) of position loss is not uncommon for this type of USBL system (e.g., due to acoustic interference, shadowing or beacon surfacing). Such periods were monitored to ensure there were no significant issues that could cause data gaps.

During the first dive on Day 3, beacon response became intermittent and then stopped reporting. In this case the dive was completed in order to preserve survey data already collected prior to returning to the dive locker and resetting the SeaTrac system. After reviewing dive notes and site conditions, it was determined that in this case, diver notes, substrate mapping, surface photographs and aerial imagery were sufficient for locating the 30 m transect and photoquadrats to an accuracy similar to the SeaTrac system. Following this dive, the SeaTrac system was reset, tested and performed normally.

2.3.2 Geospatial data processing

During the dive surveys, diver position log files were recorded on the topside laptop running PinPoint tracking software. At the end of daily surveys, Pinpoint log files were offloaded from the laptop and copied to the master field dataset. At the end of the survey, all field data was organized for processing, including the Pinpoint log files which were rendered (requiring playback in Pinpoint software) and exported to string files using the current National Marine Electronics Association (NMEA) standard. NMEA data was input to the software HoudahGeo together with dive photographs to conduct timestamp matching. This process produced georeferenced photographs, which were exported to Keyhole Markup Language (KML) files for display in Google Earth and for import into GIS (Geographic Information System) Environmental Systems Research Institute (ESRI) ArcGIS 10.3.1. These georeferenced photographs represented “markers” for the diver track lines as well as the real-world coordinates of survey features. NMEA strings representing diver track data were also imported into GIS via the software GPSTabel used to

convert NMEA strings to comma separated values (CSV) files. These track files, combined with photo “marker” files were used to identify boundaries and linear features “mapped” by the divers.

2.3.3 In-water positioning of lines and polygons

Position data used to geolocate lines and polygons delineating features such as substrate boundaries were captured by divers swimming along these features and recording (1) time at start and end of the swim, with notes and photographs, and (2) relevant feature information. For example, when collecting location data to map the transition between unconsolidated sediment and the rock spurs/rubble slope, the divers noted which side of their dive path contained which substrate.

2.3.4 In-water positioning of points

Position data used to geolocate point features (such as quadrat/transect locations or a feature of interest) were collected by taking a top-down, or close-in side-on photograph of the feature. The timestamp from each photograph was matched to the location of the diver at the time of photograph collection using the process described above.

2.3.5 GIS data and mapping

GIS data layers (i.e. collections of thematic features such as “transects” or “biological features of interest”) were created using ArcGIS (v10.3.1). Most features (e.g., transect and sample locations) were input to GIS from position data derived from the automated georeferencing techniques described above. Data layer features were then manually edited as needed using field notes, landmarks, and aerial imagery to compensate for location error in the automated methods from (a) GPS position error and (b) acoustic position error, mostly related to sound from the acoustic positioning system reflecting off structures. Note that the acoustic positioning system malfunctioned during the survey of Transect 3, so these transect positions were geolocated using landmarks only from diver and topside scientist field notes and photographs. For some features, data were collected using topside GPS (i.e., Garmin Montana) or features were interpreted from aerial imagery (i.e. Google Earth) and digitized in ArcGIS. Thematic maps featuring selected data layers were then produced using ArcGIS to represent survey methods and results in report figures. GIS data includes a field “loc_source” that contains the source of all location data.

2.4 SUBSTRATE CLASSIFICATION, MAPPING AND ASSESSMENT

In order to organize and provide context for the benthic habitat surveys, substrate types in the project area were first classified, mapped and assessed. These methods are described below.

A qualitative visual assessment of the entire project area was conducted to obtain an overview of the major substrate and benthic habitat types during the reconnaissance surveys. Based on these surveys and knowledge of the area, five general substrate types were defined at this site. These are listed below with notes on their associated benthic communities:

1. Very fine unconsolidated and uncolonized sediment
2. Unconsolidated rubble slope, typically supporting little biological growth
3. Natural rock wall (slope ranged from vertical to 45 degrees in most areas); these rock walls hosted some live coral and other organisms.

4. Tops of natural rock spurs. These areas are comprised of relatively biologically barren flat rock, mostly < 5 ft (1.7 m) deep, sloping to slightly greater depths into the harbor.
5. Anthropogenic substrate. This substrate included structures such as the metal cog rail line, concrete and wood pier pilings, and the concrete quay wall, and debris that ranged in size and material from square meters of concrete blocks and steel I-beams, to square feet of rubber tires and plastic and metal chairs, to square inches of glass bottles and ceramic mugs. Most of this substrate was colonized by fouling organisms.

Transitions between major substrate types were mapped as closely as possible using the georeferencing methods described above together with aerial photo interpretation using Google Earth imagery (2015). A minimum mapping unit (MMU) was not strictly defined for this effort, but can be estimated at 10 x 10 m (100 m² or 0.025 acres). This means that substrate features larger than 10 x 10 m were delineated, while smaller features were absorbed into the surrounding type.

Note that NOAA benthic types for Pearl Harbor were reviewed for potential adaptation to this study, but these classes were found to be a poor fit. NOAA types are not designed for enclosed basins such as Pearl Harbor and the map scale is too coarse (MMU = 1 acre) to be useful for small, focused studies such as the project reported here. For comparison, NOAA maps of the project area are presented in Appendix A. These show the entire project area as single types for each of the following: Biological Cover is “Uncolonized 90%–100%”, Geomorphological Structure is “Mud”, and Zone is “Dredged”.

Representative photographs and notes were collected during the initial reconnaissance survey for all substrate types in the project area and continued during the benthic habitat surveys. The qualitative assessment also included sketches and profile diagrams of the rock spur formations.

2.5 BENTHIC HABITAT ASSESSMENT

Qualitative assessments were conducted for all benthic habitats and then quantitative survey methods were used to target substrates with the greatest potential to host biological communities of interest. Survey methods for benthic habitat assessment were determined ahead of the field survey and are included in the scope of work. Priority substrates for quantitative assessment were identified following the reconnaissance surveys, and include the rock wall/rubble slope, cog rail and wooden pier pilings. Survey locations are shown in Figure 4. The flat tops of the rock spurs, the rubble slopes, and the unconsolidated sediment habitats did not support substantial biological growth, therefore the survey design did not include these substrates in the quantitative assessment. The methods used to assess benthic habitats were as follows:

1. Qualitative visual assessments were conducted for all benthic habitats during field reconnaissance and subsequent quantitative surveys.
2. Quantitative visual assessments of percent cover of sessile benthic habitats in the rock/rubble substrate and on the cog rail line were conducted using a combination of line intercept and quadrat methods (English, Wilkinson, and Baker, 1994; Conand, Chabanet, Quod, and Bigot, 1999; Hill & Wilkinson, 2004), hereafter referred to as the quadrat intercept method (QIM).

3. Belt transect sampling was used to record coral species, abundance counts and size class frequency data along the same transects as the QIM survey.
4. Pier piling fouling was visually estimated and extrapolated to piling dimensions to quantify the biomass of organisms on this anthropogenic substrate.

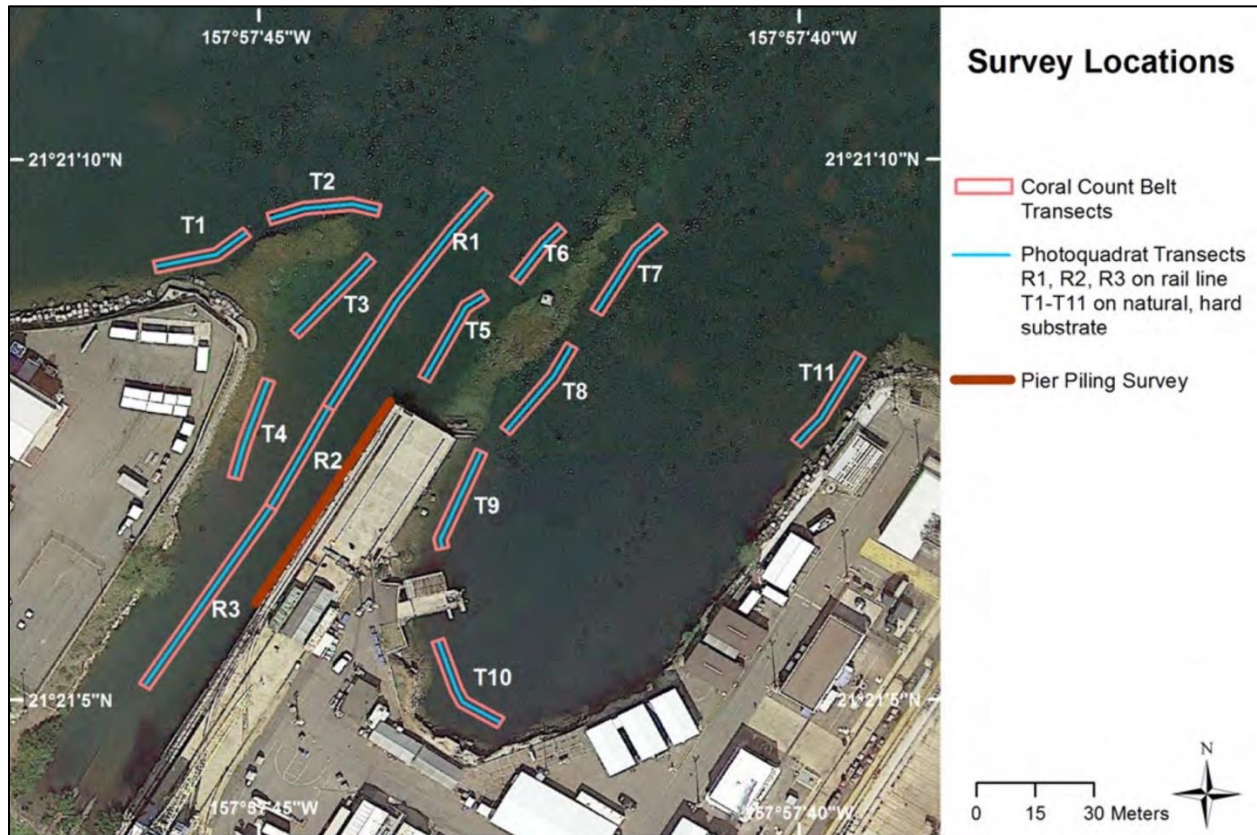


Figure 4. Survey locations of coral count belt transects, benthic cover assessment using transect/quadrat methods and pier piling survey.

2.5.1 Qualitative benthic habitat assessment

Qualitative visual assessments were conducted for all benthic habitats during field reconnaissance and subsequent quantitative surveys. These assessments included observation, field notes and photo collection for unconsolidated fine sediment, rubble, rock wall, top of rock spurs and anthropogenic substrates (quay wall, cog rail, pier piles and debris).

2.5.2 Quantitative benthic habitat cover assessment

Quadrat Intercept Methods (QIM) were conducted on the rock wall/rubble slope and cog rail substrates in the project area (Figure 4). In these areas, transect tapes were laid out and percent cover of benthic habitat classes was visually estimated inside of 1 m-square quadrats placed regularly along each transect. Transects were 30 m in length and included 10 quadrats each spaced 3 m apart in most cases (T1–T5, T7–T11 and R2). T6 included 7 quadrats along a 20 m transect. R1 and R3 were longer than 30 m and were assessed without a transect tape to maximize survey coverage over the majority of the cog rail structure. Quadrat surveys were completed approximately every 5m over these sections.

Benthic cover categories are listed in Table 2 and some examples are shown in Figure 5. Note that the benthic habitat categories “macroalgae” and “cyanobacteria” were also included in the survey plan, but no macroalgae was observed at the site. Some cyanobacteria was observed on portions of the unconsolidated sediments, but was not observed in the quadrats.

To increase the accuracy of the visual coverage estimates (actual percent cover within a quadrat), a meter stick with markings every 5 centimeters (cm) and/or the transect tape were used as guides. A photo was also taken of each quadrat to assist with mapping quadrat locations, and to serve as a permanent record, however low visibility conditions, made it impossible to obtain good quality photographs of every quadrat. Poor visibility did not affect visual estimation of benthic classes at close range, which underscores the importance of in-situ assessment, nor did it affect georeferencing, as photographs in this context were used only as time markers.

Table 2. Benthic cover categories assessed.

Category	
Living organisms	Non-living cover
Live coral	Dead coral (with little growth)
Turf algae (growing on rock or other non-living substrate)	Rock
Sponge	Scoured rock (freshly scoured, unknown source)
Barnacles	Unconsolidated sediment (with no growth)
Bivalves	Dead bivalve shells (attached in place)
Hydroid	Debris (manmade materials)
Polychaetes	Organic debris (leaves, sticks, etc.)
	Shell hash

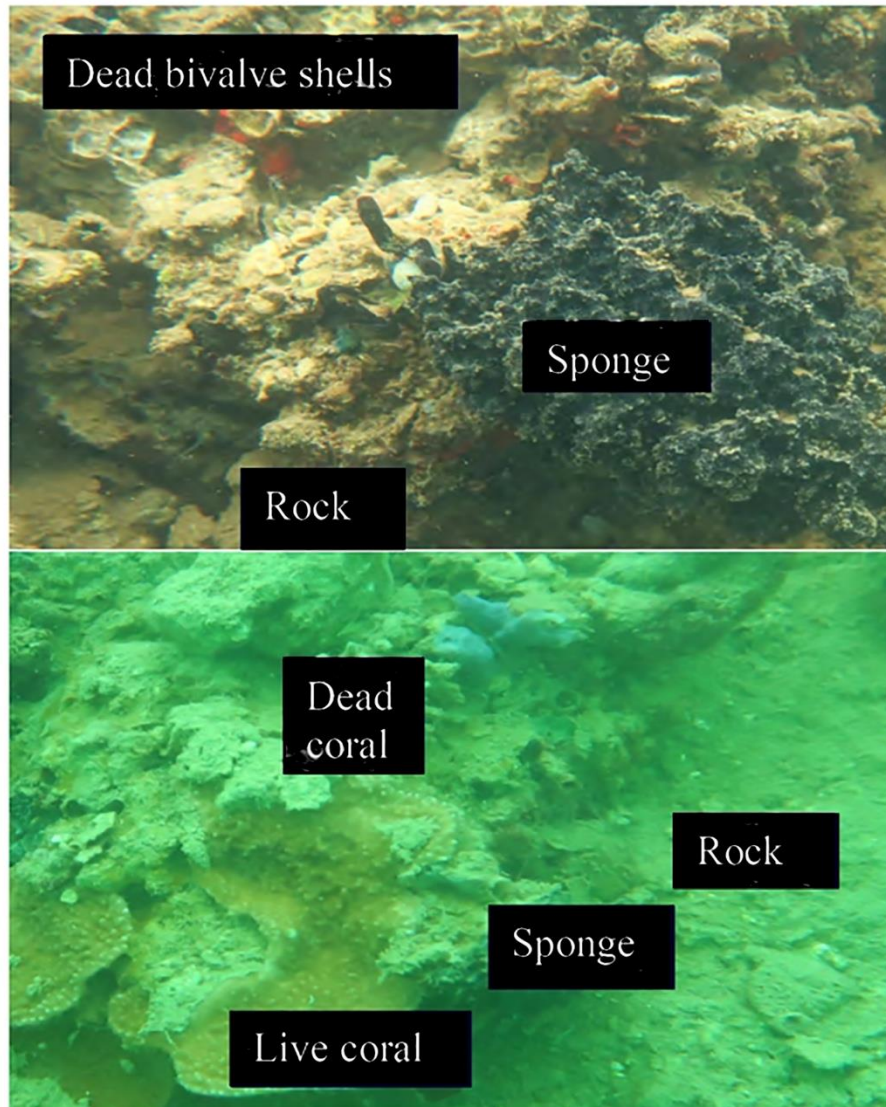


Figure 5. Examples of benthic cover categories assessed.

2.5.3 Coral size-frequency distribution survey

Along the same transects as the QIM surveys on rock substrate (T1-T5 and T7-T11), and the cog rail line where corals were most abundant (R2), coral counts by size class were conducted within a 1 x 30 m belt transect (Figure 4). On T6 coral counts were conducted within a 1x20m belt. Corals were also counted and sized within a 1m belt along R1 and R3, which were 67 m and 55 m in length, respectively. Corals were identified to species and their maximum dimension estimated to the nearest 5cm (using the meter stick marked in 5 cm increments as a guide). All coral species within the belt were counted and their frequency recorded by 5 cm size class (e.g., 0–5 cm, 5–10 cm, etc.) Actual measurements were recorded for corals larger than 50 cm.

2.5.4 Wooden pier piling semi-quantitative assessment

Wooden pier pilings and their associated fouling communities will be removed during planned construction. Therefore, these surface areas were assessed using semi-quantitative methods. The vertical height of fouling community on pilings was estimated using either the depth at the base of each piling (for intact pilings), or visual estimates of the length of pilings that were not intact. On the surface, the circumference of representative pilings were measured using a metric tape. Following fieldwork, the average circumference and height measurements were multiplied to provide a measure of the surface area of each piling covered by a fouling community, and the total fouling community area computed was summed across all pilings.

2.6 OBSERVATIONS OF SPECIES AND HABITATS OF CONCERN

During all surveys, particular attention was paid to observing and documenting the presence of species and habitats of concern including any of the following:

1. Coral colonies or habitats of unusual size, density, or composition for the area
2. Protected mobile species: turtles, monk seals, sounds or sightings of any other marine mammals
3. Preferred habitat for protected mobile species, including preferred turtle forage (certain macroalgae species and seagrass), and turtle grottos (nooks where turtles may rest and scrape clean their shells; recognized by fresh rock fragments on the floor of a recess)
4. Pearl oysters
5. Seagrass

The locations for any of these species or habitats that were encountered during surveys were recorded using field notes in reference to landmarks and/or were georeferenced using time-stamp matching between underwater photographs and diver tracking equipment, as described above.

2.7 MACROFAUNA ASSESSMENT

2.7.1 Turtles

Observations of turtles from the boat and underwater were noted and relevant features recorded to the maximum extent possible (turtle size [straight line carapace length as < 50 cm, $\geq 50 < 100$ cm, and > 100 cm], sex, species, activity during observation).

2.7.2 Fish

Two techniques were used to assess the fish fauna. First, a series of extended scuba swims were completed along the approximate paths shown in pink in Figure 6. The depth at which these swims were completed ranged from approximately 8 to 45 ft (2.8-15.7 m), to cover the range of depths that occur in the project site. All species observed were recorded. Underwater visibility in the study location was generally in the range of 3 m (8.6 ft), up to a maximum of 7m (20.1 ft) during these dives. The passage of vessels in the Main Channel reduced visibility to less than 3 m (8.6 ft) on many occasions. These levels of turbidity are normal for Pearl Harbor, based on decades of dive experience in the harbor (S. Smith, personal observations).

The second technique used to assess fish was a modified National Oceanic and Atmospheric Administration, Pacific Islands Fisheries Science Center (NOAA PIFSC) stationary point count survey method (PIFSC, 2016). This method is traditionally completed by two divers separated by a distance of 15m (43 ft), with each observing and recording fish within a 7.5 m (21.6 ft) diameter cylinder around each observer (a planar area of 176.7 m², or 1,466 ft²). For this effort, one diver completed two adjacent surveys at three locations, for a total of six stationary-diver fish quantitation surveys. One survey location was on the western spur and the other two were on either side of the eastern spur. The locations of these surveys, presented in Figure 6, were recorded using landmarks; no georeferencing data were collected, so these locations are approximate. In addition, because visibility in Pearl Harbor is lower than the coral reef sites for which the NOAA PIFSC methods were designed, the observation cylinder was smaller for this effort and differed between sites (Table 3).

Other aspects of the NOAA PIFSC stationary point count survey method were followed. Briefly, this survey methodology entails:

1. First 5 minutes: A list of fish species observed is created, with no counts or sizes recorded.
2. After 5 minutes:
 - a. The diver goes down the created species list, counting and sizing the fish currently in the cylinder and recording these data. If a species of fish is no longer in the cylinder, the diver recalls the number and size of the fish seen, and records this.
 - b. New species observed after 5 minutes are recorded separately, in a 5-10 minute section of the data sheet.
 - c. New species observed after 10 minutes are recorded separately, in a 10 minute-end of survey section of the data sheet.
 - d. Once a species is counted and recorded, it is not counted again during the remainder of the survey.

These methods are described in detail on the NOAA website (PIFSC 2018).

The NOAA PIFSC stationary point count survey method was not ideally suited for the physical conditions (turbidity and topography) within the project area; in many cases it was difficult to identify fish to species within the imagined cylinder because of low visibility conditions. In those cases, the next-lowest possible taxonomic identification was recorded (for example, “adult parrotfish”). The total length (TL) of each fish observed was visually estimated and recorded.

Despite not being ideally suited to the conditions, this method was useful in providing additional data on fish abundance and diversity in the project site, as well as an approximate assessment of fish biomass within each stationary survey cylinder.

Table 3. Observation cylinder sizes for stationary fish surveys, calculated using the mean visibility as the cylinder radius.

Fish survey	Visibility during survey (m)	Total approximate planar area of cylinder observed (m ²)
1	2–3	19.6
2	2.5–4	33.2
3	2–6	50.3
4	4–5	63.6
5	5.5–7.5	132.7
6	6	113.1

Fish biomass observed and recorded at each survey location was estimated by using Bayesian-estimated length-weight relationships (Froese, Thorson, and Reyes; 2013) compiled from published literature in the FishBase database (fishbase.org; Froese and Pauly, 2018 and references therein) to convert TL to weight (see Appendix C). The mass of all fish observed within each survey cylinder was then computed by summing all calculated weights. Finally, to compute mass/area to compare to other published data, the total estimated fish biomass for each survey was divided by the approximate planar area of each observation cylinder (Table 3).



- White circles indicate locations surveyed using NOAA PIFSC stationary diver methods.
- Pink line shows swim path for roving-diver surveys.
- Gray line shows location of cog rail.

Figure 6. Approximate locations of fish surveys.

Fish observed at this site during an earlier Harborwide survey (Smith et al., 2006) were also compiled and presented for comparison. In the 2006 fish survey, a visual fish census was undertaken first to estimate the abundance of fishes. This was conducted within a 25m by 4m corridor and all fishes within this area to the water's surface were counted. Data collected included species, numbers of individuals and an estimate of their length; the length data were later converted to standing crop estimates using linear regression techniques (Ricker, 1975). A single diver equipped with SCUBA, transect line, slate and pencil entered the water, counted and noted all fishes in the prescribed area (method modified from Brock, 1954). The 25 m transect line was laid out as the census progressed, thereby avoiding any previous underwater activity in the area which could frighten away fishes.

2.7.3 Other species

Other mobile macrofauna observed incidentally during the above surveys were recorded as present and identified to the lowest taxonomic level possible.

3. RESULTS

3.1 SUBSTRATE MAPPING AND ASSESSMENT

As described above, the project area includes two natural rock spurs, separated by inlets comprised of soft, uncolonized sediments. Generalized profiles of the spurs are shown in Figure 7. A map of major substrate types is shown in Figure 8. Descriptions and examples of each of the major substrate types follows.

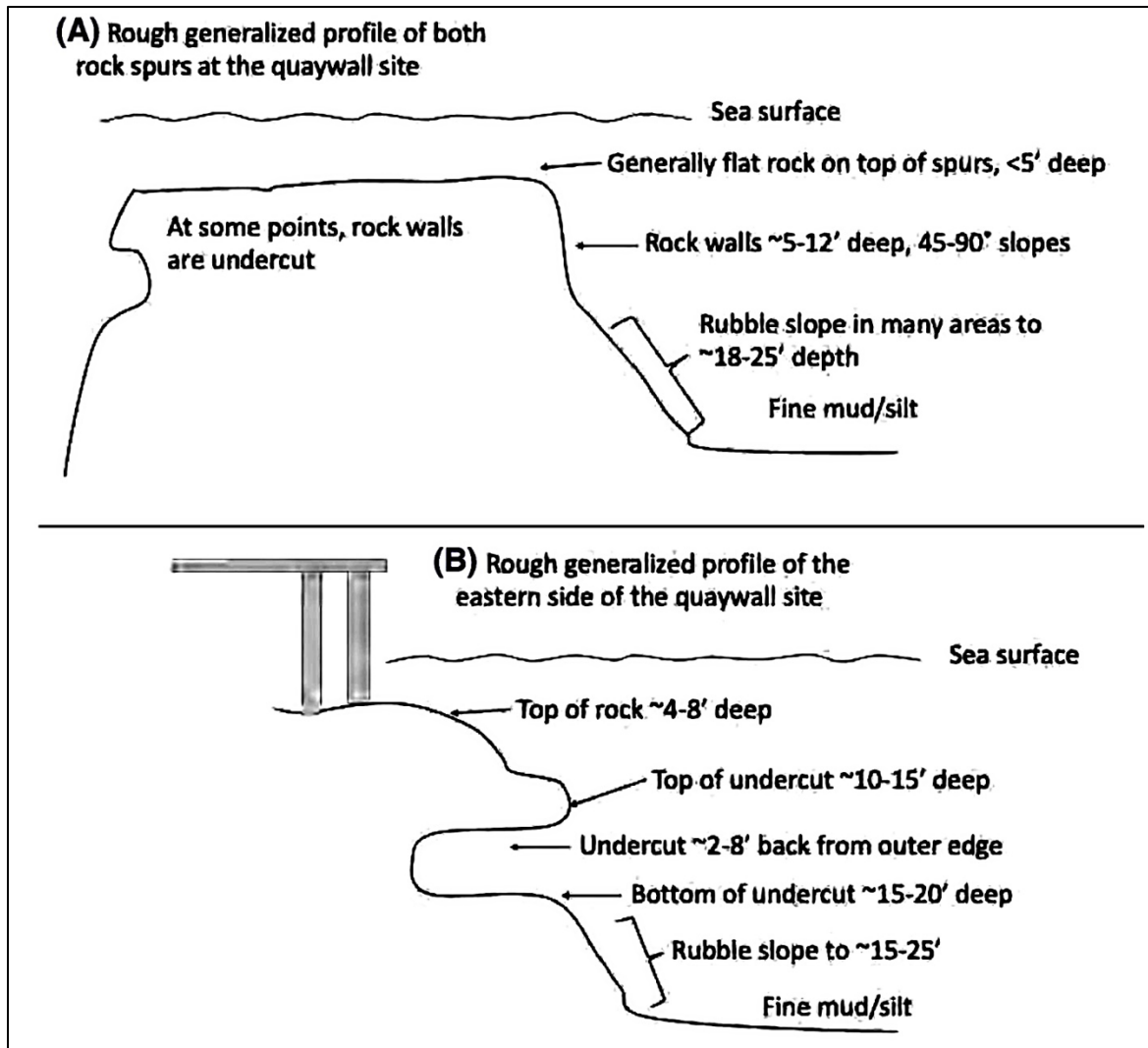


Figure 7. Generalized profile of both rock spurs at the project site (A) and profile of the substrate below the quay wall (B).

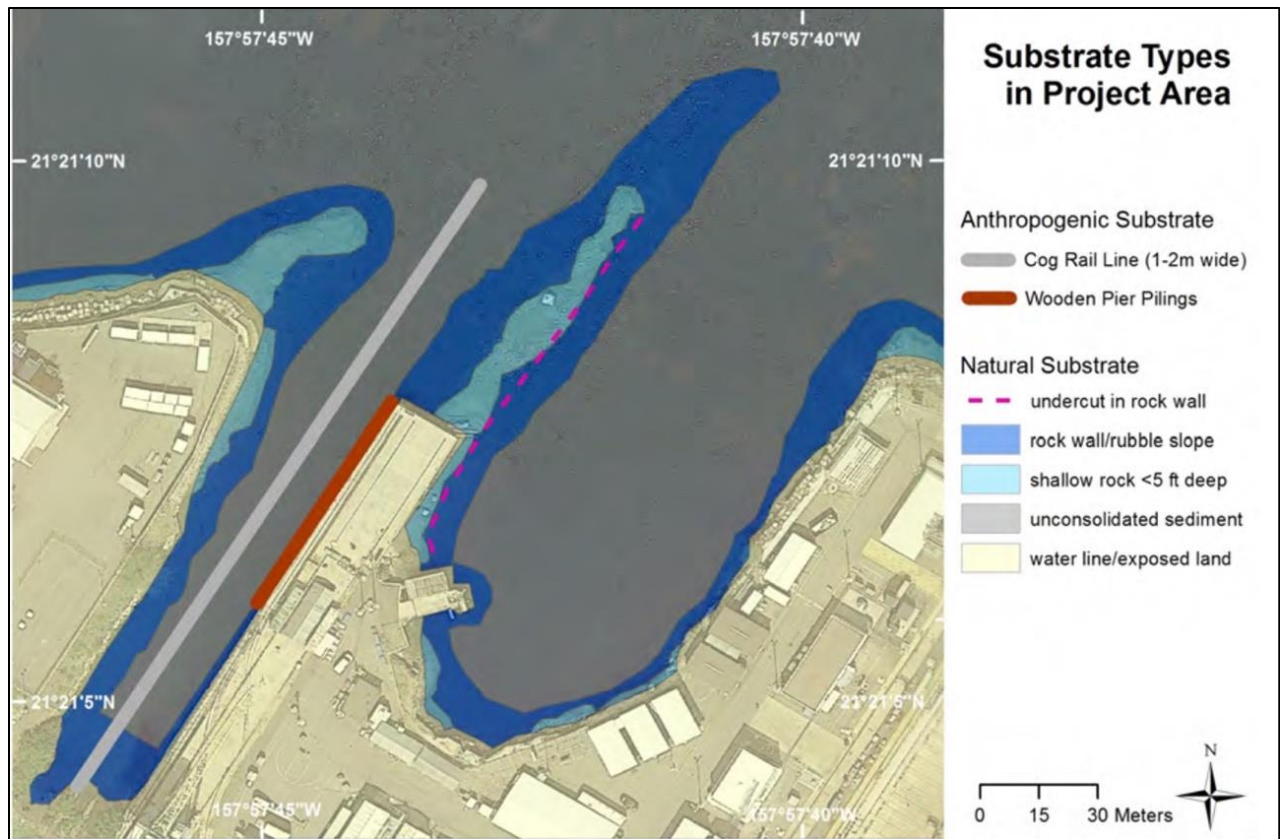
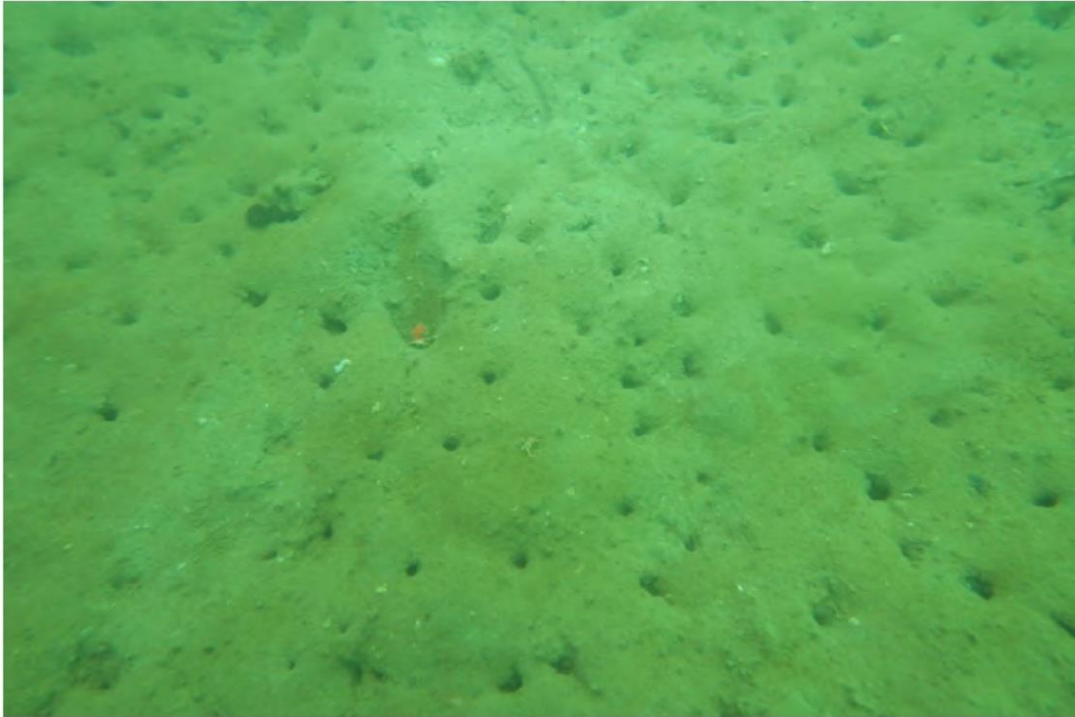


Figure 8. Substrate map of quay wall site.

3.1.1 Fine unconsolidated sediment

In nearly the entire project area, at depths between 18 and 45 ft (5.5–13.7 m) the sea floor is covered with fine unconsolidated sediment (mud/silt, Figure 9).



- Holes are burrows from infaunal organisms.
- Image 2385 detailed in Table 1.

Figure 9. Example of soft sediment substrate that dominates the project site away from the rock spurs and edges of the inlets.

3.1.2 Rubble

Beginning at the fine unconsolidated sediment junction and extending upward to a depth of between 15 and 3 ft (4.6–0.9 m), there was often a coarse rubble slope. These rubble slopes are generally unstable and unconsolidated. In some areas, this rubble slope was absent, and fine unconsolidated sediment abutted the solid rock spurs. The rubble slopes were not all the same. Most consisted of a mix of natural and anthropogenic rock or concrete fragments overlaying coarse to medium grained sand. At some locations, the rubble was dominated by oyster shell hash (Figure 10).



- Image 2383 detailed in Table 1.

Figure 10. Example of a rubble and shell-hash slope depauperate of living organisms.

3.1.3 Rock spur walls and slopes

Natural limestone rock spurs (Figure 11) descended to depths of 5–20 ft (1.7–7 m). In most areas around the spurs, this substrate graded into rubble, and then fine sediments, but, as noted above, in some places fine sediments abutted the rock walls directly.

The rock spur area adjacent to Transects T7, T8 and T9 included a series of natural, undercut ledges (Figure 8). The top of this undercut occurred generally between 10–15 ft (3.5–5.2 m) of water depth, and the bottom between about 15–20 ft (5.2–7 m) water depth (Figure 7). The undercut extended back approximately 2–8 ft (0.7–2.8 m) from the overhanging rock edge (Figure 7). Such undercut ledges are common throughout Pearl Harbor (Wells et al., 2016).



- Image 2372 .detailed in Table 1.

Figure 11. Example of sloping side of one of the rock spurs, supporting a fouling community dominated by sponges.

3.1.4 Tops of rock spurs

Tops of the natural limestone rock spurs were found in < 5 ft (1.7 m) of water, with significant portions exposed to the air, or awash during low-low tidal cycles (Figure 12). At the end of the quay, the top of the natural rock spur is covered with numerous, large pieces of concrete that are subaerially exposed (Figure 13).



- Image 2480 detailed in Table 1..

Figure 12. Example of the top of the eastern spur; depth at time of photo approximately 2 ft.

3.1.5 Anthropogenic material

Anthropogenic material at the project site includes the quay structure itself, an old cog railway used for launching and retrieving vessels, as well as debris of varying sizes. Major structures and some larger debris items are shown in Figure 13. Dive surveys encountered scattered smaller debris throughout the project site. A somewhat common feature were concrete blocks with dimensions 1–2 m (2.9–5.7 ft) on all sides. Many dozens of this type of block are piled along the shoreline on the east and west sides of the project area (Figure 13). Similar blocks were encountered during the underwater surveys.

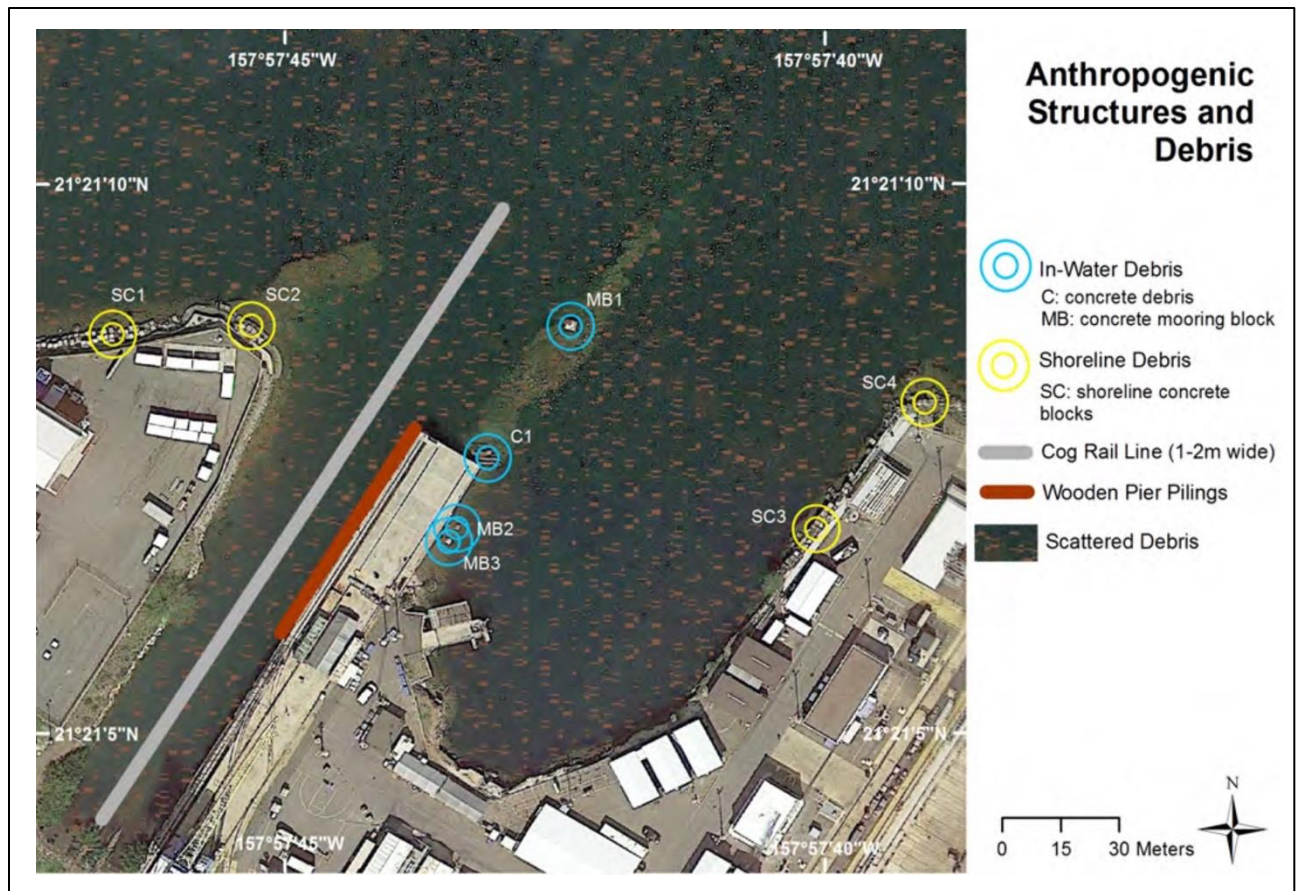
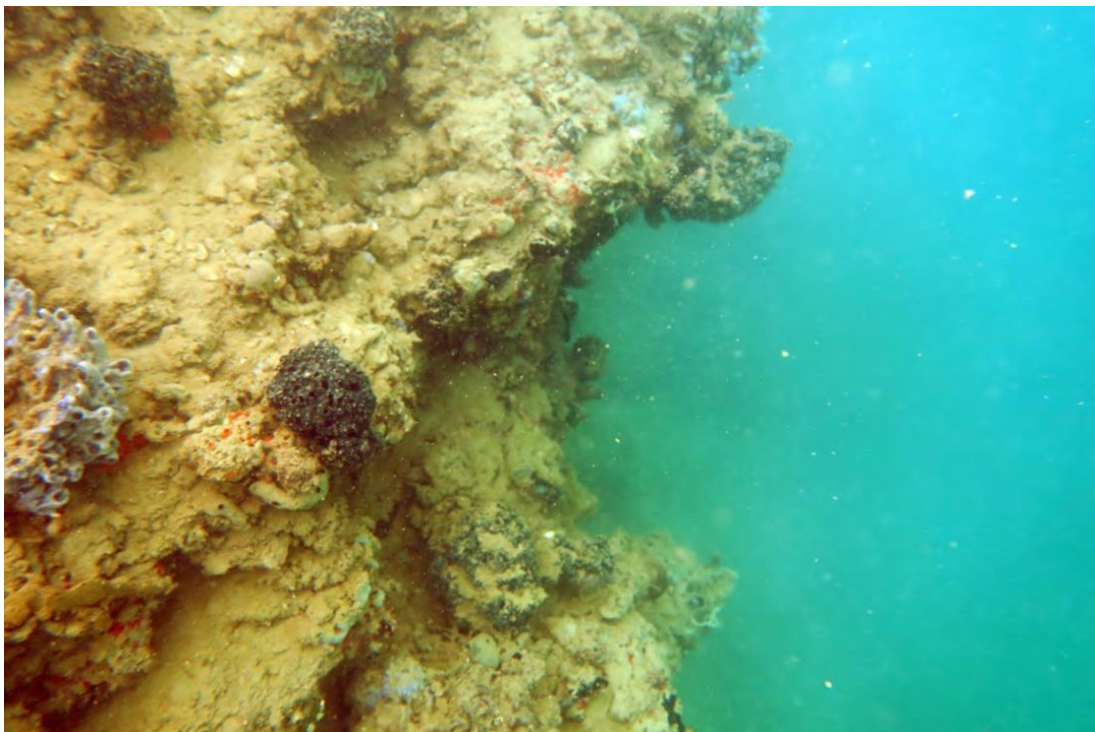


Figure 13. Major anthropogenic substrates at the project site.

3.1.6 Quay wall

The concrete portions along the eastern side of the quay wall showed extensive deterioration and spalling. In some sections, it was difficult to differentiate the deteriorating wall from the natural substrate below due to rubble and benthic organisms. Figure 14 illustrates the poor condition of the wall.



- Image 2483 detailed in Table 1. .

Figure 14. A severely spalled section of the concrete wall on the eastern side of the quay.

3.1.6.1 Cog rail

The second most substantial example of anthropogenic material is the concrete structure supporting the cog rail vessel launching and retrieval system (Figure 15). It extends from the shore to a depth of over 45 ft (15.7 m; Figure 13).

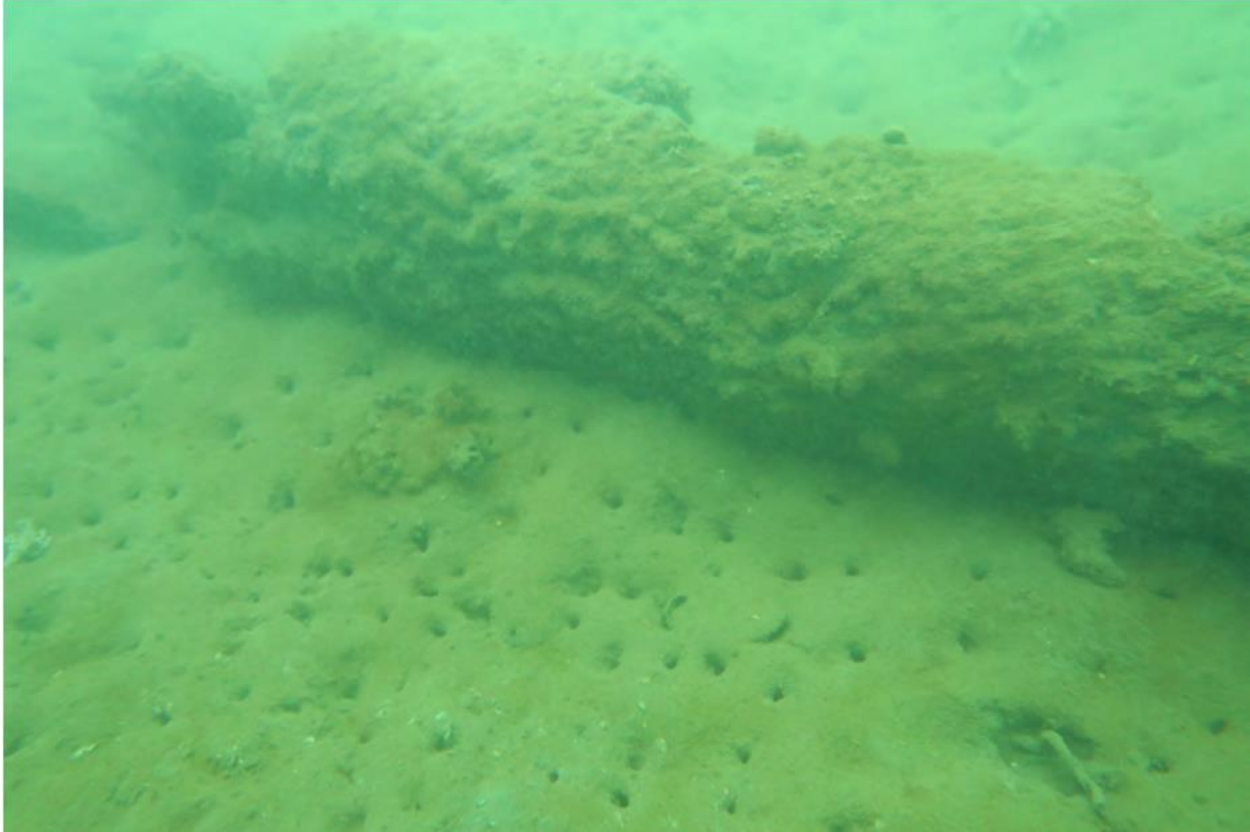


- Image 2400 detailed in Table 1..
- The concrete base extends down the length of the western inlet.
- Transects R1, R2, R3 completed on the cog rail.

Figure 15. Section of the cog rail on its concrete base.

3.1.6.2 Pier piles

Pier piles comprise the next most significant quantity of anthropogenic material. Some pier pilings were broken and sections were observed lying on the bottom, partially buried in mud (Figure 16).



- Image 2386 detailed in Table 1.

Figure 16. Example of broken wooden pier piling.

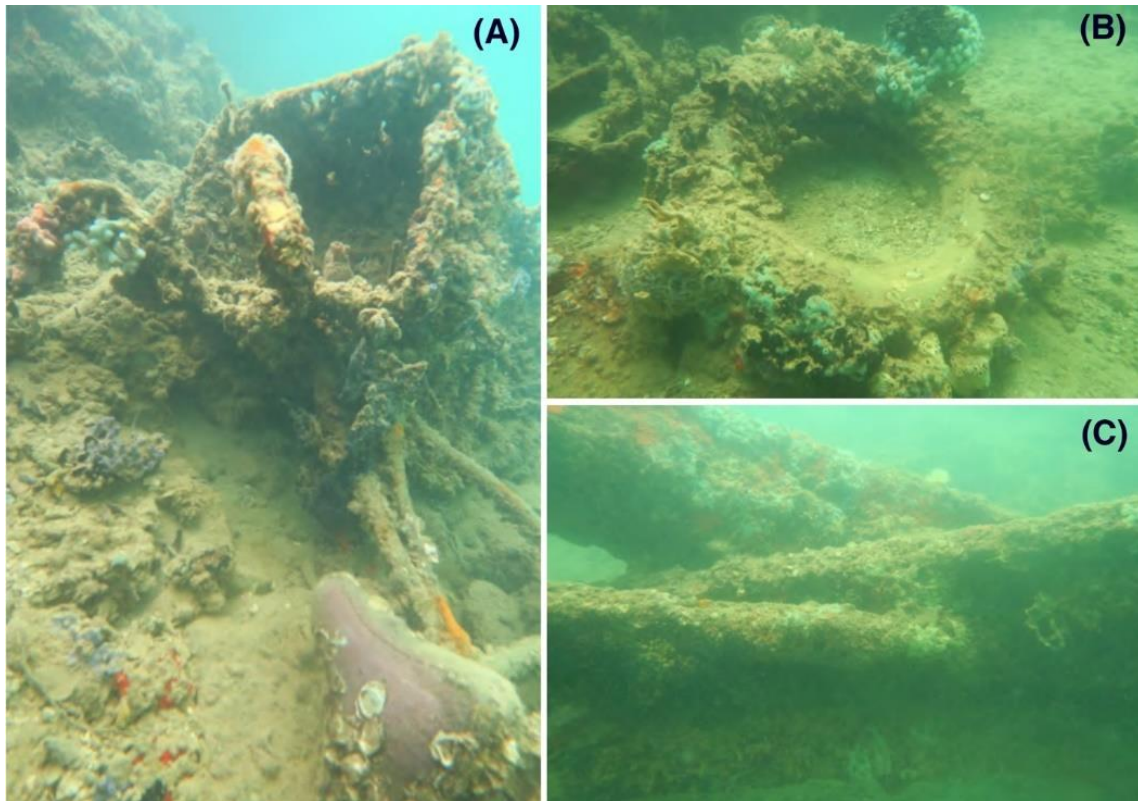
3.1.6.3 Debris

The fourth category of anthropogenic material was debris. The most abundant type of debris was numerous large concrete blocks, similar to those lining the shoreline around sections of the project site (Figure 13, Table 4), and many measuring more than a meter in one direction. Other anthropogenic materials included large steel I beams, anchor chains, large tires, a bicycle, and a chair. Figure 17 illustrates some of these materials, which are scattered heavily throughout both inlets.

Table 4. Locations of major debris items identified in Figure 13.

Debris item	Map symbol	Debris Type	Latitude (N)	Longitude (E)
Concrete Debris	C1	In-water Debris	21.35216	-157.96206
Mooring Block	MB1	In-water Debris	21.35246	-157.96187
Concrete Blocks	MB2	In-water Debris	21.35200	-157.96213
Concrete Blocks	MB3	In-water Debris	21.35197	-157.96215
Shoreline Concrete Blocks	SC1	Shoreline Debris	21.35244	-157.96293
Shoreline Concrete Blocks	SC2	Shoreline Debris	21.35246	-157.96260
Shoreline Concrete Blocks	SC3	Shoreline Debris	21.35200	-157.96130
Shoreline Concrete Blocks	SC4	Shoreline Debris	21.35229	-157.96105

- Locations identified via aerial imagery



- (A) Bicycle, Image 2522.
- (B) Tire, Image 3445.
- (C) Large metal I-beams, Image 3411.
- Images shown in figure are detailed in Table 1.

Figure 17. Examples of fouled anthropogenic debris in the inlets around the quay wall site.

3.2 QUALITATIVE BENTHIC HABITAT ASSESSMENT

The following section includes qualitative descriptions of the biological communities on each of the project area substrates, followed by quantitative assessments of a subset of the substrates (rock walls/slopes and wooden pier pilings).

3.2.1 Fine unconsolidated sediment

By area at the project site, soft sediment comprised the largest substrate type (Figure 8). The sediments in the middle of the inlets and into the harbor past the spurs supports infauna communities, as evidenced by burrows, but did not support any seagrass beds or other structural habitat-building organisms (Figure 9). Some areas of sediments were covered by a thin layer of cyanobacteria. Several mangrove propagules were sighted in the sediment at the landward heads of both inlets. This substrate was not quantitatively assessed, as it did not contain any habitat-forming organisms, which was the focus of this survey.

3.2.2 Rubble

Rubble slopes occurred in some areas between the rock spurs and fine sediments on the inlet floors. The rubble slopes were relatively depauperate of macroscopic sessile benthic organisms (Figures 10, and Figure 18), and thus were not surveyed for quantitative or georeferenced data collection.



- Image 2408 detailed in Table 1.

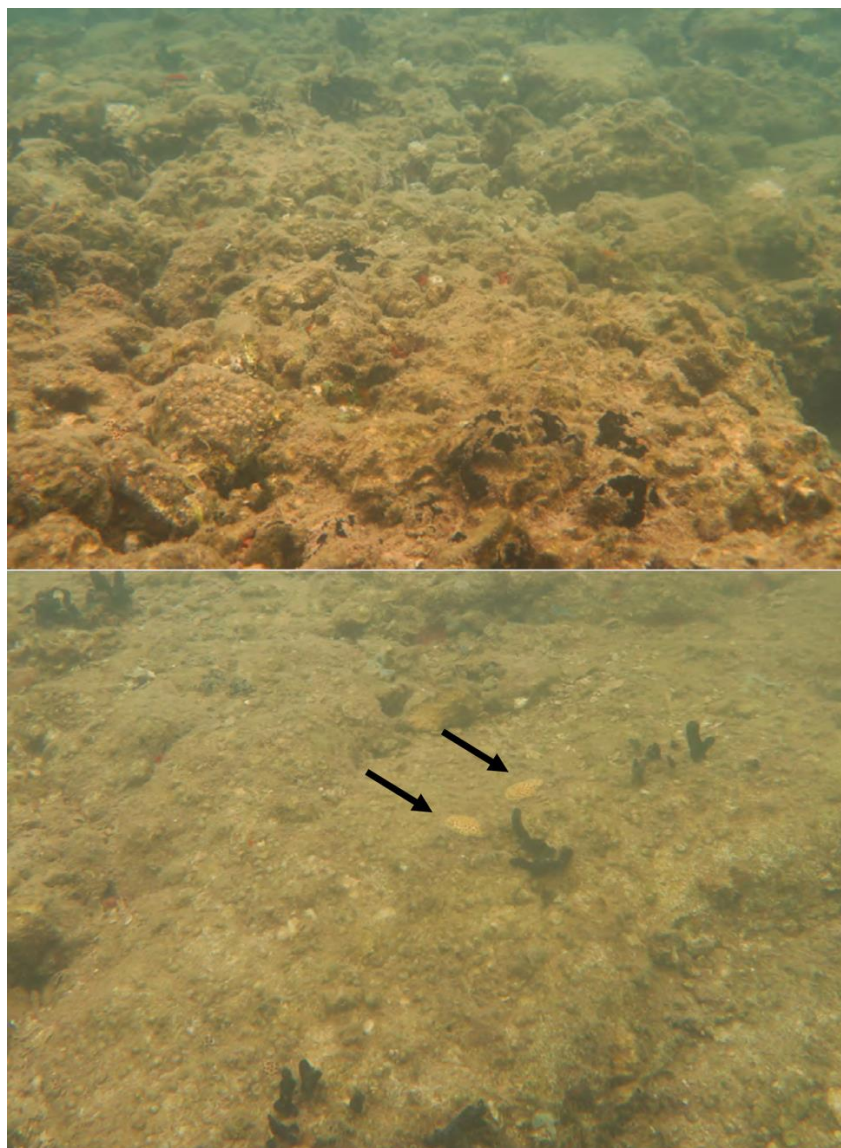
Figure 18. Another example of a rubble slope in the project area, depauperate of living organisms.

3.2.3 Rock spur walls and slopes

This substrate supported the most living materials of all natural surfaces. This substrate was surveyed quantitatively and further results are presented in the Section 3.3.

3.2.4 Tops of rock spurs

The top, shallow flat sections of the rock spurs support very limited flora and fauna. This community consists primarily of turf algae, small sponges and a limited number of unidentified bivalves. Most of the latter were less than 5cm in their maximum dimension. A very small number of corals were observed on this substrate, mostly *Leptastrea purpurea* colonies less than 5 cm in diameter (Figure 19). As described in Methods, this substrate was not targeted for quantitative data collection in the survey design.



- Arrows denote yellow *Leptastrea purpurea* colonies of approximately 2 cm diameter.
- Images: 2493, and 2480 cropped to show detail.
- Images are detailed in Table 1.

Figure 19. Examples of typical biological growth on top of the rock spurs.

3.2.5 Anthropogenic material

3.2.5.1 Quay wall

Some widely scattered colonies of coral were present on the quay wall; most were < 5cm in their maximum dimension. The species observed on the wall, and in order of abundance were: *Leptastrea purpurea*, *Pocillopora damicornis*, *Montipora capitata* and two specimens of *Porites compressa*. Transect 9 from the quantitative data collection portion of the survey was completed adjacent to the wall, and thus the habitat assessment results from that transect (presented in Section 3.3) should be extrapolated to represent the benthic habitat present on the quay wall.

3.2.5.2 Cog rail

The middle portion of the cog rail structure supported relatively abundant corals, as compared to other areas around the project site. The deeper section was almost devoid of living organisms, and the shallower section contained less growth than the middle section. Habitat on this substrate was quantitatively assessed, and is further described in the Section 3.3.

3.2.5.3 Pier pilings

Pier pilings were in general heavily fouled with various invertebrates, including a diverse sponge community, but very little coral was present. Habitat on this substrate was semi-quantitatively assessed, and is described in the Section 3.3.

3.2.5.4 Other debris

Most of the larger concrete blocks support sponges and some support scleractinian corals. The largest complex of Rice Coral (*Montipora capitata*) observed was located on such a block along the western edge of the western inlet; it measured 2.5m in its maximum dimension (Figure 20). Other debris items, such as chairs, bicycles, tires, and I-beams are also heavily fouled. Especially when debris items are found on the unconsolidated sediments that make up most of the project site, as they provide hard substrate onto which habitat-forming organisms such as corals and sponges prefer to settle. An interesting observation is that old bottles observed at the site, and at other locations around the harbor, appear to be a preferred substrate for *Leptastrea purpurea* colonies to settle (Figure 21).

Parts of both inlets also contained organic debris such as leaves, branches, and grass clippings.



- Concrete block denoted by arrow, measured 2.5 m in its maximum dimension.
- Location: western side of the western inlet.

Figure 20. *Montipora capitata* colony/complex, growing on a concrete block.



Figure 21. Throughout Pearl Harbor, old bottles are often colonized by *Leptastrea purpurea*.

3.3 QUANTITATIVE BENTHIC HABITAT COVER ASSESSMENT

Benthic habitat sampling and quantitative cover assessments were conducted for Transects T1-T11 and R1-R3 (Figure 22). A summary of results is presented in Table 5 including average percent cover of major habitat categories (organisms and substrate) by transect and by site. These surveys were conducted on rock wall and cog rail substrates, which were identified as having the highest potential for colonization. Even so, uncolonized, unconsolidated sediment dominated these transects (61.8% on average). Sponge/tunicate was the dominant biological community (18.9% on average) and coral comprised only 2.8% of these transects.

Each major category is described in more detail in the sections below. This section is organized by cover type, as presented in Table 5, in order of abundance. Note that in Table 5 and descriptions below some survey categories have been combined; the full dataset is included in Appendix D.

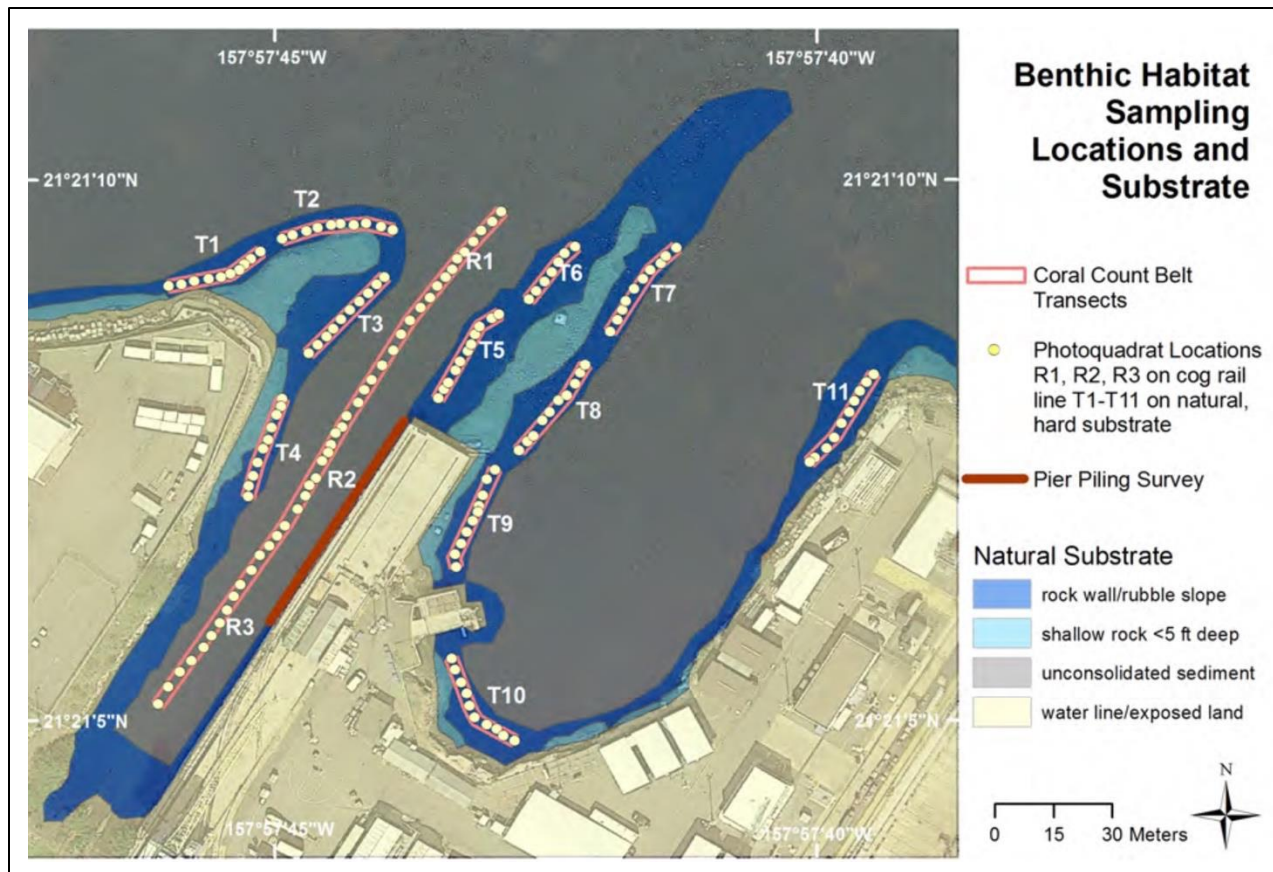


Figure 22. Benthic habitat sampling locations overlaid on site substrate map.

Table 5. Average percent cover of major habitat categories on each surveyed transect, along with the site-wide average for each category.

Transect	Coral (Live)	Coral (Dead)	Debris (all)	Other invertebrates	Turf algae	Sponge /tunicate	Dead shells /bivalves	Rock	Soft sediment
R1	0	0	0	0	0.1	2.1	0	0	97.8
R2	9.4	0	0	0	0	9	0	0	81.6
R3	5.6	0	0	0.6	0	9.5	6.8	0	77.4
1	0.8	0.1	0.8	0	0.2	30	6.2	3	58.9
2	2.2	0	0	2	0	32.5	0.4	0	62.9
3	4.8	0.3	3.6	0	0	16.5	12.3	13	49.5
4	0.1	0	0	0	0	3.9	0	12.6	83.4
5	3.7	0.1	0.3	0.3	0	19.8	6.2	16	53.6
6	1.6	0.3	1.4	0	0	26.4	3.9	10	56.4
7	2.6	0.2	0	0.1	2	37.5	1	11.9	44.7
8	1.8	0	0	0.1	0	27.5	1	7	62.6
9	2.7	0.9	7	0.1	0	21	3.1	34.6	30.6
10	4.1	0.1	14.1	0	0	12	0.5	20	49.2
11	0.4	0	14.5	0.1	0	16.5	0.3	12	56.2
Area average	2.8	0.1	3.0	0.1	0.2	18.9	3.0	10.0	61.8

3.3.1 Soft sediment

By area at the project site, soft sediment comprised the largest substrate type (Figure 9). Although no percent-cover or coral-belt transects were completed over soft sediment, there was also abundant soft sediment cover inside of quadrats on transects completed over the rock slopes and cog rail at the site. Soft sediment comprised an average of 61.8% of the benthic cover in surveyed quadrats across the site, with the highest concentration on transect R1 (97.8%), and lowest on transect 9 (30.6%; Table 5). In these cases, sediment from the turbid harbor had probably settled out onto hard substrate, in turn preventing organisms such as corals, macroalgae, and bivalves from settling onto the hard substrate below.

3.3.2 Sponges/Tunicates

The next most abundant benthic cover/habitat type was sponge and tunicate (18.9% overall; Table 5). In the field, this cover was termed “sponge,” but upon closer inspection it was determined that some organisms thought to be sponges were probably tunicates. These could not be differentiated quantitatively, so this cover category is here termed “sponge/tunicate.” This cover type was most abundant on transect 7 (37.5%), and least abundant on transect R1 (2.1%; Table 5).

3.3.3 Rock

Exposed rock without biological growth occurred on average over 10% of the surveyed quadrat area, with the highest abundance on transect 9 (34.6%), and the lowest on transect 2 (0%; Table 5). Note that the cog rail transects were conducted over a manmade structure built on the soft sediment, so no exposed rock substrate could have existed along those transects. In some cases (7 quadrats), the rock appeared to have been freshly scoured/exposed, instead of simply uncolonized (Appendix D). However, the mechanism for this scouring was not identified.

3.3.4 Debris

Debris covered an average of 3% of the surveyed substrate across the project site, with the most debris on transects 10 and 11 (~14% each, Table 5).

3.3.5 Dead bivalves (shells)

Dead, attached bivalve shells or unconsolidated shell hash covered an average of 3% of the surveyed substrate across the project site. The highest abundance of bivalve shells was on Transect 3 (12.3%, Table 5).

3.3.6 Corals

Across the project site, live corals covered an average of 2.8% of the surveyed substrate, with the highest concentration on the middle and shoreward sections of the cog rail (transects R2 and R3, 9.4% and 5.6% cover, respectively; Table 5). Several large patches of coral were identified off of surveyed transects. These observations are described below in Section 3.6.1.

3.3.7 Other invertebrates

Other invertebrates, which includes live bivalves, polychaetes, hydroids, and barnacles, only covered an average of 0.2% of the substrate surveyed at the project site, with the highest concentration of 2% on transect 2 (Table 5).

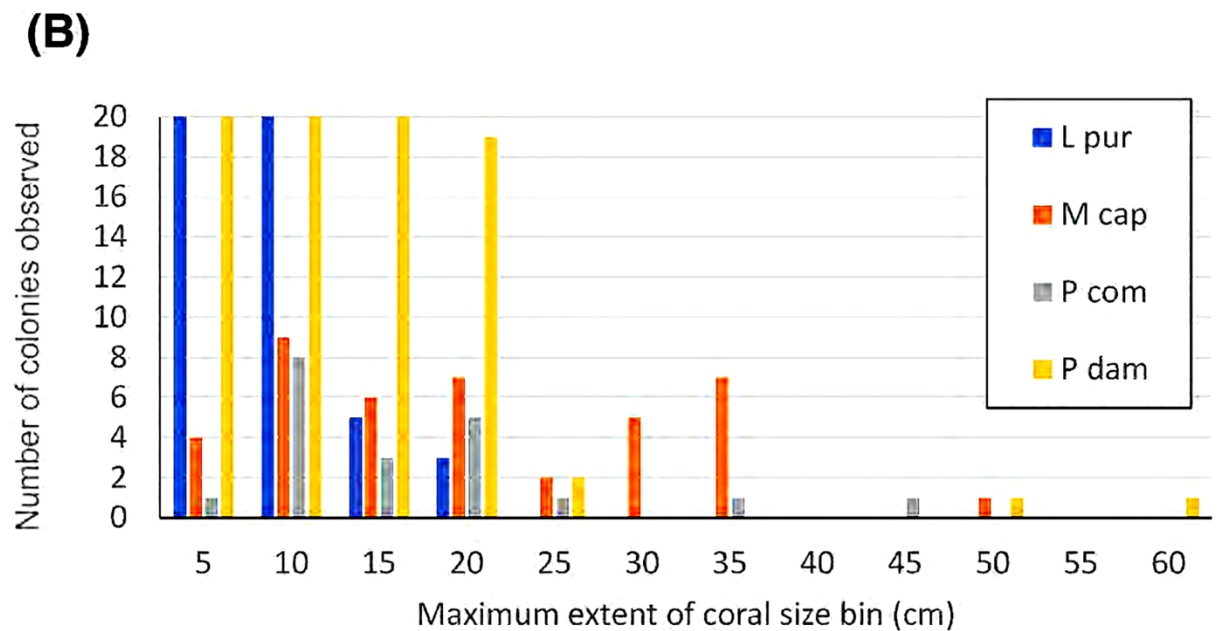
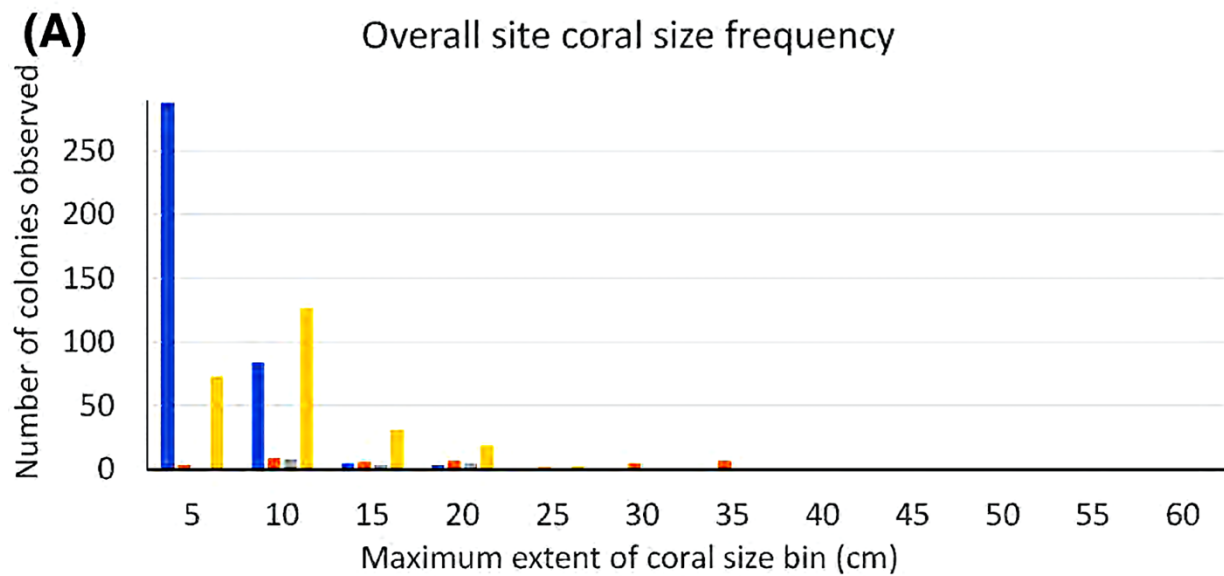
3.3.8 Plants and algae

No macroalgae was present at the project site. Turf algae was recorded in low abundance on three transects: R1 (the most seaward portion of the submerged cog rail line), T1, and T7 (Table 5). No seagrass was observed.

3.4 CORAL SIZE-FREQUENCY DISTRIBUTION

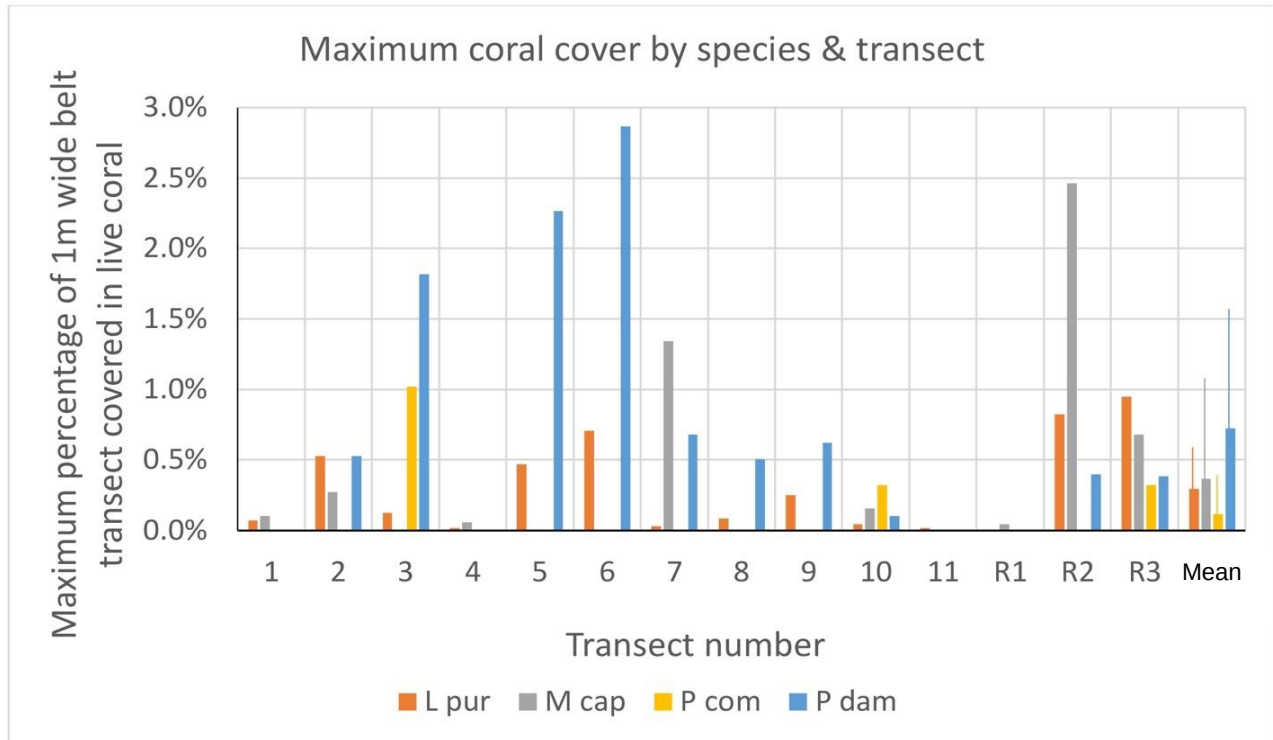
Four species of corals were observed at the project site: *Leptastrea purpurea*, *Montipora capitata*, *Porites compressa*, and *Pocillopora damicornis*. Along the survey transects, *L. purpurea* was the most numerically dominant (380 colonies measured), followed by *P. damicornis* (254 colonies; Appendix E, Figure 23). However, most coral colonies in the survey transects were small: 85.5% of the colonies fell into either the 0-5cm or 5-10cm size classes (Figure 23).

Coral area was computed from belt transect data by using the upper size limit of each bin as the diameter of circular colonies, and the equation for an area of a circle ($\text{area} = \pi r^2$), where r is colony radius. *P. damicornis* covered the most surface area overall on the transects, partly because of several relatively large colonies (Appendix E; Figure 24). Each transect contained a maximum of 3.7% living coral by area (highest cover on R2; Figure 24).



- (A) All colonies measured from project site to 50 cm in size and
- (B) Corals of all size bins with a truncated y-axis to allow visualization of numerically sparse larger colonies on transects.

Figure 23. Coral size-frequency distributions measured along transects.

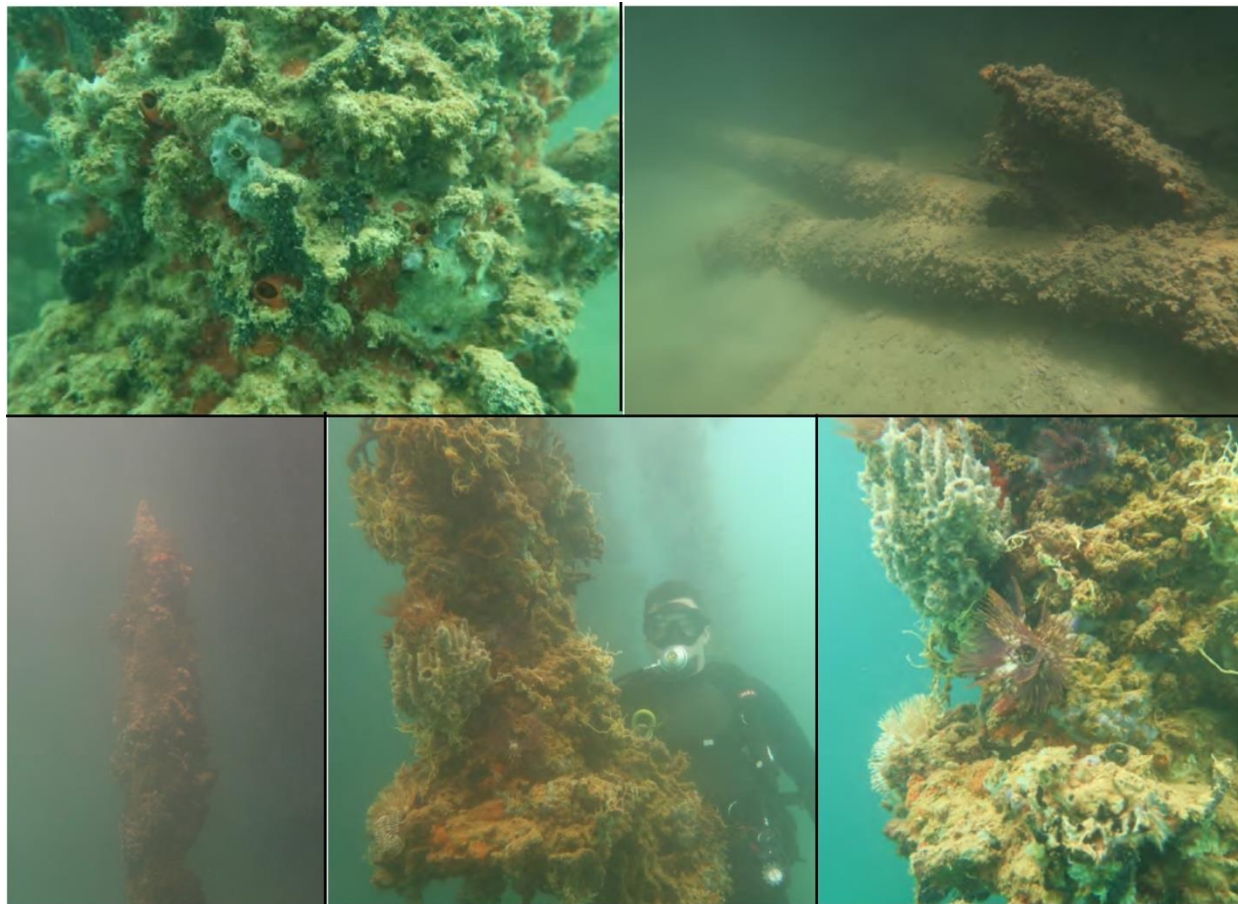


- Bars are one standard deviation on site mean values.

Figure 24. Percent cover of corals on each transect and project site mean cover (far right) using data from all transects.

3.5 WOODEN PIER PILING ASSESSMENT

The wooden pier piles around the quay are heavily fouled with algal turf, sponges, bryozoans, tunicates, oysters, and barnacles (Figure 25). Only one scleractinian coral was seen on the wooden piles, a *Pocillopora damicornis* (in the 5–10 cm size bin). Other corals may have been present and not seen, but the piles did not support significant coral growth.



- Images (left to right) 2500, 2501, 4407, 4408, and 4409.
- Images are detailed in Table 1.

Figure 25. Typical fouling communities on the wooden piles along the western side of the quay.

Wooden pier piling circumferences ranged between 90–105 cm, with an average circumference of 102.5 cm. A total of 22 below-water wooden pilings were observed and their heights estimated; safety concerns related to broken and dangling piling fragments did not allow the divers to physically measure the pilings. Instead, water depth was used to estimate the length of intact piles. Broken piles were sized by visually estimating as compared to water depth at each piling. The number of piles counted and sized underwater is smaller than the number of pilings visible above-water because some pilings were completely missing below water. Two pilings (numbers 14 and 15) were lying on the seafloor, so their lengths were estimated and surface area of fouling calculated by multiplying their length by half of the circumference value above. For the other 20 piles, their estimated lengths were multiplied by the 102.5cm circumference, and then all of these surface area values were summed. These calculations resulted in an estimated surface area of 98.9 m² of fouling communities that will be lost by removal of the wooden pilings from the site (Table 6).

Table 6. Measurements and calculations of fouling community surface area on wooden pilings to be removed from site.

Piling underwater ID	Seafloor depth (ft)	Piling height (ft)	Piling height (cm; h)	Piling circumference (cm; c)	Piling surface area of fouling (m ²) = h * c
1	27	27	823.0	102.5	8.4
2	27	8	243.8	102.5	2.5
3	27	27	823.0	102.5	8.4
4	27	27	823.8	102.5	8.4
5	24	24	731.5	102.5	7.5
6	22	22	670.6	102.5	6.9
7	22	22	670.6	102.5	6.9
8	21	21	640.1	102.5	6.6
9	20	8	243.8	102.5	2.5
10	19	19	579.1	102.5	5.9
11	19	19	579.1	102.5	5.9
12	19	19	579.1	102.5	5.9
13	19	4	121.9	102.5	1.2
14	19	19	579.1	51.25	3.0
15	18	18	548.6	51.25	2.8
16	18	2	61.0	102.5	0.6
17	16	1	30.5	102.5	0.3
18	16	16	487.7	102.5	5.0
19	15	15	457.2	102.5	4.7
20	15	3	91.4	102.5	0.9
21	13	1	30.5	102.5	0.3
22	13	13	396.2	102.5	4.1
				Total	98.9

3.6 OBSERVATIONS OF SPECIES AND HABITATS OF CONCERN

Species and habitats of concern and biological feature of interest were noted when encountered throughout the survey period. Biological features of interest that included location data are indicated on the map in Figure 26, and approximate GPS locations of the centers of all features are included in Table 7.

Notes on observations of corals and mangroves are included in this section. Notes on observations of green sea turtles and turtle grottos are included in section 3.7.1. Notes on pearl and cliff oyster observations are included in section 3.7.3.

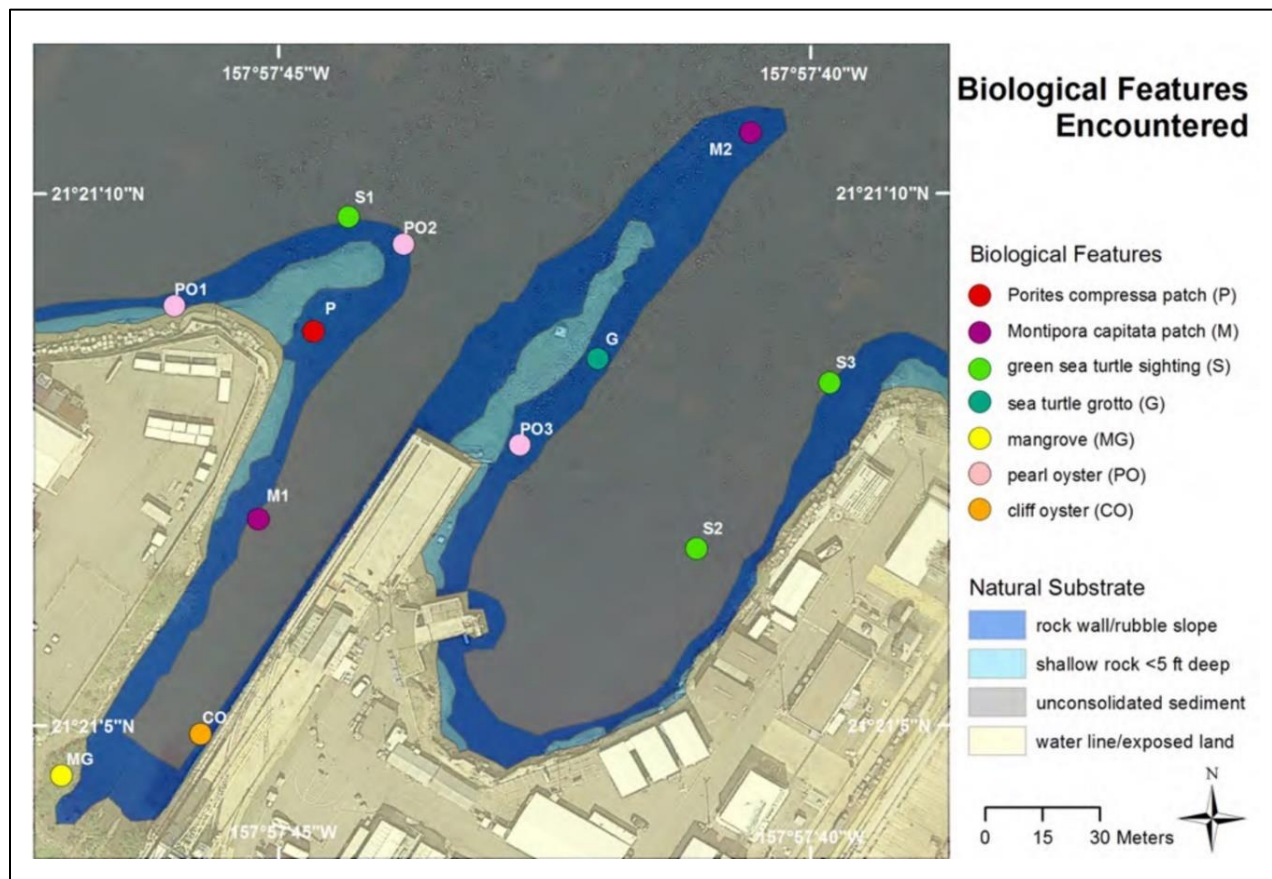


Figure 26. Biological features of interest encountered at the project site.

Table 6. Locations of features of interest shown in Figure 26.

Feature	Map symbol	Latitude (N)	Longitude (E)	Location source
<i>Porites compressa</i> patch	P	21.35246	-157.96245	Georeferenced photos
<i>Montipora capitata</i> patch	M1	21.35202	-157.96258	Georeferenced photos
<i>Montipora capitata</i> patch	M2	21.35293	-157.96142	Field notes
Green sea turtle sighting	S1	21.35273	-157.96237	Field notes
Green sea turtle sighting	S2	21.35195	-157.96154	Field notes
Green sea turtle sighting	S3	21.35234	-157.96123	Topside GPS reading
Sea turtle grotto	G	21.35240	-157.96178	Georeferenced photo
Mangrove	MG	21.35142	-157.96304	Aerial imagery
Pearl oyster	PO1	21.35253	-157.96278	Field notes
Pearl oyster	PO2	21.35267	-157.96224	Field notes
Pearl oyster	PO3	21.35220	-157.96196	Georeferenced photo
Cliff oyster	CO	21.35152	-157.96272	Georeferenced photo

3.6.1 Coral observations

In addition to the mostly small coral areas surveyed on transects, several other coral patches were encountered during the survey. One large *Porites compressa* patch with fused morphology was observed on the western spur (Figures 26, 27); the dimensions of this patch were measured along the north, south, west, and east sides of the patch at 4.8 m (north), 4.6 m (south), 6.4 m (west), and 5.6 m (east), which equates to approximately 28.6 m².

Two *Montipora capitata* coral patches were also identified; the largest colony/complex (shown in Figure 20) was just landward of the end of transect 4 (M1, Figure 26; see Figure 9 for transect locations). This colony/complex was approximately 2.5 m in its maximum dimension. At the seaward end of the eastern spur between 30 and 40 ft deep, a number *Montipora capitata* colonies were grouped together (M2, Figure 26). The four largest colonies each measured 30cm in their maximum dimension.

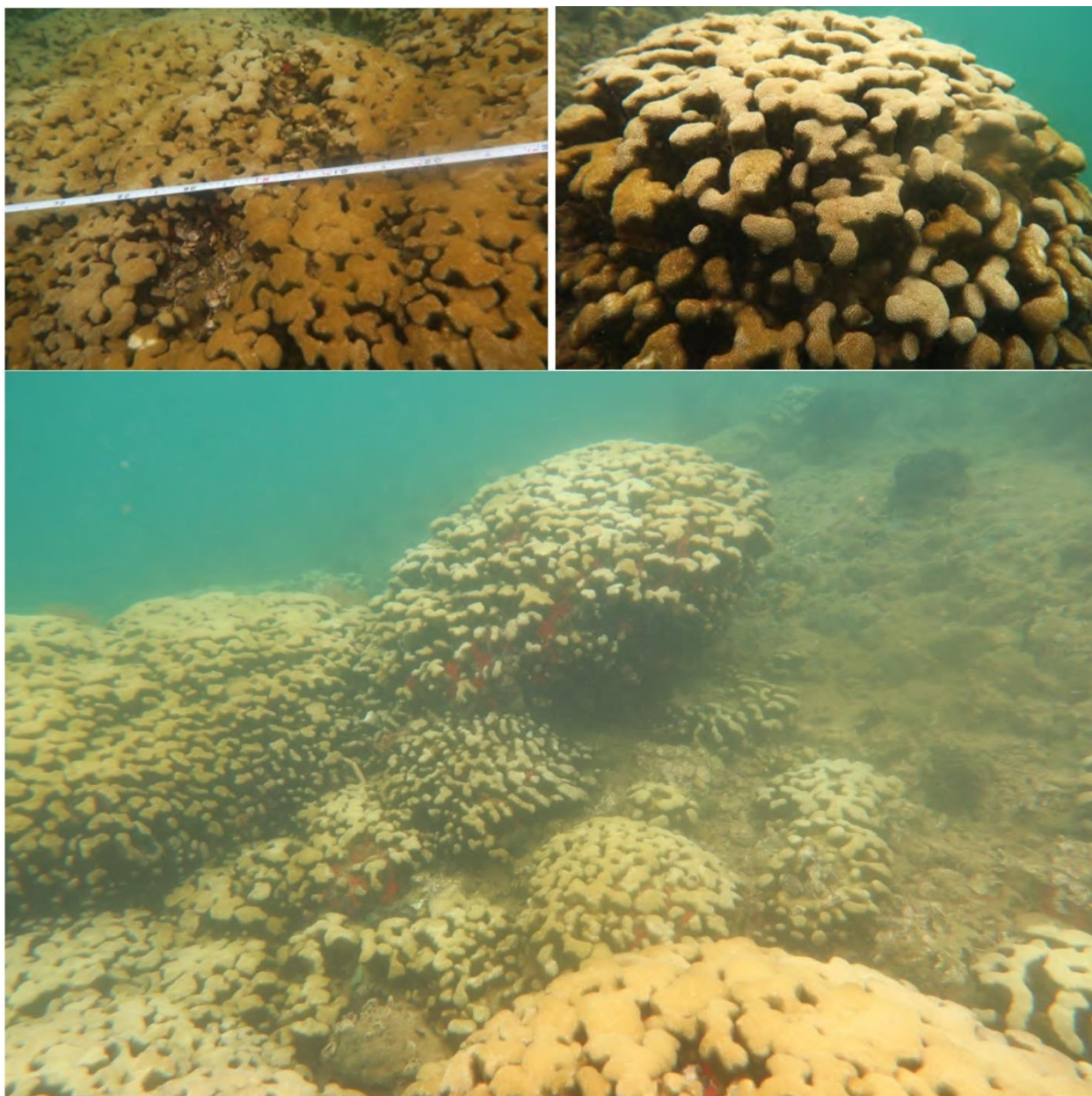


Figure 27. Portions of a large *Porites compressa* coral patch on the western spur.

3.6.2 Mangrove observations

In addition to several mangrove propagules that were sighted in the sediment at the landward heads of both inlets, there was a small area in which mangrove roots from *Rhizophora mangle* overhung the western side of the western inlet (Figures 26, 28).



Figure 28. Mangrove roots from *Rhizophora mangle* on the western side of the western inlet.

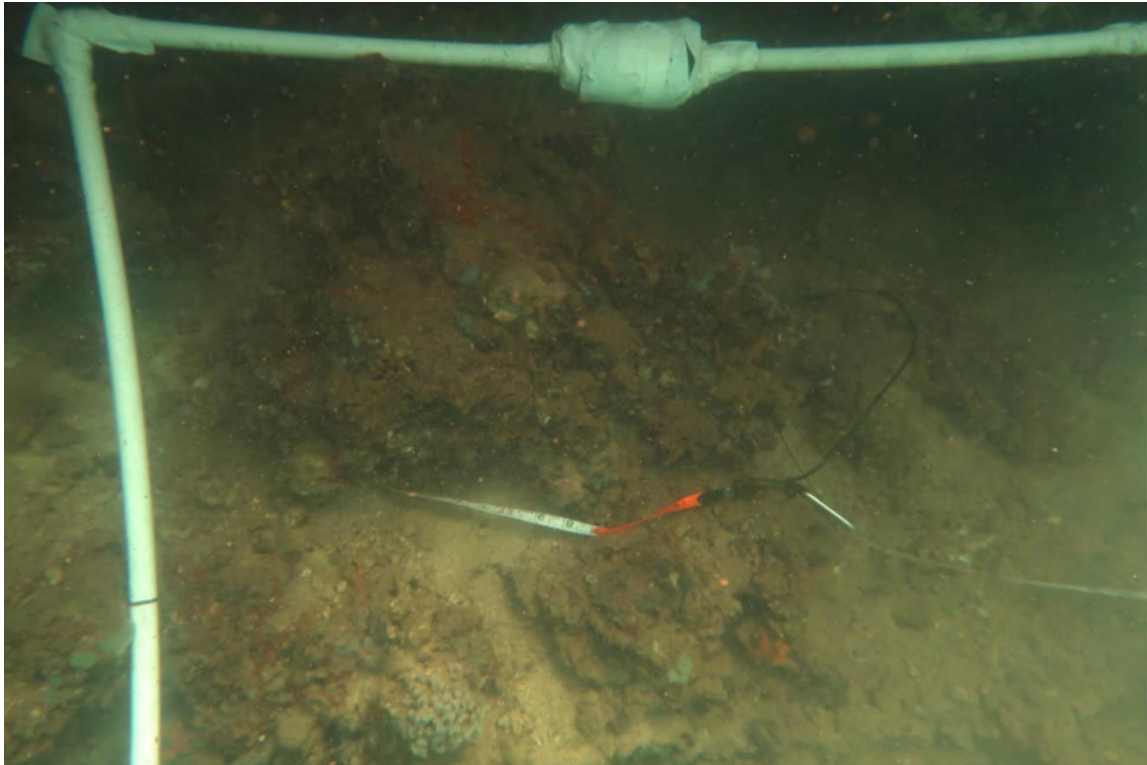
3.7 MACROFAUNA ASSESSMENT

3.7.1 Turtles

One green sea turtle (*Chelonia mydas*) was observed at the surface from the dive boat during the March 2018 dives, in the eastern inlet. Another green sea turtle was also observed from the boat in the eastern inlet during the April 2018 dives; the location of the boat at the time of that sighting was marked via GPS. The size and sex of those turtles could not be determined. A third green sea turtle was sighted underwater at the tip of the Western spur. That turtle was a female, and total carapace length was estimated to be 60 cm. The turtle was resting on a steep slope when first observed. It did not have any visible fibro-papilloma tumors, bite marks or scars, but it did have a number of large barnacles on its carapace. None of the preferred algal forage species were observed to be present. The approximate locations of all turtles sighted are noted on the map in Figure 26. No photographs of the turtles were captured.

The project area contained a series of undercut ledges; these are common throughout Pearl Harbor (Wells et al., 2016). One section of the rock undercut on the east side of the east spur, measuring approximately 2 m wide, appeared to have been recently used by a green sea turtle as resting habitat; the ceiling of that grotto was scraped smooth, exposing bare rock on the roof of the undercut and small uncolonized rock fragments covered the grotto floor. At other grotto/undercut locations within Pearl Harbor, where turtles have been repeatedly sighted, the ceilings and floors exhibit those characteristics (S. Smith, personal observations). Such conditions can be created when turtles scrape their carapaces against the ceiling of a grotto, dislodging pieces of rock. A photograph taken at the location of the possible turtle grotto (map,

Figure 26) is included below (Figure 29), but note that the image does not clearly capture the diagnostic features described.



- Note that diagnostic features are unfortunately not well captured in this photograph.
- First quadrat of transect 7; Image 4530 detailed in Table 1.

Figure 29. Edge of suspected turtle grotto.

3.7.2 Fish

Table 8 lists all the fish species recorded during the current study, as well as fishes recorded within the project area during surveys conducted previously (Smith et al., 2006). A total of 46 species were field identified, and no specimens were taken. Low levels of visibility reduced the divers' ability to identify fish accurately (Figure 30). Additionally, a moderate number of fishes less than 5cm TL were observed. Most of those very small specimens were believed to be in the Family Gobiidae, with some specimens of the Families Blennidae and Apogonidae (Cardinalfishes) also present. Juvenile parrotfishes, less than 12cm TL were also seen at the limit of visibility, but could not be identified. Acanthuridae (Surgeonfishes and Unicornfishes) had both the largest number of identified species (9), and were the most numerically abundant group. *Acanthurus blochii* (Ringtail Surgeonfish) was the most abundant based upon both fish assessment methods. Mullidae (Goatfishes) were second (5 species identified), followed by Chaetodontidae (Butterflyfishes) with 4 species recorded. Scaridae (Parrotfishes), Labridae (Wrasses), and Pomacentridae (Damselfishes) each had 3 species identified.

Table 8 also includes the approximate total number of individual fish observed from each survey effort, as well as the number of species observed. To calculate the number of individuals observed in cases where ranges were used, the median was computed, and where unbounded ranges were presented, the minimum was used. In cases where only presence was recorded, it was assumed that this was a single individual.

Table 7. List of all fish species observed in the quay wall area.

Fish Group and species		2018 Reconnaissance dives	Stationary Point Count	Legacy
Scientific name	Common name/Hawaiian name	(Total recorded from all dives)	(Total recorded from all dives)	From Smith, 2006
MURAENIDAE <i>Gymnothorax melatremus</i>	MORAY EELS Dwarf Moray	1	1	0
SYNODONTIDAE <i>Saurida gracilis</i>	LIZARDFISHES Slender Lizardfish	3	0	1
ENGRAULIDAE <i>Encrasicholima purpurea</i>	ANCHOVIES Hawaiian anchovy/Nehu	>50	0	0
CHANIDAE <i>Chanos chanos</i>	MILKFISH Milk-fish	6	0	0
MUGILIDAE <i>Mugil cephalus</i>	MULLET Striped Mullet	Between 5–10	0	0
HOLOCENIRIDAE <i>Myripristis sp.</i>	SQUIRREL AND SOLDIERFISHES Soldierfish	3	0	0
PRIACANTHIDAE <i>Priacanthlis meeki</i> or <i>Heteropriacanthinis cruentatus</i>	BIGEYES Hawaiian Bigeye or Glasseye	3	0	0
APOGONIDAE <i>Foa brachygramma</i> <i>Unidentified Apogonidae</i>	CARDINALFISHES Weed Cardinalfish Unidentified Cardinalfish	0 between 20–50	0 15	3 N/A
CARANGIDAE <i>Caranx melampygus</i> <i>Decapterus macarellus</i>	JACKS AND TREVALLIES Bluefin Trevally Mackerel Scad/Opelu	3 between 50–100	0 0	0 0
LUTJANIDAE <i>Lutjanus fulvus</i> <i>Lutjanus kasmira</i>	SNAPPERS Blacktail Snapper Bluelined Snapper/Tā ape	between 20–50 between 10–20	4 0	124 0
MULLIDAE <i>Parupeneus porphyreus</i> <i>Parupeneus multifascianis</i> <i>Parupeneus cyclostomus</i> <i>Mulloidichthys vanicolensis</i> <i>Upeneus taeniopterus</i>	GOATFISHES Whitesaddle Goatfish Manybar Goatfish Blue Goatfish Yellowfin Goatfish Bandtail goatfish	between 10–20 between 10–20 2 between 10–20 5	0 0 0 0 0	6 2 N/A 0 0
CHAETODONTIDAE <i>Chaetodon Auriga</i> <i>Chaetodon horula</i> <i>Chaetodon hunalatus</i> <i>Chaetodon ephippium</i>	BUTTERFLYFISHES Threadfin Butterflyfish Raccoon butterflyfish Oval Butterflyfish Saddled Butterflyfish	between 5–10 4 0 7	1 0 0 5	15 1 2 8
POMACENTRIDAE <i>Abudefduf abdominalis</i> <i>Abudefduf sordidus</i> <i>Dascyllus albisella</i>	DAMSELFISHES Hawaiian Sergeant Blackspot Sergeant Hawaiian Dascyllus	between 20–50 0 between 10–20	8 0 0	105 1 N/A

- Table includes approximate numbers of individuals observed during initial March 2018 reconnaissance dives and stationary point count dives.
- Table also contains data from earlier surveys published in Smith et al., (2006).

Table 7. List of all fish species observed in the quay wall area. (Continued)

Fish Group and species		2018 Reconnaissance dives	Stationary Point Count	Legacy
Scientific name	Common name	(Total recorded from all dives)	(Total recorded from all dives)	From Smith, 2006
SPHYRAENIDAE <i>Sphyaena genie</i> <i>Sphyaena barracuda</i>	BARRACUDAS Blacktail Barracuda Great Barracuda	2 1	0 1	0 0
LABRIDAE <i>Unidentified Wrasse</i> <i>Oxycheilinus unifasciatus</i> <i>Thalassoma duperrey</i> <i>Anampses sp.</i>	WRASSES Ringtail Wrasse Saddle/Bluehead Wrasse Psychedelic/Pearl Wrasse	between 10–20 1 2 1	1 0 0 0	0 1 0 0
SCARIDAE Unid. juveniles < 20 cm Unid. acb.lts 20–50 cm <i>Scarus perspicillatus</i> <i>Scarus rubroviolaceus</i> <i>Calotomus carolinus</i>	PARROIBSHES Ringtail Wrasse Saddle/Bluehead Wrasse Psychedelic/Pearl Wrasse	between 25–50 between 5–10 1 0 2	86 6 0 2 0	N/A N/A 13 2 0
GOBIIDAE Unidentified members of the <i>Gobiidae</i>	GOBIES	between 25–50	>33	0
BLENNIDAE AND TRIPTEGIDAE	BLENNIES & TRIPLEFINS	between 25–30	1	0
PINGUIPEDIDAE (PARAPERCIDAE) <i>Parapercis schauinslandii</i>	SANDPERCHES Redspot Sandperch	3	0	0
ACANTHURIDAE <i>Acanthurus blochii</i> <i>Acanthurus guttatus</i> <i>Acanthurus triostegus</i> <i>Acanthurus xanthopterus</i> <i>Acanthurus nigrofasciatus</i> <i>Zebbrasoma flavescens</i> <i>Zebbrasoma veliferum</i> <i>Naso brevirostris</i> <i>Naso hexacanthus</i>	SURGEON & UNICORNFISHES Ringtail surgeon Whitespot Surgeon Convict Surgeon Yellowfin Surgeon Brown AKA Lavender Tang Yellow Tang Sailfin Tang Paleface Unicornfish Sleek Unicornfish	> 100 between 10–20 between 10–20 between 5–10 2 between 25–50 3 0 between 5–10	31 0 1 1 1 2 5 0 > 20	390 0 0 0 0 0 0 13 0
ZANCLIDAE <i>Zanclus corninus</i>	MOORISH IDOL Moorish Idol	15	0	0
TETRAODONTIDAE <i>Arothron hispidus</i>	PUFFERFISHES Stripebelly Puffer	4	0	1
DIODONTIDAE <i>Diodon hystrix</i>	PORCUPINEFISHES Porcupinefish	3	0	0
<i>Approximated</i>	Total species Total individuals	46 ~716	2 ~225	17 688

- Table includes approximate numbers of individuals observed during initial March 2018 reconnaissance dives and stationary point count dives.
- Table also contains data from earlier surveys published in Smith et al., (2006).

Only one moderate sized predator was sighted during each of the 2018 fish survey types, a Great Barracuda (*Sphyaena barracuda*) estimated to be 60cm TL. Although jacks and trevallies (Carangidae) with TL over 75 cm have often been sighted by the authors in the harbor, the largest

member of that family observed during this study was a Bluefin Trevally (*Caranx melampygus*) with an estimated TL of 32cm. Four groups of fish were observed in schools: a school of Mackerel Scad – Opelu (*Decapterus macarellus*) estimated to number between 50 and 100 individuals, a school of Hawaiian Anchovies – Nehu (*Stolephorus purpurea*, 50–75 individuals); mixed schools of Surgeonfishes (mostly *Acanthurus blochii*, the Ringtailed Surgeonfish); and lastly, small schools of juvenile parrotfishes unidentified to species. For each of the stationary point count surveys, total fish biomass was estimated to range between 682.6–5878.2 g, or about 6.8–58.8 kg (Table 9). Using the average estimated visibility during the survey to calculate the planar area of each cylinder surveyed, the total fish biomass per area ranged between 14.5 g/m²–69.9 g/m², with a site mean of 36.2 g/m² (Table 9). The collated data from the stationary point count surveys, including fish species observed, number of individuals, and the sizes of all individuals observed, is presented in Appendix B.

Table 8. Estimated fish biomass at each of the stationary point count survey locations at the quay wall site.

Stationary point count survey location/survey number	Total fish biomass estimated (g)	Visibility during survey (m)	Total approximate area (m ²)	Total fish biomass/area (g/m ²)
West spur outer (3)	912.4	2-3	19.6	46.5
West spur western (6)	682.6	2.5-4	33.2	20.6
East spur west outer (1)	3516	2-6	50.3	69.9
East spur west inner (2)	925.3	4-5	63.6	14.5
East spur east outer (4)	5878.2	5.5-7.5	132.7	44.3
East spur east inner (5)	2392.7	6	113.1	21.2
			MEAN	36.2

- Survey numbers and locations are presented in Figure 6



Figure 30. Example of fish and relatively low visibility conditions observed at the project site.

3.7.3 Other species

3.7.3.1 Bivalves

There were 2 species of large oysters within the survey area, based upon field level identification: the cliff oyster (*Spondylus violacescens*) and the black-lipped pearl oyster (*Pinctada margaritifera*). Other smaller, unidentified oysters and bivalve species were also present. Two pearl oysters were sighted during the initial reconnaissance surveys: one at the west/southwest end of where Transect 1 was later conducted at a depth of approximately 18 ft (6.3 m), and the other near the far tip of the Western spur at about 35 ft (12.2 m). A third pearl oyster was seen and photographed during the habitat quantitation dives on the east side of the quay wall (Figure 31). One of the pearl oysters was measured at 24cm across. The locations of these observations, as well as one of the cliff oysters that was photographed, are noted on Figure

26. The authors have observed pearl oysters in all of the lochs of Pearl Harbor, and on both sides of the main channel. Based upon opportunistic observations made during surveys (2000 to 2018) for other fauna, the authors believe the pearl oyster is becoming less rare throughout the harbor.

Unidentified oysters in the 2–6 cm size range, along with shell hash from these oysters, were abundant in the project area.



- Image 3423 detailed in Table 1.

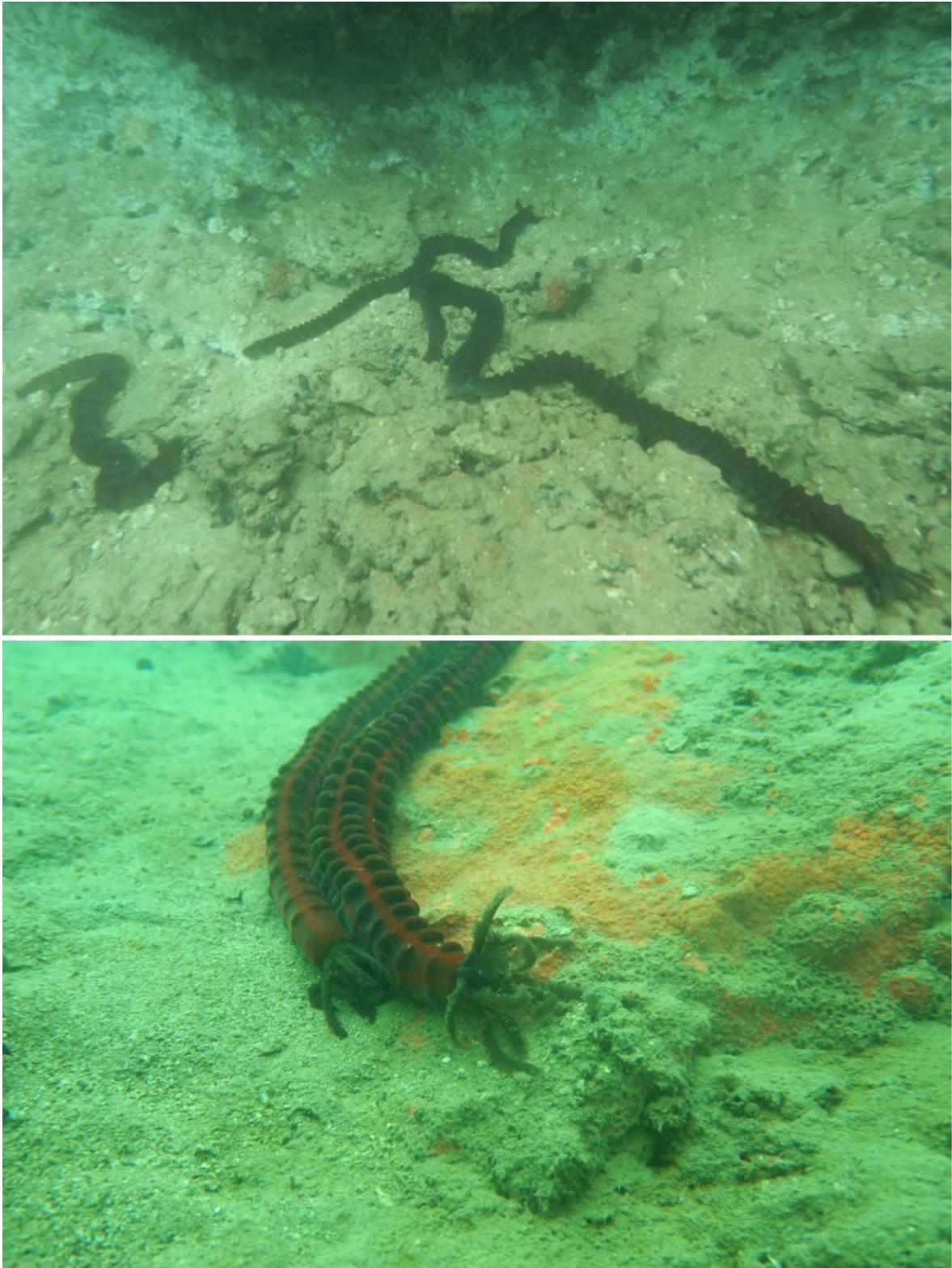
Figure 31. Pearl oyster observed on the eastern spur.

3.7.3.2 Other invertebrates

The sponge fauna at the quay wall site is quite diverse, as was the polychaete community (Figure 32). Identifying sponges to species requires sampling and microscopic identification of spicules. Numerous sea cucumbers from the family Synaptidae were sighted, field identified as the Conspicuous sea cucumber (*Opheodesoma spectabilis*; Figure 33).



Figure 32. Examples of the diverse invertebrate communities observed at the project site.



- Two alternate views shown.

Figure 33. Conspicuous sea cucumber (*Opheodesoma spectabilis*) Many of these organisms were a meter or more in length.

4. DISCUSSION

4.1 INTERPRETATION OF SITE CONDITION

The habitat types observed were, as expected, comparable to those previously studied and documented throughout Pearl Harbor. There were no unusual or new habitat types observed. Additionally, the relative proportions of unconsolidated sediment, rubble/shell hash and natural hard substrate was approximately equivalent to other locations throughout Pearl Harbor.

The site was dominated by unconsolidated and uncolonized sediment. Some hard substrates, including rock spur walls and slopes and anthropogenic debris provided surface areas for colonization by benthic organisms. Quantitative surveys of these areas showed that benthic communities were dominated by sponge/tunicate (18.9% cover). Live coral comprised 2.8% cover on average with highest cover on the cog rail line (5.6% and 9.4% cover in some exposed sections).

Some of the anthropogenic debris/discarded materials, such as concrete blocks, steel I-beams and anchor chain were densely colonized. Scleractinian corals were present on some of these materials. Debris items were scattered throughout the project site but represented a relatively small proportion of the substrate overall.

Within the coral community surveyed, *Leptastrea purpurea* was the most numerically dominant, followed by *Pocillopora damicornis*. However, most coral colonies in the survey transects were small: 85.5% of the colonies fell into either the 0-5cm or 5-10cm size classes. No large coral patches were recorded on the survey transects, although several patches were encountered during the two weeks of diving on site. The largest individual coral colony, or colony complex encountered was *Montipora capitata* (see Figure 20). Similar sized *Montipora capitata* colonies or colony complexes have been observed by the authors in West Loch, around Ford Island and in the Main Channel north of Bishop Point. By contrast, in 2005, no colonies of *Porites compressa* or *Montipora capitata* over 10 cm were sighted at the site (Smith et al., 2006).

Essential Fish Habitat (EFH) has been designated from the intertidal zone to depths of 1,000 feet around all the Hawaiian Islands, for one or more life stages of one or more management species. Therefore, all of Pearl Harbor is designated as EFH. Habitat Areas of Particular Concern (HAPC) can be designated within EFH zones for areas that meet prescribed criteria. No HAPC has been designated within Pearl Harbor and the current project area does not meet any of the criteria for HAPC designation.

4.2 FISH BIOMASS COMPARISON

The methods used for the 2006 report on Pearl Harbor's fish stocks (Smith et al., 2006) were significantly different than those prescribed for this project. However, data collected from the two study sites within or adjacent to the current project area and presented in Smith (2006) indicate fewer species and a lower estimated biomass than nearly any other sites investigated. Based upon unpublished data and observations by S.H. Smith, the project site surveyed in 2018 still appears to support fewer fish than most other portions of the harbor. A summary of coral reef fish survey data collected across the Pacific between 2010-2016 by scientists at the Pacific Islands Fisheries Science Center (PIFSC) found comparable average biomass of coral-reef associated fishes in the Main Hawaiian Islands: 29.8 g/m² (McKoy et al., 2017). This fish biomass is slightly lower than the site average estimate of 36.2 g/m², and both are much lower than fish biomass in the unfished Northwest Hawaiian Islands (115.8 g/m²) and Pacific Remote Islands Area (157.4 g/m²). Note that

the PIFSC data were collected at forereef sites, and not inside estuarine/harbor environments, as was the data collected for this survey, so this is not a direct comparison.

Acanthurids (surgeonfish and unicornfish) ranked first at the site based upon number of species observed and estimated biomass (Table 8, 9). It should be noted, that mixed schools of surgeonfish have been observed to routinely move around the harbor, grazing hard substrates (S. Smith, personal observations). This is particularly true for larger members of the family, such as the Ringtail Surgeon, *A. blochii*. Therefore, it is likely that the majority of fish biomass recorded in this area is not resident to the area, but ranges throughout the harbor. The hard surface areas in and around the Quay Wall represent a small percentage of the harbor's total hard surface area, and the proposed project will not ultimately reduce the total hard surface area; it is therefore unlikely to have long term adverse impacts upon the fish population. If the project results in the placement of additional hard surface area, due to installation of new concrete piles, the total biomass of both sessile invertebrates and fishes could increase at the site.

4.3 PIER PILING REMOVAL

Figure 25 illustrates the dense fouling that was present on the wooden pier piles. These communities included algal turf, sponges, bryozoans, tunicates, oysters, and barnacles but pier piles did not support significant coral growth. Only one scleractinian coral was observed on the wooden piles.

Many of these piles were broken and posed a serious safety hazard. While these pile communities clearly support biological communities, it is reasonable to expect that the new piles will recruit new fouling communities. Fouling communities, visually comparable to those pictured, have been observed to develop relatively rapidly on newly installed steel, concrete and wood piles in Pearl Harbor, and on test plates in Hawaii (e.g., Bailey-Brock, 1989). Indeed, during a test of antifouling coatings in Pearl Harbor, Holm et al., (2000) found that their control surfaces developed thick and stable fouling communities in ~6–7 months.

While removing the wooden pilings at this site will cause a short-term loss in fouling community biomass, it may in the longer term be more beneficial to the site by removing potential contaminants. These wooden pilings were creosote-treated for preservation before installation; creosote is a chemical mixture typically made from tar, and leaches potentially harmful chemicals such as polycyclic aromatic hydrocarbons (PAHs) into the surrounding water (e.g., Katz, Chadwick, and Skinner, 1995). Some studies have found negative impacts to marine life from creosote-treated pier pilings, for example deformation and death of fish larvae exposed to leachate (Vines, Robbins, Griffin, and Cherr, 2000).

4.4 SUGGESTIONS

The use of standard Best Management Practices (BMPs) should effectively eliminate and/or reduce potential impacts to marine natural resources in the project vicinity. The corals and other organisms which are present within the project area are routinely subjected to high levels of turbidity, from both natural and anthropogenic causes. In the latter category, ship traffic and tug boat traffic activity resuspends large volumes of sediment daily (Wang et al., 2016). In spite of those conditions, several species of coral and other organisms have been able to successfully recruit to and survive at the project site. These organisms are presumably adapted to these relatively poor conditions. The authors suggest that it is possible that placement of silt curtains, which requires the use of weighted chains to secure the lower edge, may inadvertently cause more damage to corals and other organisms that could be crushed or abraded by the equipment,

compared with temporary turbidity increases associated with the required in-water work. If silt curtains are to be used, particular care should be taken to avoid the placement of any equipment at the three locations where moderate coral is present: the *Porites compressa* patch on the western spur, the *Montipora capitata* group at the tip of the eastern spur and the *Montipora capitata* complex along the western wall of the western inlet (map, Figure 26).

Regardless of whether turbidity curtains are used, realtime turbidity monitoring could be conducted to monitor for turbidity curtain failure and/or to assess changes in turbidity from project activities. Concurrently, the health of corals at the site could be monitored (for example using a real-time fluorescence system tested in Guam by SSC Pacific, supplemented with diving). This effort might allow better understanding of turbidity levels that corals in Pearl Harbor can withstand, and could be particularly useful for future implementation of Best Management Practices in the harbor during future work.

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5. CONCLUSIONS

The proposed project area supports a diverse array of sessile invertebrate species, including four species of scleractinian corals. All the species observed have been previously recorded throughout Pearl Harbor and the Main Hawaiian Islands, by numerous investigators (e.g., Coles, 1999; Smith, Deslarzes, and Brock, 2006). The only relatively rare species sighted were the pearl oysters. No sea grass was present, nor were any species of preferred green sea turtle forage, though turtles were sighted during the survey and one potential preferred turtle resting area was observed. The fin fish population was estimated to be comparatively low, relative to fish surveys completed in other portions of Pearl Harbor. No portion of the proposed project area, nor of the immediately adjacent areas surveyed meet the criteria for designation as Habitat Area of Particular Concern. Strict adherence to standard Best Management Practices will reduce negative impacts to surrounding marine natural resources.

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APPENDIX A

BENTHIC HABITAT MAPS OF THE QUAY WALL PROJECT AREA USING THE NOAA CLASSIFICATION SCHEME

A.1 OVERVIEW

Defining a common map classification system can improve project assessment and comparison; however class types and map scale must be relatable between project areas in order apply a classification system between projects in a meaningful way. We evaluated the NOAA benthic habitat mapping classification for the Quay Wall Project Site and determined that the NOAA system is not well-suited to project site benthic habitat types and is too coarse scale (MMU 1 acre compared to approx. MMU 0.02 acres) to be relevant for fine-scale project mapping. NOAA maps are presented here for informational purposes. The maps and map legends in Figure A-1 were extracted from the Printable Benthic Habitats Maps for the Main Hawaiian Islands 2007 shown in the web link in A.2. The project study site falls within Map 126.pdf and is highlighted in the red circle in the images in Figure A-1.

A.2. WEB LINK TO HAWAII MAPS

A full assortment of maps used to create Figure A-1 are can be found in the following link:

<https://products.coastalscience.noaa.gov/collections/benthic/e97hawaii/maps2007.aspx>

A.3 DETAIL AREA MAP OF UNCOLONIZED 90–100% BIOLOGICAL COVER

The project study site falls within Map 126.pdf and is highlighted in the red circle in the images in Figure A-1. Note the map in the red circle is the same area study but the legends and area maps show a different focus for each map nested in Figure A-1, map focus is detailed in the legends.

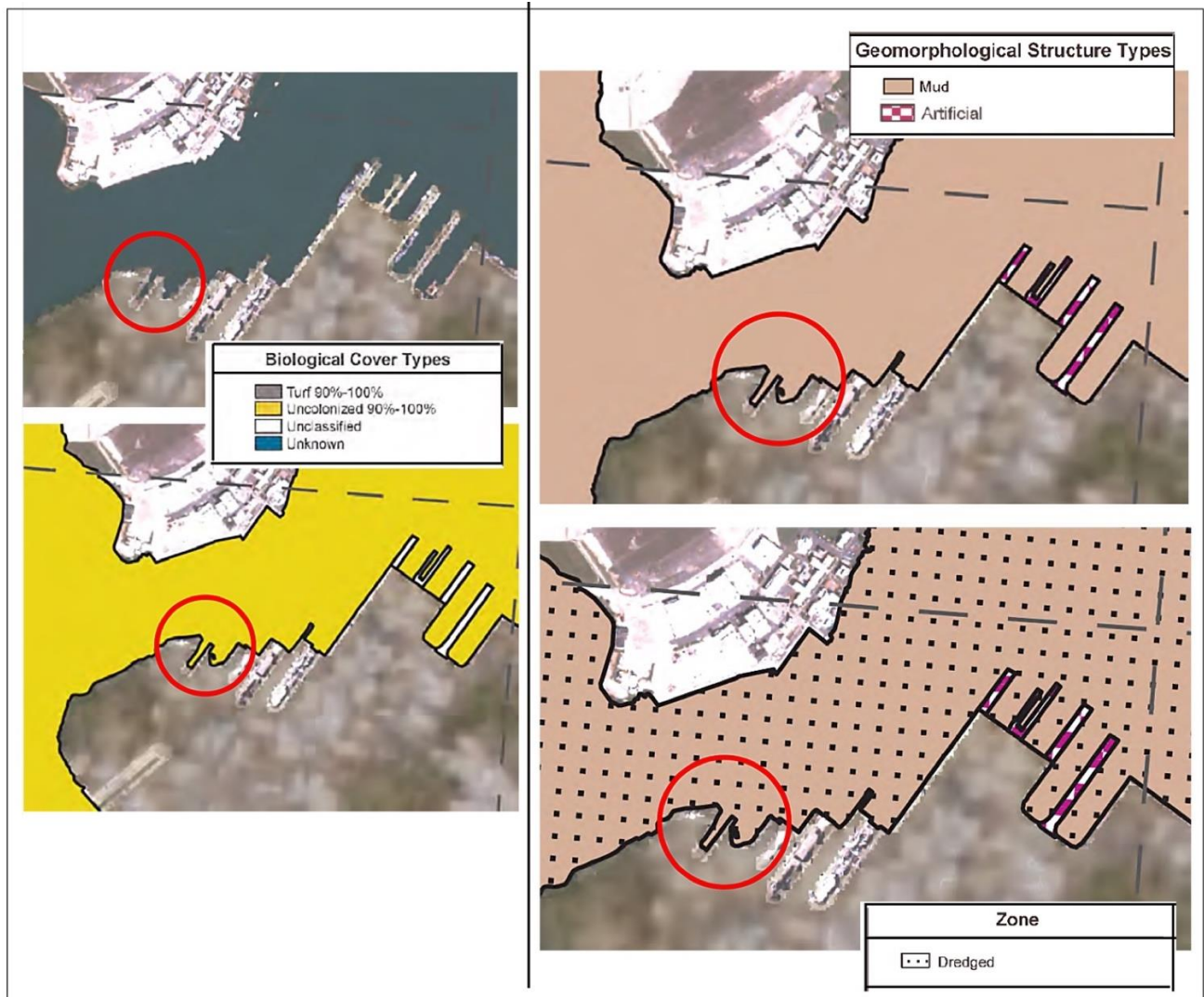


Figure A-1. Detail area map (left top) source aerial photo untouched, (left bottom) uncolonized 90–100% soil. (Right) Mud, artificial, and dredged areas are also shown.

APPENDIX B

SUMMARIZED FISH DATA COLLECTED DURING STATIONARY POINT COUNT SURVEYS

B.1 OVERVIEW

Appendix B has summarized fish data collected during stationary point count surveys in March 2018.

B.2 FISH METRICS COMPARISON TABLES

The tables presented in Appendix B: Table B-1 to Table B-6, show metrics compared on fish data collected:

Table B-1. Count #1, eastern spur west side center section.

Fish group	Fish genera	Fish species	Number observed	Size observed (cm)	Estimated weight (g)	Total biomass (g)
Surgeonfish	Acanthurus	<i>Acanthurus blochii</i>	1	8	10.5	10.5
			1	12	35.3	35.3
			3	15	68.9	206.8
			2	20	163.4	326.7
			1	25	319.1	319.1
			1	28	448.3	448.3
		<i>Acanthurus triostegus</i>	1	12	38.5	38.5
Damsel fish	Abudefduf	<i>Abudefduf abdominalis</i>	1	5	2.5	2.5
			2	7	7.0	14.1
			1	12	36.4	36.4
			1	16	87.6	87.6
			1	18	125.5	125.5
Butterflyfish	Chaetodon	<i>Chaetodon ephippium</i>	2	15	79.8	159.5
Unicornfish	Naso	<i>Naso Hexacanthus</i>	20	15	70.2	1404.6
Parrotfish	Scarus	<i>Scarus rubroviolaceus</i>	1	25	268.9	268.9
	N/A	Unidentified juvenile parrotfishes	5	5	1.9	9.3
			2	7	5.3	10.5
			2	6	3.3	6.5
Cardinalfish	Unidentified Apogonidae	N/A	5	5	1.1	5.5
					Total biomass (g)	3516.0

- Count #1, eastern spur west side center section, below exposed concrete block.
- Date: 3/20/2018, Start 10:13, end 10:43
- Depth: 16–20 ft (5.6–7 m), slope 45 degrees. Substrate: Rubble and rock outcrops with turf Visibility: 2–6 m (5.7–17.4 ft)

Table B-2. Count #2, eastern spur west side midway between exposed concrete block and seaward end of pier.

Fish group	Fish genera	Fish species	Number observed	Size observed (cm)	Estimated weight (g)	Total biomass (g)
Unidentified Surgeonfishes	N/A	N/A	1	15	72.9	72.9
			1	20	171.5	171.5
Unidentified juvenile parrotfishes	N/A	N/A	5	6	3.3	16.3
			1	7	5.3	5.3
			10	8	8.0	79.5
			20	10	15.8	316.9
			3	15	55.5	166.4
			1	17	81.7	81.7
Unidentified Wrasses	N/A	N/A	1	10	14.8	14.8
Unidentified Gobies	N/A	N/A	N/A	N/A	N/A	N/A
					Total biomass (g)	925.3

- Count #2, eastern spur west side midway between exposed concrete block and seaward end of pier.
- Date: 3/20/2018, Start 10:59, end 11:25
- Depth: 20 ft (7 m), slope 45 degrees. Substrate: Rubble, sponge, turf algae; more rugose than Count 1.
- Visibility: 4–5 m (11.5–14.4 ft)

Table B-3. Count #3, western spur near seaward tip.

Fish group	Fish genera	Fish species	Number observed	Size observed	Estimated weight (g)	Total biomass (g)
Unidentified benthic fish	N/A	N/A	10	<2 cm	N/A	N/A
Parrotfish	N/A	Unidentified juvenile parrotfishes	10	7	5.3	52.6
	Scarus	<i>Scarus rubroviolaceus</i>	1	25	268.9	268.9
Unidentified Gobies	N/A	N/A	2	3	0.3	0.5
			3	2	0.1	0.2
			11	5	1.2	13.2
Cardinalfish	Unidentified Apogonidae	N/A	5	5	1.1	5.5
Damselfish	Abudefduf	<i>Abudefduf abdominalis</i>	1	25	341.7	341.7
					Total biomass (g)	682.6

- Count #3, western spur near seaward tip. Date: 3/20/2018, Start 12:29, end 13:04
- Depth: 16 ft (5.6 m), slope 30 degrees. Substrate: Rubble Visibility: variable, 2–3 m (2.7–8.6 m)

Table B-4. Count #4, eastern east side between exposed concrete block and seaward end of pier.

Fish group	Fish genera	Fish species	Number observed	Size observed	Estimated weight (g)	Total biomass (g)
Surgeonfish	Acanthurus	<i>Acanthurus blochii</i>	12	20	163.4	1960.3
			1	30	551.3	551.3
		<i>Acanthurus nigrofuscus</i>	1	12	40.3	40.3
		<i>Acanthurus xanthopterus</i>	1	30	539.9	539.9
	Zebrasoma	<i>Zebrasoma veliferum</i>	1	18	117.6	117.6
			1	20	160.3	160.3
			1	25	309.0	309.0
Snapper	Lutjanus	<i>Lutjanus fulvus</i>	1	25	221.8	221.8
			1	30	381.9	381.9
Barracuda	Sphyraena	<i>Sphyraena barracuda</i>	1	60	1373.6	1373.6

- Count #4, eastern east side between exposed concrete block and seaward end of pier. Date: 3/22/2018, Start 11:03, end 11:28
- Depth: 18 ft (6.3 m), slope 45 degrees, then undercut ledge deeper. Substrate: Rock with turf and sponge dominant
- Visibility: 7.5 m (21.6 ft) until 15 mins, then dropped to 5.5 m (15.8 ft)

Table B-4. Count #4, eastern east side between exposed concrete block and seaward end of pier. (Continued)

Fish group	Fish genera	Fish species	Number observed	Size observed	Estimated weight (g)	Total biomass (g)
Butterflyfish	Chaetodon	<i>Chaetodon auriga</i>	N/A	N/A	N/A	N/A
		<i>Chaetodon ephippium</i>	1	20	54.3	54.3
Unidentified parrotfish	N/A	N/A	3	15	55.5	166.4
Unidentified gobies	N/A	N/A	3	2.5	0.1	0.4
			1	3	0.3	0.3
			1	4	0.6	0.6
					Total biomass (g)	5878.2

- Count #4, eastern east side between exposed concrete block and seaward end of pier. Date: 3/22/2018, Start 11:03, end 11:28
- Depth: 18 ft (6.3 m), slope 45 degrees, then undercut ledge deeper. Substrate: Rock with turf and sponge dominant
- Visibility: 7.5 m (21.6 ft) until 15 mins, then dropped to 5.5 m (15.8 ft)

Table B-5. Count #5, eastern spur east side midway between end of pier and thumb pier.

Fish group	Fish genera	Fish species	Number observed	Size observed	Estimated weight (g)	Total biomass (g)
Surgeonfish	Acanthurus	<i>Acanthurus blochii</i>	1	15	68.9	68.9
			2	18	119.1	238.2
			1	25	319.1	319.1
			1	30	551.3	551.3
	Zebrasoma	<i>Acanthurus nigrofuscus</i>	N/A	N/A	N/A	N/A
		<i>Zebrasoma veliferum</i>	2	18	117.6	235.3
		<i>Zebrasoma flavescens</i>	2	12	31.3	62.6
Unicornfish	Naso	<i>Naso hexacanthus</i>	N/A	N/A	N/A	N/A
Snapper	Lutjanus	<i>Lutjanus fulvus</i>	1	25	221.8	221.8
			1	30	381.9	381.9
Unidentified gobies	N/A	N/A	1	2	0.1	0.1
Unidentified parrotfish	N/A	N/A	3	15	55.5	166.4
Butterflyfish	Chaetodon	<i>Chaetodon ephippium</i>	1	15	79.8	79.8
			1	12	40.7	40.7
Moray eel	Gymnothorax	<i>Gymnothorax melatremus</i>	1	25	26.7	26.7
					Total biomass (g)	2392.7

- Count #5, eastern spur east side midway between end of pier and thumb pier.
- Date: 3/22/2018, Start 11:30, end 11:55
- Depth: 18 ft (6.3 m), slope 45 degrees-90, then undercut ledge deeper. Substrate: Rock with turf and sponge dominant
- Visibility: 6 m (17.2 ft)

Table B-6. Count #6, western spur 15m west of exposed metallic post.

Fish group	Fish genera	Fish species	Number observed	Size observed	Estimated weight (g)	Total biomass (g)
Unidentified benthic fish	N/A	N/A	10	<2 cm	N/A	N/A
Parrotfish	N/A	Unidentified juvenile parrotfishes	10	7	5.3	52.6
	Scarus	<i>Scarus rubroviolaceus</i>	1	25	268.9	268.9
Unidentified Gobies	N/A	N/A	2	3	0.3	0.5
			3	2	0.1	0.2
			11	5	1.2	13.2
Cardinalfish	Unidentified Apogonidae	N/A	5	5	1.1	5.5
Damselfish	Abudefduf	<i>Abudefduf abdominalis</i>	1	25	341.7	341.7
					Total biomass (g)	682.6

- Count #6, western spur 15m west of exposed metallic post.
- Date: 3/22/2018, Start 12:18, end 12:43
- Depth: 16 ft (5.6 m), slope >45 degrees. Substrate: Rubble with some exposed solid rock
- Visibility: variable, 2.5–4 m (7.2–11.5 ft)

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APPENDIX C

FISH SPECIES LENGTH AND WEIGHT COMPARISON CHART

C.1 OVERVIEW

Fish length-weight relationships used, derived from Bayesian relationships summarized on Fishbase.org. When no entries were available for a particular species (or for species not identified), source of measurement is noted to the right. Equation used to convert total length (TL, in cm) to weight (W, in g):

$$W = a * TL^b$$

C.2 FISH SPECIES IDENTIFIED, DETAIL LENGTH/WEIGHT

See Figure C-1 for fish species length-weight relationships used to estimate biomass from top to bottom: (A) relationships used for fish that were identified to species level, (B) relationships used for fish that could not be identified to species level.

	Fish species identified	Length-weight		Notes when data not readily available
		a	b	
(A)	<i>Acanthurus blochii</i>	0.02042	3	Used data from sargeant-major
	<i>Acanthurus triostegus</i>	0.02399	2.97	
	<i>Acanthurus nigrofusus</i>	0.02512	2.97	
	<i>Acanthurus xanthopterus</i>	0.02291	2.96	
	<i>Abudefduf abdominalis</i>	0.01862	3.05	
	<i>Chaetodon auriga</i>	0.02512	2.99	
	<i>Chaetodon ephippium</i>	0.02239	3.02	
	<i>Naso Hexacanthus</i>	0.02138	2.99	
	<i>Scarus rubroviolaceus</i>	0.01288	3.09	
	<i>Lutjanus fulvus</i>	0.01514	2.98	
	<i>Zebrasoma flavescens</i>	0.01905	2.98	
	<i>Zebrasoma veliferum</i>	0.02399	2.94	
	<i>Sphyræna barracuda</i>	0.00813	2.94	
	<i>Gymnothorax melatremus</i>	0.00132	3.08	
				Used data from Mediterranean moray
	Unidentified fish	Length-weight		
		a	b	
(B)	Cardinalfish	0.00646	3.19	Used data from Hartzfeld's cardinalfish (Phillipines)
	Parrotfish	0.01288	3.09	Used data from <i>Scarus rubroviolaceus</i>
	Wrasse	0.0166	2.95	Used data from fourline wrasse
	Goby	0.00871	3.06	Used data from eyebar goby
	Surgeonfish	0.02311	2.975	Used averages of <i>Acanthurus</i> above

- (A) Length-weight relationships for fish identified to species.
- (B) Length-weight relationships used for species that could not be identified to species.

Figure C-1. This figure shows fish species length-weight relationships used to estimate biomass.

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APPENDIX D

VISUAL PERCENT COVER ASSESSMENTS FOR EACH BENTHIC CATEGORY

D.1 OVERVIEW

The entries shown in Appendix D are visual percent cover assessments for each benthic category contained in 1m² (8.4ft²) quadrats laid on transects. Georeferenced photographs are included as a separate attachment. There are 14 Tables in Appendix D: Transects specific to Rail are shown in Tables D1 to D3 Visual percent cover assessments transects are shown in Tables D4 to D11.

D.2. VISUAL PERCENT COVER ASSESSMENTS TABLES

This section contains tables that show transect details by quadrant. Included are photo number, and a detail of which specific subject is listed, i.e., live coral, rock, shell hash and other subjects as shown.

Table D-1. Visual percent cover assessments transect #R1.

Quadrat Number	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
1	4351	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
2	4352	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
3	4353	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
4	4354	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
5	4355	0	0	0	0	0	0	0	0	1	0	0	0	0	0	99
6	4356	0	0	0	0	0	0	0	0	1	0	0	0	0	0	99
7	4357	0	0	0	0	0	0	0	0	2	0	0	0	0	0	98
8	4358	0	0	0	0	0	0	0	0	2	0	0	0	0	0	98
9	4359	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
10	4360	0	0	0	0	0	0	0	0	3	0	0	0	0	0	97
11	4361	0	0	0	0	0	0	0	0	2	0	0	0	0	0	98
12	4362	0	0	0	0	0	0	0	0	1	0	0	0	0	0	99
13	4363	0	0	0	0	0	0	0	0	2	0	0	0	0	0	98
14	4365	0	0	0	0	0	0	0	0	1	0	0	0	0	0	99
15	4367	0	0	0	0	0	0	0	0	5	0	0	0	0	0	95
16	4368	0	0	0	0	0	0	0	0	2	0	0	0	0	0	98
17	4370	0	0	0	0	0	0	0	0	10	0	0	0	0	0	90
18	4371	0	0	0	0	0	0	0	1	3	0	0	0	0	0	96
19	4374	0	0	0	0	0	0	0	0	5	0	0	0	0	0	95

Table D-2. Visual percent cover assessments transect #R2.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4376	45	0	0	0	0	0	0	0	5	0	0	0	0	0	50
3	4377	5	0	0	0	0	0	0	0	5	0	0	0	0	0	90
6	4379	5	0	0	0	0	0	0	0	10	0	0	0	0	0	85
9	4381	2	0	0	0	0	0	0	0	5	0	0	0	0	0	93
12	4382	1	0	0	0	0	0	0	0	30	0	0	0	0	0	69
15	4383	10	0	0	0	0	0	0	0	5	0	0	0	0	0	85
18	4384	15	0	0	0	0	0	0	0	5	0	0	0	0	0	80
21	4385	1	0	0	0	0	0	0	0	5	0	0	0	0	0	94
24	4386	5	0	0	0	0	0	0	0	10	0	0	0	0	0	85
27	4388	5	0	0	0	0	0	0	0	10	0	0	0	0	0	85

Table D-3. Visual percent cover assessments transect #R3.

Quadrat Number	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
20	4389	5	0	0	0	0	0	0	0	10	0	5	0	0	0	80
21	4390	1	0	0	0	0	0	0	0	20	0	0	0	0	0	79
22	4391	10	0	0	0	0	0	0	0	20	0	0	0	0	0	70
23	4392	1	0	0	0	0	0	0	0	15	0	0	0	0	0	84
24	4394	15	0	0	0	0	1	0	0	10	0	0	0	0	0	74
25	4395	36	0	0	0	0	0	0	0	10	0	0	0	0	0	54
26	4396	2	0	0	0	0	0	0	0	5	0	5	0	0	0	88
27	4397	1	0	0	0	0	0	0	0	5	0	15	0	0	0	79
28	4398	1	0	0	0	3	0	0	0	5	0	20	0	0	0	71
29	4399	5	0	0	0	0	0	0	0	15	0	25	0	0	0	55
30	4401	1	0	0	0	0	0	0	0	3	0	10	0	0	0	86
31	4402	0	0	0	0	0	0	0	0	5	0	10	0	0	0	85
32	4403	0	0	0	0	5	0	0	0	5	0	5	0	0	0	85
33	4404	1	0	0	0	0	0	0	0	5	0	0	0	0	0	94
25	4395	36	0	0	0	0	0	0	0	10	0	0	0	0	0	54
26	4396	2	0	0	0	0	0	0	0	5	0	5	0	0	0	88
27	4397	1	0	0	0	0	0	0	0	5	0	15	0	0	0	79
28	4398	1	0	0	0	3	0	0	0	5	0	20	0	0	0	71
29	4399	5	0	0	0	0	0	0	0	15	0	25	0	0	0	55
30	4401	1	0	0	0	0	0	0	0	3	0	10	0	0	0	86
31	4402	0	0	0	0	0	0	0	0	5	0	10	0	0	0	85
32	4403	0	0	0	0	5	0	0	0	5	0	5	0	0	0	85
33	4404	1	0	0	0	0	0	0	0	5	0	0	0	0	0	94

Table D-4. Visual percent cover assessments, Transect #1.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4575	0	1	0	0	0	0	0	0	50	0	0	0	0	0	49
3	4576	0	0	2	0	0	0	0	0	60	0	0	1	0	0	37
6	4577	1	0	0	0	0	0	0	0	20	0	0	3	0	0	76
9	4578	5	0	0	0	0	0	0	0	35	0	0	2	0	0	58
12	4580	0	0	0	0	0	0	0	0	20	0	0	1	0	0	79
15	4581	0	0	0	0	0	0	0	0	25	0	0	20	0	0	55
18	4582	1	0	0	0	0	0	0	2	20	0	0	5	0	0	72
21	4583	0	0	1	0	0	0	0	0	20	0	30	0	0	0	49
24	4584	0	0	0	5	0	0	0	0	30	0	0	0	0	15	50
27	4585	1	0	0	0	0	0	0	0	20	0	0	0	0	15	64

Table D-5. Visual percent cover assessments, Transect #2.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4553	5	0	0	0	0	0	0	0	35	0	0	1	0	0	59
3	4555	5	0	0	0	0	0	0	0	40	0	0	0	0	0	55
6	4558	0	0	0	0	0	0	0	0	20	0	0	0	0	0	80
9	4560	0	0	0	0	0	0	0	0	40	0	0	1	0	0	59
12	4561	1	0	0	0	0	0	1	0	60	1	0	0	0	0	37
15	4564	1	0	0	0	0	10	0	0	20	0	0	0	0	0	69
18	4565	10	0	0	0	0	0	0	0	20	0	0	1	0	0	69
21	4567	0	0	0	0	0	5	0	0	40	0	0	1	0	0	54
24	4569	0	0	0	0	0	2	0	0	30	0	0	0	0	0	68
27	4570	0	0	0	0	0	1	0	0	20	0	0	0	0	0	79

Table D-6. Visual percent cover assessments, Transect #3.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4443	1	0	20	0	0	0	0	0	35	0	0	3	0	20	21
3	4445	1	0	0	0	0	0	0	0	25	0	0	20	0	20	34
6	4446	0	0	10	0	0	0	0	0	10	0	0	10	0	30	40
9	4448	1	0	5	0	0	0	0	0	5	0	0	5	0	20	64
12	4449	1	0	1	0	0	0	0	0	20	0	0	5	0	20	53
15	4450	20	0	0	0	0	0	0	0	10	0	0	0	0	20	50
18	4452	10	0	0	0	0	0	0	0	10	0	50	0	0	0	30
21	4454	3	0	0	0	0	0	0	0	15	0	20	0	0	0	62
24	4455	10	3	0	0	0	0	0	0	15	0	0	10	0	0	62
27	4457	1	0	0	0	0	0	0	0	20	0	0	0	0	0	79

Table D-7. Visual percent cover assessments, Transect #4.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	3407	0	0	0	0	0	0	0	0	1	0	0	0	0	30	69
3	3408	0	0	0	0	0	0	0	0	5	0	0	0	0	0	95
6	3409	0	0	0	0	0	0	0	0	2	0	0	0	0	20	78
9	3410	0	0	0	0	0	0	0	0	2	0	0	0	0	0	98
12	3411	0	0	0	0	0	0	0	0	3	0	0	0	0	10	87
15	3412	1	0	0	0	0	0	0	0	2	0	0	0	0	3	94
18	3413	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
21	3414	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100

Table D-8. Visual percent cover assessments, Transect #5.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4418	2	0	1	0	0	0	0	0	3	0	0	15	0	0	79
3	4419	1	0	1	0	0	0	0	0	15	0	0	20	0	0	63
6	4421	1	0	0	0	1	0	0	0	20	0	0	1	0	5	72
9	4422	5	0	0	0	0	1	0	0	25	0	0	5	0	15	49
12	4423	4	0	0	0	0	0	0	0	15	0	0	0	0	75	6
15	4425	1	0	1	0	0	0	0	0	20	0	0	5	0	30	43
18	4426	1	0	0	0	0	1	0	0	25	0	0	5	0	5	63
21	no photo	5	0	0	0	0	0	0	0	30	0	0	3	0	5	57
24	3397	15	1	0	0	0	0	0	0	25	0	0	5	0	10	44
27	3398	2	0	0	0	0	0	0	0	20	0	0	3	0	15	60

Table D-9. Visual percent cover assessments, Transect #6.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	3399	1	0	0	0	0	0	0	0	20	0	5	0	40	0	34
3	3400	1	0	0	0	0	0	0	0	40	0	2	0	0	0	57
6	3401	0	1	10	0	0	0	0	0	15	0	5	0	0	0	69
9	3402	1	1	0	0	0	0	0	0	20	0	15	0	0	0	63
12	3403	2	0	0	0	0	0	0	0	20	0	0	0	15	0	63
15	3404	3	0	0	0	0	0	0	0	30	0	0	0	10	0	57
18	3405	3	0	0	0	0	0	0	0	40	0	0	0	5	0	52

Table D-10. Visual percent cover assessments, Transect #7.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4530	0	0	0	0	0	0	0	0	30	0	0	1	0	20	49
3	4531	0	0	0	0	0	0	0	0	30	0	0	0	0	30	40
6	4532	0	0	0	0	0	0	0	0	30	0	0	1	69	0	0
9	4533	1	0	0	0	0	0	0	0	60	0	0	0	0	0	39
12	4534	10	1	0	0	0	0	0	0	25	0	0	1	0	0	63
15	4536	12	1	0	0	0	0	0	0	20	0	0	1	0	0	66
18	4538	0	0	0	0	0	0	0	0	40	0	0	1	0	0	59
21	4539	1	0	0	0	0	1	0	0	30	0	0	1	0	0	67
24	4540	1	0	0	0	0	0	0	0	50	0	0	1	0	0	48
27	4542	1	0	0	0	0	0	0	20	60	0	0	3	0	0	16

Table D-11. Visual percent cover assessments, Transect #8.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4516	0	0	0	0	0	0	0	0	20	0	0	0	0	30	50
3	4517	1	0	0	0	0	0	0	0	30	0	0	5	0	0	64
6	4518	1	0	0	0	0	0	0	0	30	0	0	0	0	0	69
9	4520	5	0	0	0	0	0	0	0	40	0	0	1	0	0	54
12	4521	7	0	0	0	0	0	0	0	30	0	0	1	0	0	62
15	4523	1	0	0	0	0	1	0	0	35	0	0	0	0	0	63
18	4524	1	0	0	0	0	0	0	0	25	0	0	1	0	0	73
21	4525	1	0	0	0	0	0	0	0	15	0	0	1	0	0	83
24	4526	0	0	0	0	0	0	0	0	50	0	0	1	0	0	49
27	4527	1	0	0	0	0	0	0	0	0	0	0	0	40	0	59

Table D-12. Visual percent cover assessments, Transect #9.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4462	2	0	0	0	0	0	0	0	10	0	0	5	0	45	38
3	4464	5	1	0	0	0	0	0	0	15	1	0	0	0	55	23
6	4465	4	0	0	0	0	0	0	0	20	0	0	0	0	15	61
9	4466	1	0	0	0	0	0	0	0	15	0	0	0	0	60	24
12	4468	1	0	0	0	0	0	0	0	30	0	0	5	0	60	4
15	4469	5	0	0	0	0	0	0	0	35	0	0	0	0	20	40
18	4470	2	0	10	0	0	0	0	0	30	0	0	5	0	30	23
21	4472	1	0	60	0	0	0	0	0	10	0	0	1	0	0	28
24	4474	5	5	0	0	0	0	0	0	20	0	0	5	0	30	35
27	4475	1	3	0	0	0	0	0	0	25	0	0	10	0	31	30

Table D-13. Visual percent cover assessments, Transect #10.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4484	4	0	5	0	0	0	0	0	5	0	0	5	0	40	41
3	4486	2	0	0	0	0	0	0	0	25	0	0	0	0	0	73
6	4487	30	0	5	0	0	0	0	0	5	0	0	0	0	20	40
9	4489	0	1	0	0	0	0	0	0	10	0	0	0	0	25	64
12	4491	5	0	0	0	0	0	0	0	30	0	0	0	0	20	45
15	4493	0	0	0	0	0	0	0	0	20	0	0	0	0	0	80
18	4495	0	0	0	0	0	0	0	0	5	0	0	0	0	5	90
21	4496	0	0	1	20	0	0	0	0	15	0	0	0	0	40	24
24	4498	0	0	10	0	0	0	0	0	5	0	0	0	0	50	35
27	4501	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0

Table D-14. Visual percent cover assessments, Transect #11.

Quadrat location (m)	Photo Number	Live Coral	Dead Coral	Debris	Organic Debris	Barnacle	Polychaete	Hydroid	Turf Algae	Sponge/Tunicate	Live Bivalves	Shell Hash	Dead Bivalves	Scoured Rock	Rock	Soft Sediment
0	4595	0	0	0	0	0	0	0	0	20	0	0	0	20	0	60
3	4596	1	0	10	0	0	0	0	0	15	0	0	1	0	50	23
6	4597	1	0	0	50	0	0	0	0	10	0	0	1	0	0	38
9	4598	0	0	0	50	0	0	0	0	10	0	0	1	0	0	39
12	4599	0	0	0	0	0	0	0	0	20	0	0	0	0	30	50
15	4600	0	0	15	15	0	0	0	0	30	0	0	0	0	0	40
18	4601	0	0	0	0	0	0	0	0	20	0	0	0	0	0	80
21	4602	1	0	0	0	0	1	0	0	20	0	0	0	0	15	63
24	4603	0	0	5	0	0	0	0	0	10	0	0	0	0	0	85
27	4604	1	0	0	0	0	0	0	0	10	0	0	0	0	5	84

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APPENDIX E

CORAL BELT TRANSECT DATA

E.1 OVERVIEW

Coral belt transect data: all corals within a 1 m (2.9ft) belt around each transect were identified to species and measured to the nearest bin size.

E.2. CORAL BELT TRANSECT DATA TABLE

The following transect table shows the number of corals identified in each size bin ranging in size from 0 to 60 cm in increments of five cm. The Corals identified under each belt transect are shown in Table E-1.

Table E-1. Corals identified under each belt transect.

Transect #	Coral species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60
1	<i>Leptastrea purpurea</i>	7	1	0	0	0	0	0	0	0	0	0	0
1	<i>Montipora capitata</i>	0	0	0	1	0	0	0	0	0	0	0	0
1	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
1	<i>Pocillopora damicornis</i>	0	0	0	0	0	0	0	0	0	0	0	0
2	<i>Leptastrea purpurea</i>	3	3	2	3	0	0	0	0	0	0	0	0
2	<i>Montipora capitata</i>	0	2	2	1	0	0	0	0	0	0	0	0
2	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
2	<i>Pocillopora damicornis</i>	3	3	2	3	0	0	0	0	0	0	0	0
3	<i>Leptastrea purpurea</i>	11	2	0	0	0	0	0	0	0	0	0	0
3	<i>Montipora capitata</i>	0	0	0	0	0	0	0	0	0	0	0	0
3	<i>Porites compressa</i>	1	6	2	4	0	0	1	0	0	0	0	0
3	<i>Pocillopora damicornis</i>	6	7	0	0	0	0	0	0	0	1	0	1
4	<i>Leptastrea purpurea</i>	3	0	0	0	0	0	0	0	0	0	0	0
4	<i>Montipora capitata</i>	0	0	1	0	0	0	0	0	0	0	0	0
4	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
4	<i>Pocillopora damicornis</i>	0	0	0	0	0	0	0	0	0	0	0	0
5	<i>Leptastrea purpurea</i>	52	5	0	0	0	0	0	0	0	0	0	0
5	<i>Montipora capitata</i>	0	0	0	0	0	0	0	0	0	0	0	0
5	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
5	<i>Pocillopora damicornis</i>	17	36	0	10	1	0	0	0	0	0	0	0
6	<i>Leptastrea purpurea</i>	52	5	0	0	0	0	0	0	0	0	0	0

- Coral sizes shown in table are bins of 5 cm.

Table E-1. Corals identified under each belt transect. (Continued)

Transect #	Coral species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60
6	<i>Montipora capitata</i>	0	0	0	0	0	0	0	0	0	0	0	0
6	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
6	<i>Pocillopora damicornis</i>	17	36	10	1	1	0	0	0	0	0	0	0
7	<i>Leptastrea purpurea</i>	5	0	0	0	0	0	0	0	0	0	0	0
7	<i>Montipora capitata</i>	0	0	1	0	0	0	4	0	0	0	0	0
7	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
7	<i>Pocillopora damicornis</i>	3	5	9	0	0	0	0	0	0	0	0	0
8	<i>Leptastrea purpurea</i>	5	2	0	0	0	0	0	0	0	0	0	0
8	<i>Montipora capitata</i>	0	0	0	0	0	0	0	0	0	0	0	0
8	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
8	<i>Pocillopora damicornis</i>	0	8	5	0	0	0	0	0	0	0	0	0
9	<i>Leptastrea purpurea</i>	30	2	0	0	0	0	0	0	0	0	0	0
9	<i>Montipora capitata</i>	0	0	0	0	0	0	0	0	0	0	0	0
9	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
9	<i>Pocillopora damicornis</i>	25	13	2	0	0	0	0	0	0	0	0	0
10	<i>Leptastrea purpurea</i>	7	0	0	0	0	0	0	0	0	0	0	0
10	<i>Montipora capitata</i>	3	3	1	0	0	0	0	0	0	0	0	0
10	<i>Porites compressa</i>	0	2	0	1	1	0	0	0	0	0	0	0
10	<i>Pocillopora damicornis</i>	0	0	0	1	0	0	0	0	0	0	0	0
11	<i>Leptastrea purpurea</i>	3	0	0	0	0	0	0	0	0	0	0	0
11	<i>Montipora capitata</i>	0	0	0	0	0	0	0	0	0	0	0	0

- Coral sizes shown in table are bins of 5 cm.

Table E-1. Corals identified under each belt transect. (Continued)

Transect #	Coral species	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60
11	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
11	<i>Pocillopora damicornis</i>	0	0	0	0	0	0	0	0	0	0	0	0
R1	<i>Leptastrea purpurea</i>	1	0	0	0	0	0	0	0	0	0	0	0
R1	<i>Montipora capitata</i>	0	0	0	1	0	0	0	0	0	0	0	0
R1	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
R1	<i>Pocillopora damicornis</i>	0	0	0	0	0	0	0	0	0	0	0	0
R2	<i>Leptastrea purpurea</i>	50	19	0	0	0	0	0	0	0	0	0	0
R2	<i>Montipora capitata</i>	1	2	1	4	2	4	0	0	0	1	0	0
R2	<i>Porites compressa</i>	0	0	0	0	0	0	0	0	0	0	0	0
R2	<i>Pocillopora damicornis</i>	1	7	0	2	0	0	0	0	0	0	0	0
R3	<i>Leptastrea purpurea</i>	59	45	3	0	0	0	0	0	0	0	0	0
R3	<i>Montipora capitata</i>	0	2	0	0	0	1	3	0	0	0	0	0
R3	<i>Porites compressa</i>	0	0	1	0	0	0	0	0	1	0	0	0
R3	<i>Pocillopora damicornis</i>	1	12	3	2	0	0	0	0	0	0	0	0
Site-wide	<i>Leptastrea purpurea</i>	288	84	5	3	0	0	0	0	0	0	0	0
Site-wide	<i>Montipora capitata</i>	4	9	6	7	2	5	7	0	0	1	0	0
Site-wide	<i>Porites compressa</i>	1	8	3	5	1	0	1	0	1	0	0	0
Site-wide	<i>Pocillopora damicornis</i>	73	127	31	19	2	0	0	0	0	1	0	1

- Coral sizes shown in table are bins of 5 cm.

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This report tracks progress on a project that consisted of three tasks: Task 1. Dive survey of quay wall project site, consisting of four subtasks: Initial roving diver assessment to assess general conditions and refine full survey requirements based on presence of features of interest including essential fish habitat (EFH) that must be quantitatively assessed for regulatory approval. Quantitative mobile organism survey including dedicated fish data collection dives using methods adapted from NOAA's Rapid Ecological Assessment survey methodology, and qualitative observations of turtles, marine mammals and mobile invertebrates. Geospatial benthic habitat survey including: collection of quantitative benthic habitat cover estimates using transect and quadrat sampling, coral cover and size-frequency distribution assessment using belt transects and collection of scaled, georeferenced photographs of representative substrates, habitats, and features collection of geospatial (map) data including: survey locations, features of interest, approximate borders of substrate types and locations of quantitative benthic habitat cover estimates. Task 2. Geospatial and photographic data processing and delivery Task 3. Dive survey and assessment report.						
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