Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration

NATIONAL MARINE SANCTUARIES CONSERVATION SCIENCE SERIES

Baseline Ecological Assessment of Artificial Reef, High Island A-389-A: Pre- and Post-partial Structure Removal

August 2020 | sanctuaries.noaa.gov | National Marine Sanctuaries Conservation Series ONMS-20-11

U.S. Department of Commerce
Wilbur Ross, Secretary

National Oceanic and Atmospheric Administration
Neil A. Jacobs, Ph.D.
Assistant Secretary of Commerce for
Environmental Observation and Prediction

National Ocean Service
Nicole LeBoeuf, Assistant Administrator (Acting)

Office of National Marine Sanctuaries
John Armor, Director

Report Authors:

Michelle A. Johnston[1], Marissa F. Nuttall[2], Kelly O’Connell[2], Jimmy MacMillan[2], Raven D. Blakeway[2], Erik Ebert[3], Chris Taylor[3], Emma L. Hickerson[1], John A. Embesi[2], and G.P. Schmahl[1]

[1]NOAA Flower Garden Banks National Marine Sanctuary, Galveston, TX

[2]Cardinal Point Captains, Inc., Galveston, TX

[3]NOAA National Centers for Coastal Ocean Science, Beaufort, NC

Suggested Citation:
Johnston, M.A., M.F. Nuttall, K. O’Connell, J. MacMillan, R.D. Blakeway, E. Ebert, C. Taylor, E.L. Hickerson, J.A. Embesi, and G.P. Schmahl. 2020. Baseline Ecological Assessment of Artificial Reef, High Island A-389-A: Pre- and Post-Structure Removal. National Marine Sanctuaries Conservation Series ONMS-20-11. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Flower Garden Banks National Marine Sanctuary, Galveston, TX. 201 pp.

Cover Photo:
Diver conducts roving fish survey at High Island A-389-A. Photo: Ryan Eckert/CPC

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

NATIONAL MARINE
SANCTUARIES

About the National Marine Sanctuaries Conservation Series

The Office of National Marine Sanctuaries, part of the National Oceanic and Atmospheric Administration, serves as the trustee for a system of underwater parks encompassing more than 600,000 square miles of ocean and Great Lakes waters. The 14 national marine sanctuaries and two marine national monuments within the National Marine Sanctuary System represent areas of America's ocean and Great Lakes environment that are of special national significance. Within their waters, giant humpback whales breed and calve their young, coral colonies flourish, and shipwrecks tell stories of our nation's maritime history. Habitats include beautiful coral reefs, lush kelp forests, whale migration corridors, spectacular deep-sea canyons, and underwater archaeological sites. These special places also provide homes to thousands of unique or endangered species and are important to America's cultural heritage. Sites range in size from less than one square mile to almost 583,000 square miles. They serve as natural classrooms and cherished recreational spots, and are home to valuable commercial industries.

Because of considerable differences in settings, resources, and threats, each marine sanctuary has a tailored management plan. Conservation, education, research, monitoring, and enforcement programs vary accordingly. The integration of these programs is fundamental to marine protected area management. The National Marine Sanctuaries Conservation Series reflects and supports this integration by providing a forum for publication and discussion of the complex issues currently facing the National Marine Sanctuary System. Topics of published reports vary substantially and may include descriptions of educational programs, discussions on resource management issues, and results of scientific research and monitoring projects. The series facilitates integration of natural sciences, socioeconomic and cultural sciences, education, and policy development to accomplish the diverse needs of NOAA's resource protection mandate. All publications are available on the Office of National Marine Sanctuaries website (https://sanctuaries.noaa.gov).

Disclaimer

Report Availability

Electronic copies of this report may be downloaded from the Office of National Marine Sanctuaries web site at https://sanctuaries.noaa.gov.

Contact

G.P. Schmahl, Superintendent
NOAA Flower Garden Banks National Marine Sanctuary
NOAA Galveston Laboratory
4700 Avenue U, Bldg. 216
Galveston, TX 77551
(409) 356-0383
George.Schmahl@noaa.gov

Or

Douglas Peter, Artificial Reef Coordinator
Bureau of Safety and Environmental Enforcement
Gulf of Mexico OCS Region
1201 Elmwood Park Blvd., GE466
New Orleans, LA 70123
(504) 736-7514
Douglas.Peter@bsee.gov

Table of Contents

Table of Contents iii

Abstract vi

Key Words vi

Chapter 1. Introduction to Assessment of High Island A-389-A........ 1

  Background 2

  Biological Community on HI-A-389-A 7

  Assessment Objectives 11

  Assessment Components 11

  Field Operations and Data Collection 12

Chapter 2. Methods 14

  Study Design 15

  Methods Conducted Using Scuba 20

    Random Photographic Transects 20

    Repetitive Photostation Images 25

    Roving Diver Fish Surveys 28

    Belt Transect Fish Surveys 31

  ROV Methods 32

    Repetitive Photographic Transects 32

    Seafloor Random Photographic Transects 34

    Seafloor Random and Repetitive Transect Fish Surveys 35

    Roving ROV Fish Surveys 36

  Fish Acoustics Methods 36

    Fish Acoustics Surveys 36

  Water Quality 40

    Water Column Profiles 40

Chapter 3. Benthic Surveys 41

  Photographic Transects on Horizontal Beams 42

    Pre-Removal Horizontal Beam Benthic Results 42

    Post-Removal Horizontal Beam Benthic Results 54

    Comparison of Pre- and Post-Removal Horizontal Beam Benthic Results 64

Photographic Transects on Vertical Pilings 77
  Pre-Removal Vertical Piling Benthic Results 77
  Opportunistic Vertical Pile Survey Results after EFGB Localized Mortality Event 84
  Post-Removal Vertical Piling Benthic Results 85
  Comparison of Pre- and Post-Removal Vertical Piling Benthic Results 92
Repetitive Photostations 101
  Repetitive Photostation Analysis and Results 101
Seafloor Surveys 105
  Pre-Removal Seafloor Surveys Benthic Results 105
  Post-Removal Seafloor Surveys Benthic Results 106
  Comparison of Pre- and Post-Removal Seafloor Surveys Benthic Results 109
Benthic Community Comparison and Discussion 109
  Pre-Removal Benthic Community 109
  Post-Removal Benthic Community 110
  Pre- and Post-Removal Benthic Community 112
Chapter 4. Fish Surveys 122
Fish Surveys 123
  Pre-Removal Fish Abundance Results 123
  Post-Removal Fish Abundance Results 139
  Comparison of Pre- and Post-Removal Fish Abundance Results 152
Fish Surveys Comparison and Discussion 161
  Pre-Removal Fish Abundance 161
  Post-Removal Fish Abundance 161
  Pre- and Post-Removal Fish Abundance 162
Chapter 5. Fish Acoustic Surveys 164
Fish Acoustic Surveys Results 165
  Pre-Removal Acoustic Results 165
  Post-Removal Acoustic Results 168
  Comparison of Pre- and Post-Removal Acoustic Results 171
Fish Acoustic Comparison and Discussion 172
  Pre-Removal Acoustic Surveys 172
  Post-Removal Acoustic Surveys 172

        Pre- and Post-Removal Fish Acoustics 173
Chapter 6. Water Quality Profiles 174
    Water Quality Profiles 175
        Pre-Removal Water Column Profile Results 175
        Post-Removal Water Column Profile Results 181
        Comparison of Pre- and Post-Removal Water Column Profile Results 184
    Water Quality Comparison and Discussion 189
        Pre-Removal Water Quality Profiles 189
        Post-Removal Water Quality Profiles 189
        Pre- and Post-Removal Water Quality Profiles 190
Chapter 7. Conclusions 191
Literature Cited 194
Acknowledgments 201
Glossary of Acronyms 201

Abstract

This report summarizes fish and benthic community observations collected from the oil and gas platform High Island A-389-A (HI-A-389-A) in the northwestern Gulf of Mexico before and after removal of the upper 20 m of the platform in July 2018. HI-A-389-A is located within Flower Garden Banks National Marine Sanctuary boundaries, near East Flower Garden Bank. The monitoring program is funded by NOAA's Flower Garden Banks National Marine Sanctuary and the Bureau of Safety and Environmental Enforcement. The artificial structure is dominated by a fouling community comprised of sponges, hydroids, macroalgae, bivalves, barnacles, tunicates, zoanthids, bryozoans, and several stony coral species. The most abundant stony coral was an exotic species, orange cup coral (*Tubastraea* sp.), native to the Indo-Pacific. Analysis of the benthic community suggests four distinct biological zones occur, likely driven by light availability, wave action, temperature, and sedimentation. Significant changes in the biological community were reported after the removal of the working deck and associated equipment above water, which served as shade structure. The loss of hydroids documented from pre- to post-removal surveys was the most significant difference in the benthic community. Fish species on the platform were primarily invertivores, illustrating a strong link to food sources, given the dominant benthic community. Fishery acoustic surveys documented individual and schools of fish in close proximity to the platform during both pre- and post-removal surveys. Fish were observed throughout the water column prior to removal. Following removal, schools of fish were no longer present in the upper water column, but were present at depth. The water surrounding the platform had minimal changes from 2016 to 2019 and was characteristic of typical open ocean water with seasonal fluctuations. The changes presented in this study reflect a snapshot in time after removal of the upper portion of the platform, and aid in documenting the shift in benthic and fish communities.

Key Words

artificial reef, benthic community, fish community, Flower Garden Banks National Marine Sanctuary, Gulf of Mexico, platform

Chapter 1: Introduction to Assessment of High Island A-389-A

A yellowmouth grouper (*Mycteroperca interstitialis*) hovers above horizontal beams on HI-A-389-A. Photo: Ryan Eckert/CPC

Background

High Island A-389-A (HI-A-389-A) is an oil and gas production platform situated in 125 m of water at 27° 54’ 02” N, 93° 34’ 38” W, 193 km southeast of Galveston, Texas in the northwestern Gulf of Mexico. The platform structure consists of eight primary support legs with horizontal and diagonal support members and nine gas wells (Figure 1.1).

Figure 1.1. HI-A-389-A, an oil and gas production platform located in the northwestern Gulf of Mexico. Photo: G.P. Schmahl/NOAA

The platform was installed by Mobil Exploration and Producing U.S., Inc. in October 1981 outside the existing Bureau of Ocean Energy Management (BOEM) No Activity Zone for oil and gas activity, at East Flower Garden Bank. In 1992, East Flower Garden Bank (EFGB) and West Flower Garden Bank were designated by the National Oceanic and Atmospheric Administration (NOAA) as Flower Garden Banks National Marine Sanctuary (FGBNMS). Upon designation, sanctuary boundaries were drawn using the outer edges of the No Activity Zone, enclosing HI-A-389-A inside the southeast corner of the EFGB sanctuary boundary. This location is approximately 1.6 km southeast from the center of the EFGB coral reef cap and 0.5 km from the lower base of the bank (Figure 1.2).

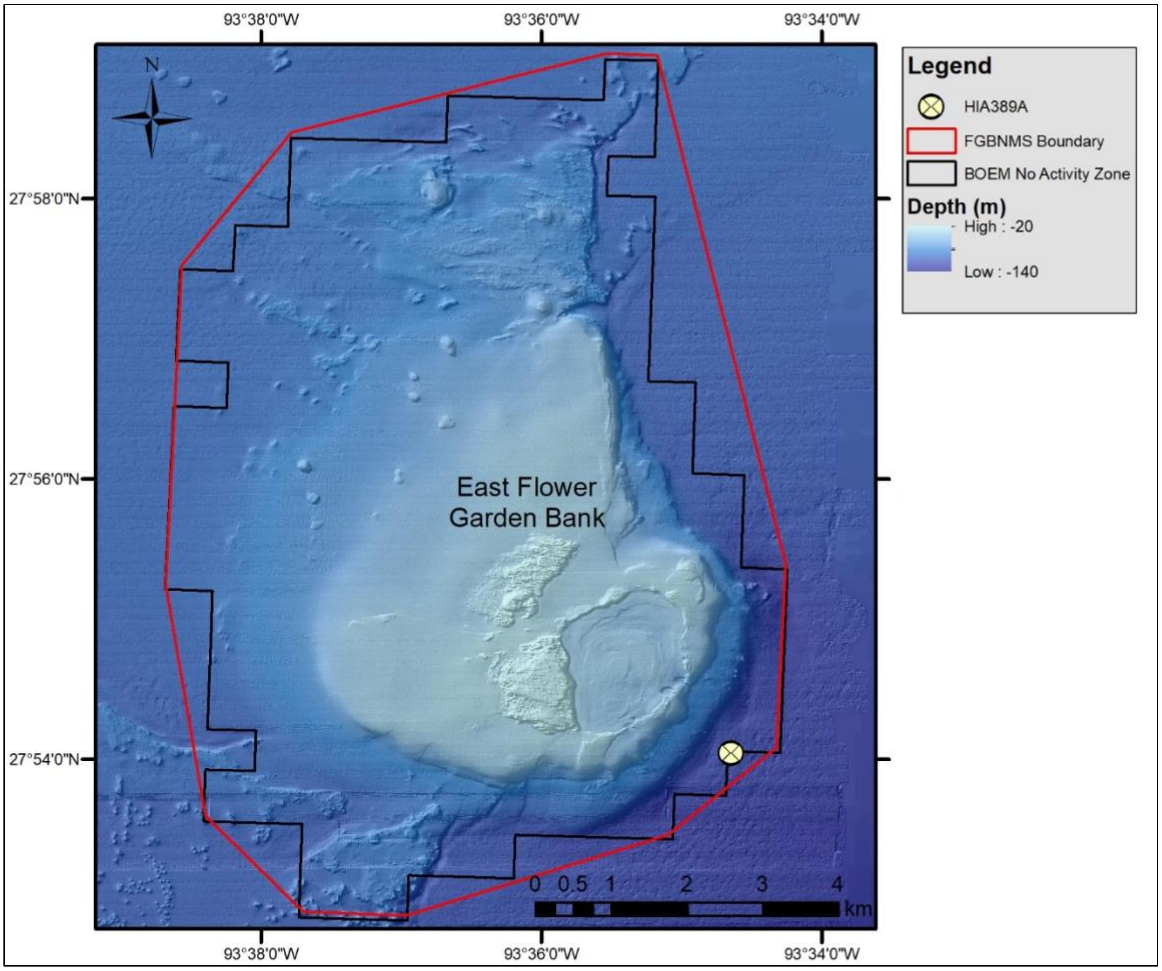


Figure 1.2. HI-A-389-A is located outside of the No Activity Zone at EFGB, but inside FGBNMS boundaries. Image: Marissa Nuttall/CPC

Oil and gas production platforms and pipelines are transferred between individual companies and partnerships on a regular basis. In addition, the company operating a production platform or a pipeline may or may not be the current owner of that asset. The ownership and operation of HI-A-389-A changed several times between 1981 and 2018. W&T Offshore, Inc. and Chevron Corporation acquired the platform in 1999. W&T Offshore, Inc. operated the platform independently of Chevron Corporation and attained full ownership of the facility soon after a 2000 acquisition. A 7.5 km pipeline, connecting HI-A-389-A to a sub-sea well located in outer continental shelf (OCS) Block Garden Banks 139 (GB-139), was installed by W&T Offshore, Inc. in 2004 (Figure 1.3). Less than 300 m of the pipeline is located within the EFGB sanctuary boundary. The pipeline delivered natural gas to the platform for processing, and continued to primarily produce natural gas until 2012. For more details on the history of HI-A-389-A ownership and operators, refer to Embesi (2020).

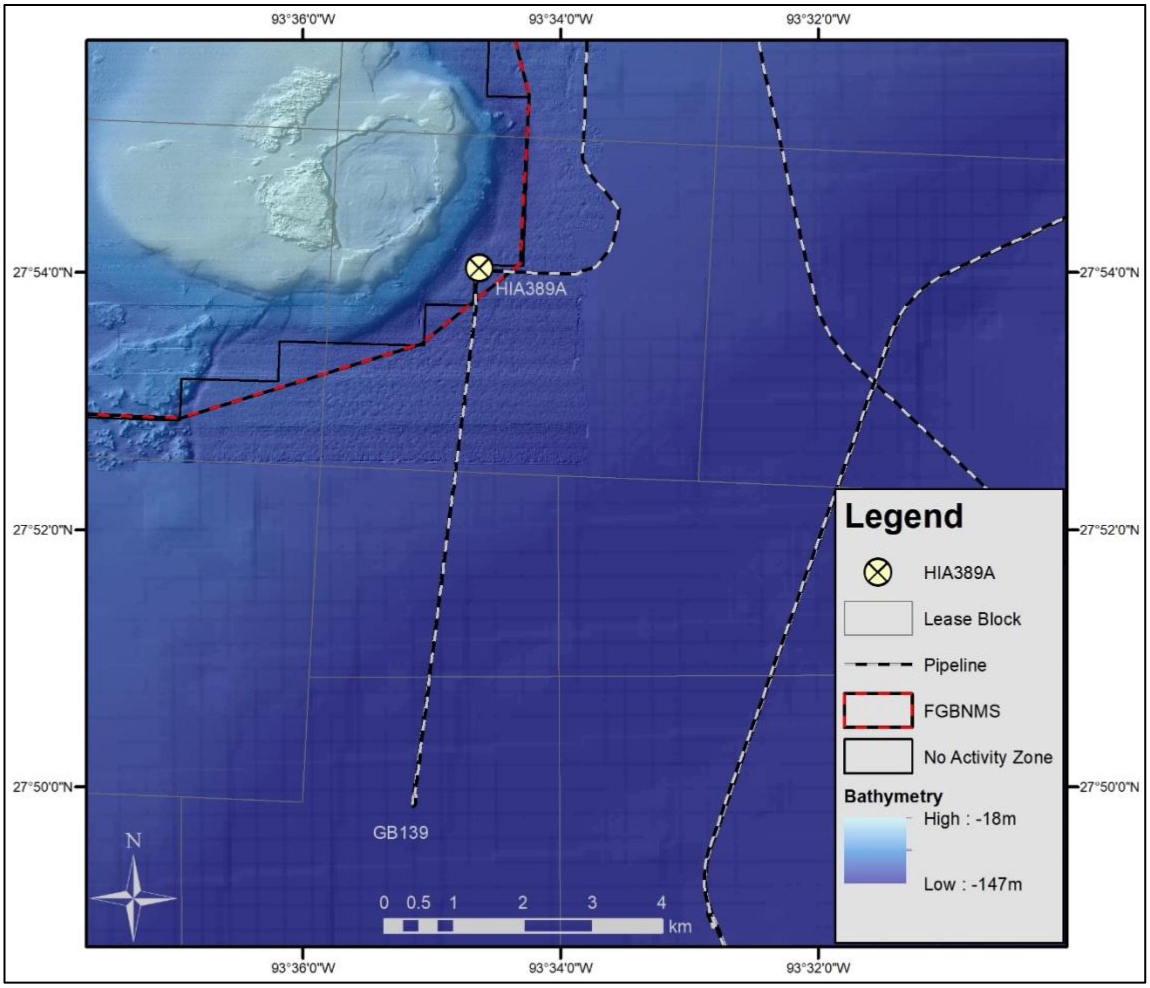


Figure 1.3. HI-A-389-A and associated pipeline (GB-139) located inside EFGB sanctuary boundaries. Image: Marissa Nuttall/CPC

The long-term fate of HI-A-389-A was the subject of extensive discussions from the time of its installation in 1981. The platform ceased production in 2012, which began the decommissioning process. The original lease issued by the U.S. Department of the Interior, Minerals Management Service, now BOEM, required the complete removal of the platform at the end of its productive life. However, as the time for decommissioning of the platform in 2014 drew nearer, more in-depth reviews and public discussion took place, as many stakeholders from the diving and fishing community were in favor of maintaining a portion of the structure in place. Due to the abundant marine life that has colonized the platform, it has historically been a popular destination for both scuba diving and fishing. In 2013 NOAA and the Bureau of Safety and Environment Enforcement (BSEE), with comments from the Sanctuary Advisory Council, diving, and fishing communities, approved a partial removal, leaving the lower portion (20 m to 125 m depth) intact for fishing and diving activities while removing the upper 20 m of the structure.

In 2014, W&T Offshore, Inc. negotiated with FGBNMS for the platform to be partially removed and established as a component of the Texas Parks & Wildlife Department (TPWD) Artificial Reef Program. The decommissioning process requires plugging and abandonment of the wells prior to the partial removal process, which involves the removal of the working deck, as well as the top sections of the platform jacket and well conductors. The artificial reef would be held under the liability of TPWD, while liability for pipelines and wells would remain with the respective owners. Significant interest by the public and the Sanctuary Advisory Council led to the sanctuary's willingness to accept this decommissioned platform within EFGB boundaries. Removal of the deck (where oil and gas production occurred) and the top portion of the platform was completed on July 25, 2018 (Figures 1.4 and 1.5). The materials were taken to shore for recycling or reuse.

Figure 1.4. Dynamic positioning vessel *Nor Goliath* lifting the top section of the platform's underwater structure in July 2018. Photo: G.P. Schmahl/NOAA

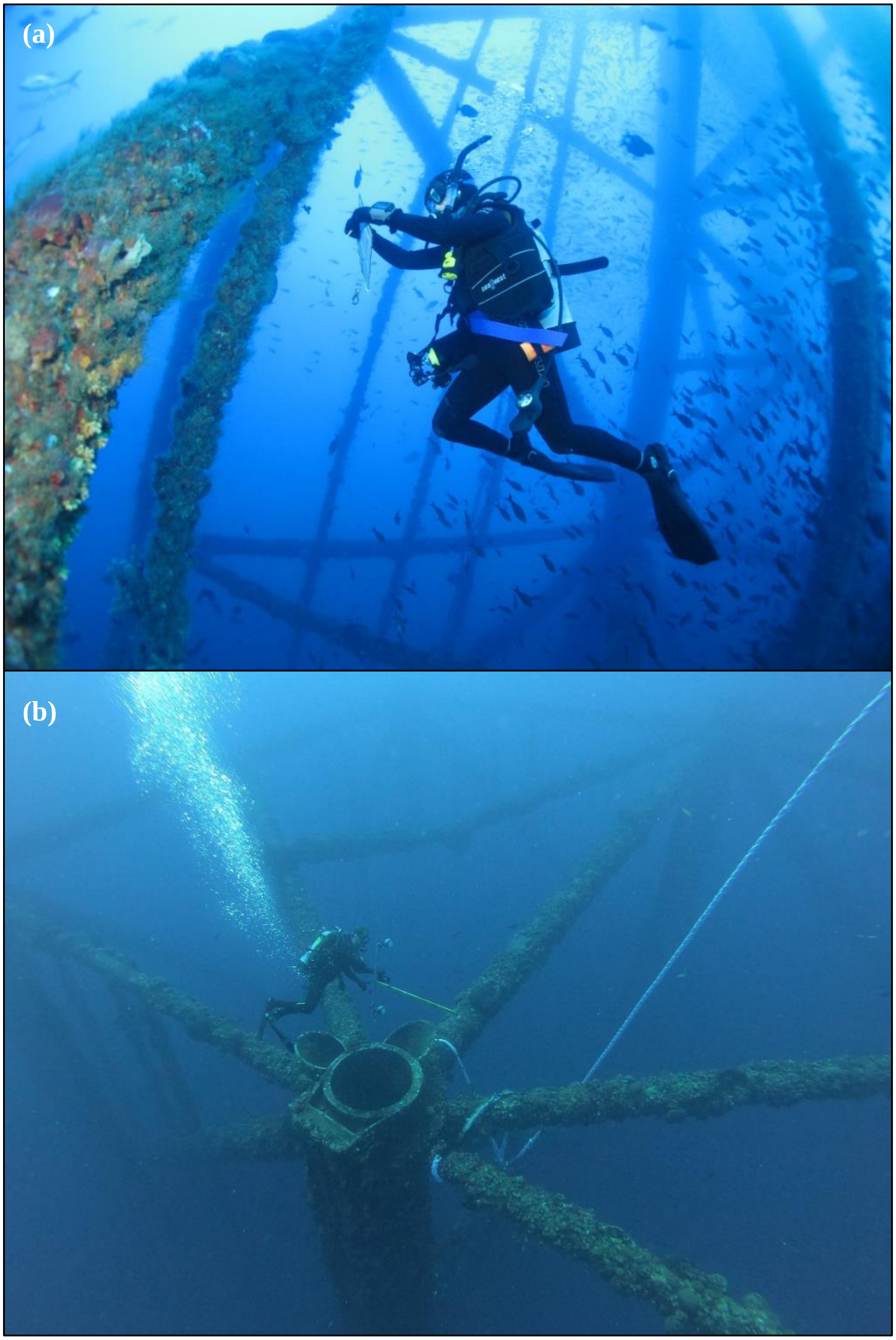


Figure 1.5. (a) Diver swimming through the upper portion of HI-A-389-A before partial removal and (b) diver conducting surveys on the platform after partial removal in 2018. Photos: (a) Ryan Eckert/CPC and (b) Fernando Calderón Gutiérrez/TAMUG

Biological Community on HI-A-389-A

Since installation in 1981, a diverse array of fouling and encrusting organisms have colonized the underwater vertical and horizontal platform pilings. The platform is covered primarily with sponges, hydroids, macroalgae, bivalves, barnacles, tunicates, zoanthids, and a few stony coral species (Embesi et al. 2013). Orange cup coral (*Tubastraea* sp.), an exotic species, is the most abundant species of stony coral colonizing the platform (Figure 1.6).

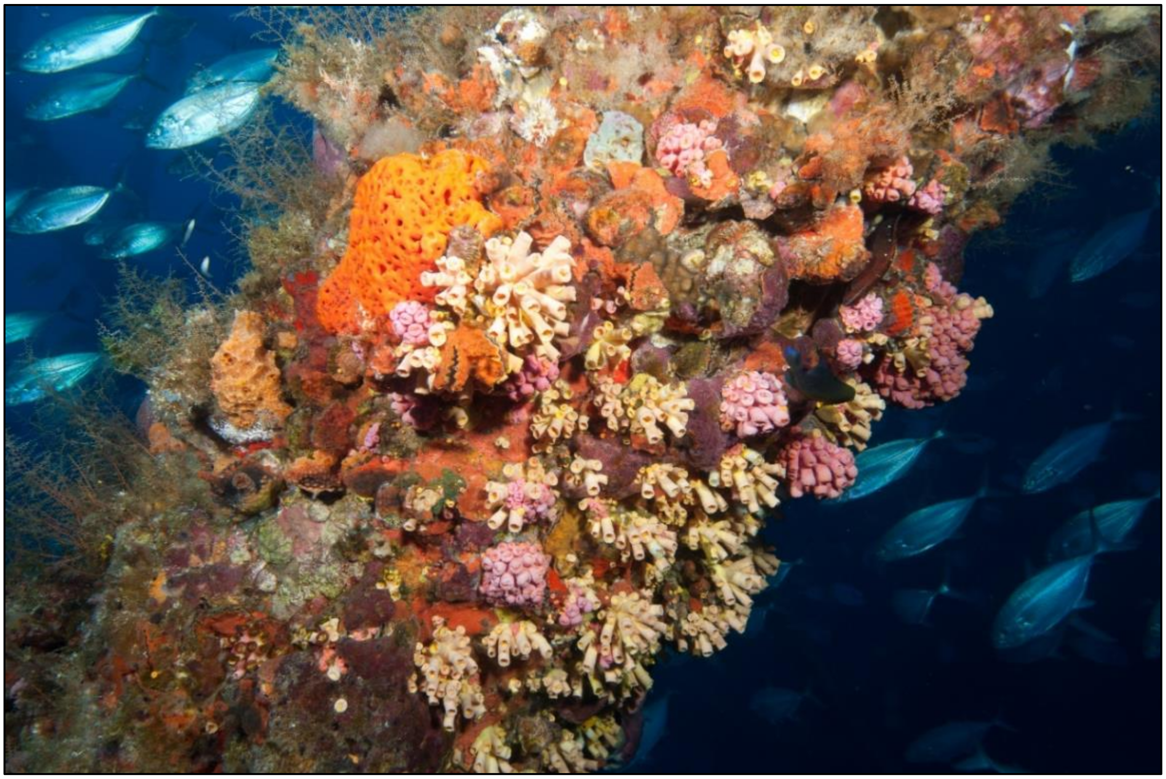


Figure 1.6. Sponges, orange cup coral, and bivalves cover one of the vertical HI-A-389-A platform pilings while a school of blue runner (*Caranx crysos*) swim in the background. Photo: G.P. Schmahl/NOAA

To aid in the readability of this report, FGBNMS staff created a poster of the common taxa of the benthic fouling community of HI-A-389-A (Figure 1.7). Since organisms can exhibit various morpho-physical characteristics, several examples for each taxon are included.

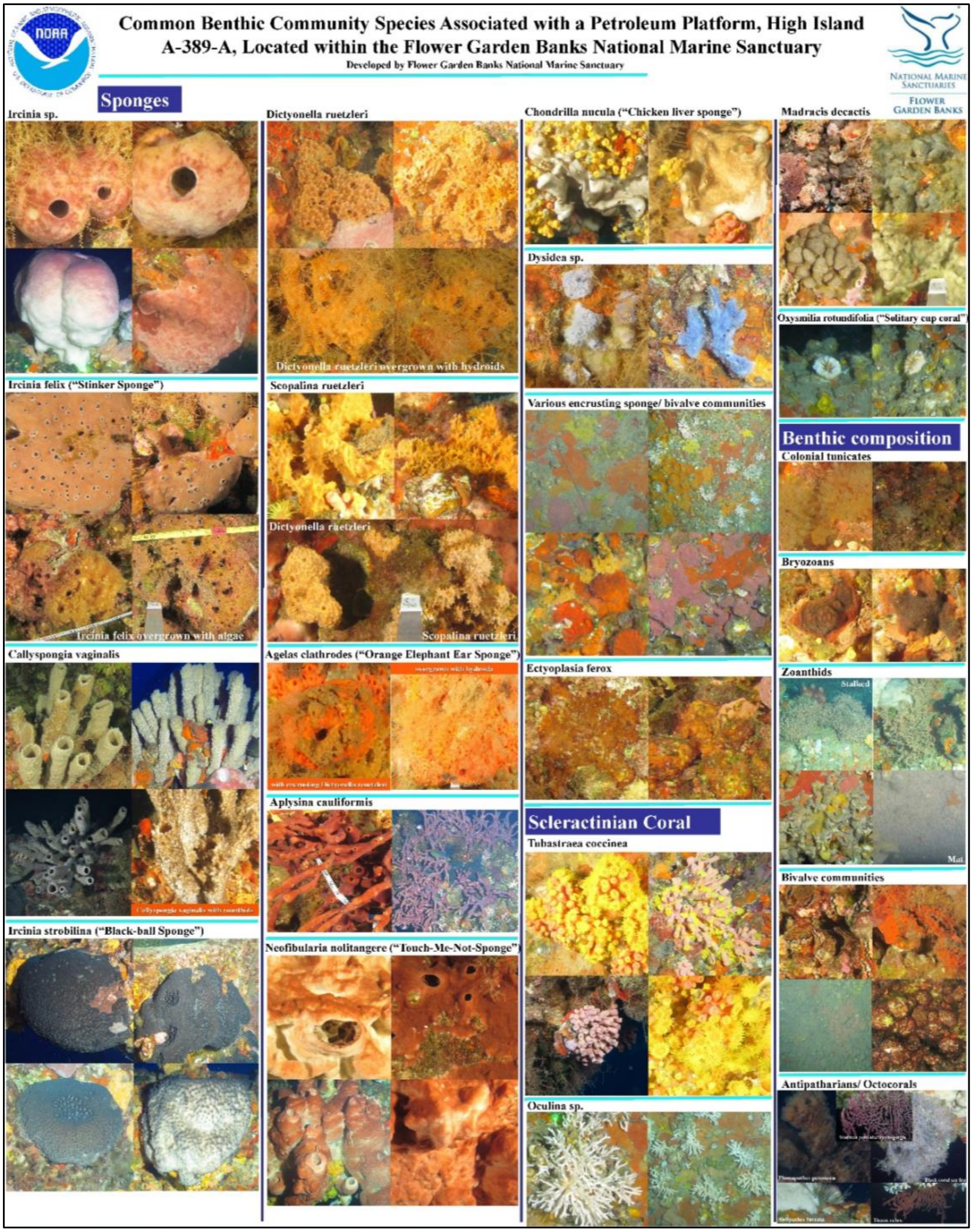


Figure 1.7. Common benthic organisms on HI-A-389-A. Contact FGBNMS for a full-size version of this poster. Photos: NOAA

On platform pilings, the distribution of colonial organisms changes with depth. Sponges, macroalgae, and bivalves are common on the shallower portions within recreational dive limits (40 m) and ample light, while mat anthozoans and antipatharians are common in deeper, mesophotic depths where light is limited (Gallaway and Lewbel 1982; Lewbel et al. 1987). A variable but persistent nepheloid zone (layer of suspended sediment with high turbidity) above the ocean floor limits light penetration and the number of species near the base of the platform (Shideler 1981; Rezak et al. 1990) (Figure 1.8).

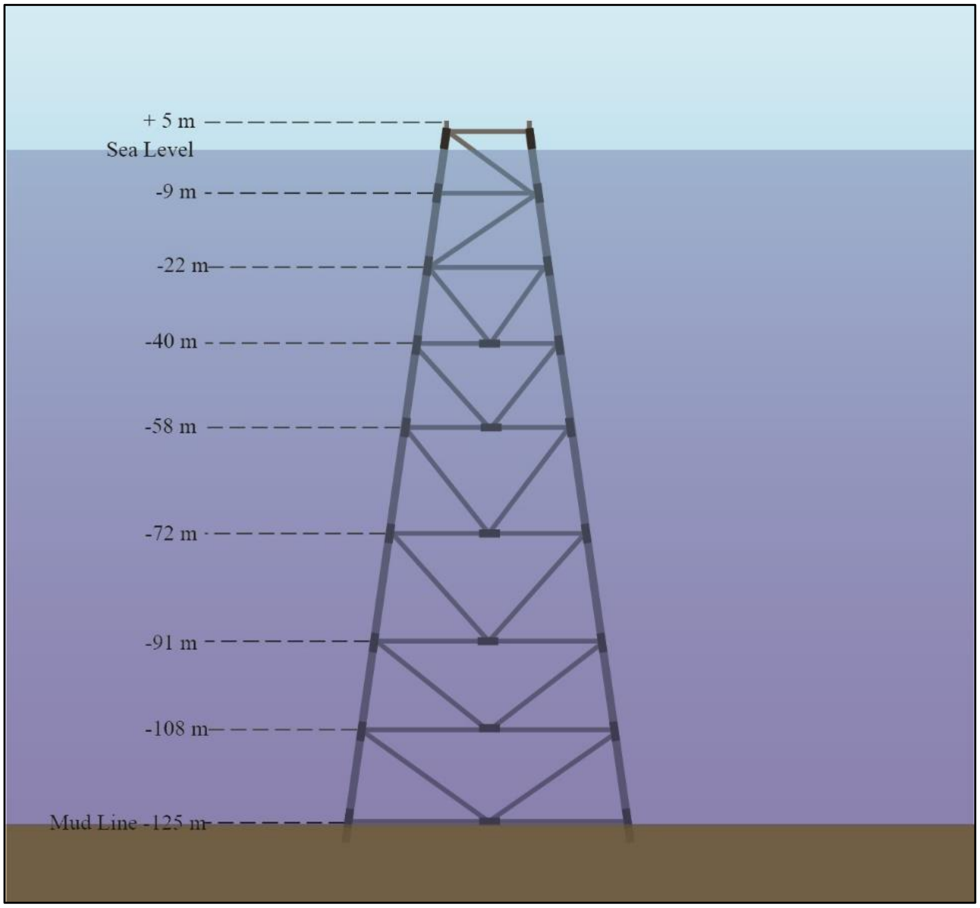


Figure 1.8. Underwater profile of HI-A-389-A. Image: Ryan Eckert/NOAA

Along with colonial organisms, HI-A-389-A attracts demersal reef fish and pelagic fish species common in the Gulf of Mexico and Caribbean region (Boland 2002). Damselfish, wrasse, jack, grouper, and sharks regularly congregate on or near the platform (Rezak et al. 1990; Boland 2002). Non-native species, including red lionfish (*Pterois volitans*), regal demoiselle (*Neopomacentrus cyanomos)*, and tessellated blenny (*Hypsoblennius invemar*) have also been reported on the structure. A poster of the common reef fish species found at both FGBNMS and on HI-A-389-A can be observed in Figure 1.9. For more detailed information on fish species, reference Humann and DeLoach (2014).

Figure 1.9. Common fish species associated with HI-A-389-A. Contact FGBNMS for a full-size version of this poster. Photos: Joyce and Frank Burek, NOAA, and Reef Environmental Education Foundation

Assessment Objectives

An interagency agreement between FGBNMS and BSEE was established to investigate changes in the benthic and fish communities on different sections and depths of the platform before and after removal of the upper 20 m of the structure. The permanent presence of HI-A-389-A in FGBNMS boundaries presented the need to assess the habitat and its continuing influence on and interaction with the nearby natural reef at EFGB, particularly given the distinct benthic assemblage on the structure. This assessment is of significant interest to both NOAA and BSEE. The objectives include:

- Analyzing existing information relevant to HI-A-389-A,
- Establishing a baseline of ecological information before platform decommissioning, and
- Assessing the ecological community after partial removal of the platform.

Assessment Components

The assessment was designed to evaluate baseline ecological conditions, monitor the possible change of biological communities associated with the platform pre- and post-partial structural removal, provide baseline data for future observations and monitoring at HI-A-389-A, and assess the artificial habitat's interaction with and potential influence on EFGB. The interagency agreement between FGBNMS and BSEE was established based on extensive monitoring experience and the availability of research equipment at the sanctuary.

Benthic and fish surveys were conducted by scuba divers at depths less than 40 m and by a remotely operated vehicle (ROV) at depths greater than 40 m, both before and after the partial removal of the platform. These surveys were conducted from the R/V *Manta*, the FGBNMS dedicated research vessel. Acoustic surveys were also completed from the R/V *Manta* in partnership with NOAA's National Centers for Coastal Ocean Science (NCCOS) before and after removal.

R/V *Manta* is an 83-foot catamaran used primarily as a research platform, conducting research and monitoring activities in the waters of the northwestern Gulf of Mexico. The vessel is outfitted with a scuba tank filling system, an A-frame list system, winches, knuckle boom crane, onboard chase boat, wet and dry lab space, and can accommodate ROV and other shipboard operations. Berthing, stowage, galley, and safety equipment allow for multiple-day operations supporting four crew and ten scientists.

The following techniques were used to evaluate the benthic and fish community on HI-A-389-A both before and after partial removal of the structure:

- Benthic community surveys

  - Random scuba diver photographic transects and repetitive photostations document benthic cover;
  - Repetitive scuba diver photostations detect and evaluate benthic cover changes at the stations;
  - ROV repetitive photographic transects of vertical structures detect and evaluate benthic cover changes on vertical structures;
  - ROV repetitive photographic transects of horizontal structures detect and evaluate benthic cover changes on horizontal structures;
  - ROV seafloor repetitive photographic transects detect and evaluate benthic cover changes on the seafloor;
  - ROV seafloor random transects document benthic cover on the seafloor;
- Fish community surveys
  - Belt transect scuba diver surveys assess community structure of coral reef fishes;
  - Roving diver scuba surveys assess fish species and abundance;
  - ROV roving surveys assess fish species and abundance at deeper depths;
  - ROV seafloor repetitive surveys assess fish species found at the seafloor in repetitive locations;
  - ROV seafloor random transects assess fish species found at the seafloor in random locations;
  - Fishery acoustic surveys provide densities of fish and fish schools in the water column surrounding the platform.

Field Operations and Data Collection

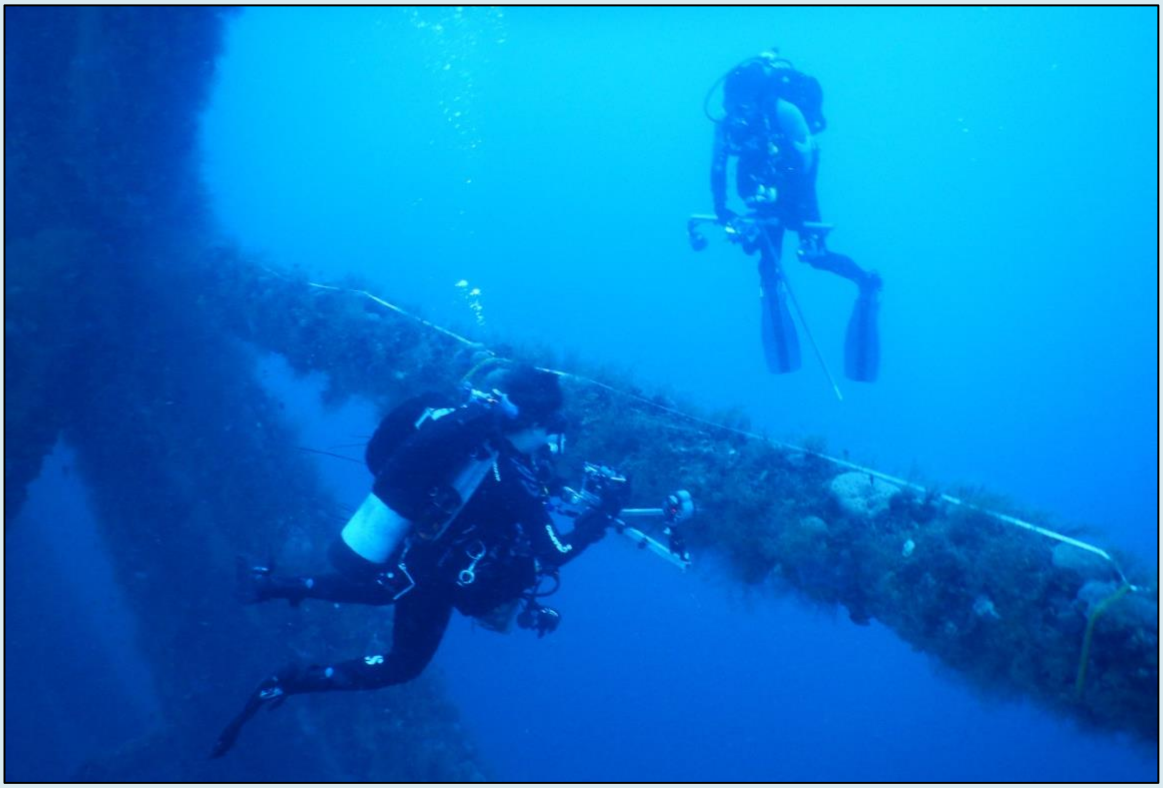
Operations for baseline data collection before and after partial platform removal were conducted off NOAA's R/V *Manta* in 2015, 2016, 2017, and 2019 (Table 1.1). An additional opportunistic survey was conducted in 2016 following a localized mortality event at EFGB. The deck and upper 20 meters of HI-A-389-A was removed in July 2018 by *Nor Goliath*, a dynamically positioned platform decommissioning vessel.

Table 1.1. Cruises and tasks completed at HI-A-389-A from 2015 to 2019.

Date	Cruise and Tasks Completed
07/27/2015 – 07/29/2015	Pre-removal ROV cruise - fish surveys, benthic surveys, and water column temperature profile: • Vertical piling photographic transects (4) • Horizontal photographic transects (29) • Horizontal junction photographs (32) • Roving fish surveys on jacket (51) • Roving fish surveys on seafloor (0) • Random belt transect fish surveys on seafloor (0) • Random belt benthic transects on seafloor (0) • Repetitive belt transects on seafloor (4) • Full water column temperature profile (1)

Date	Cruise and Tasks Completed
06/1/2016 – 06/2/2016	Pre-removal bioacoustic cruise - acoustic surveys and water column temperature profile: • Acoustic surveys at HI-A-389-A (5) • Acoustic surveys at EFGB (2) • Full water column temperature profile (1)
09/13/2016	Pre-removal ROV opportunistic survey - photographic transect: • Northwest vertical pile photographic transect (1)
07/12/2017 – 07/14/2017	Pre-removal scuba cruise - fish surveys, benthic surveys, repetitive photographic stations, and water column temperature profile: • Random photographic transects (39) • Repetitive photostation images (27) • Roving diver fish surveys (33) • Belt transect fish surveys (11) • Current meter profiles (3) • Full water column temperature profile (1)
07/25/2018	Deck and upper 20 meters of HI-A-389-A removed by *Nor Goliath*, a dynamically positioned platform decommissioning vessel.
06/18/2019 – 06/19/2019	Post-removal scuba cruise - benthic surveys and water column temperature profile: • Random photographic transects (35) • Full water column temperature profile (1)
09/10/2019 – 09/14/2019	Post-removal ROV cruise - fish surveys and benthic surveys: • Vertical piling photographic transects (4) • Horizontal photographic transects (18) • Horizontal junction photographs (19) • Roving fish surveys on jacket (18) • Roving fish surveys on seafloor (0) • Random transects on seafloor (0) • Repetitive transects on seafloor (1)
10/09/2019 – 10/11/2019	Post-removal scuba cruise - fish surveys, repetitive photographic stations, and water column temperature profile: • Belt transect fish surveys (4) • Roving diver fish surveys (18) • Repetitive photostation images (27) • Water column profile (1) • Acoustic surveys HI-A-389-A (5)

Chapter 2: Methods



NOAA divers with camera and strobes mounted on an aluminum t-frame take random transect photographs at HI-A-389-A. Photo: John Embesi/CPC

Study Design

For the upper 40 m of HI-A-389-A for both pre- and post- platform partial removal cruises, benthic and fish surveys were primarily completed using scuba. For surveys below recreational diving limits (40 m to 125 m), fish and benthic surveys were completed using a Mohawk 18 ROV (Figure 2.1).

The Mohawk ROV was purchased by the National Marine Sanctuary Foundation in 2013 for use by the sanctuary and other scientists in the region. It is operated and maintained by the University of North Carolina Wilmington Undersea Vehicles Program (UNCW-UVP). The ROV has a depth rating of 300 m and is equipped with an Insite Pacific Mini Zeus II HD video camera with two Deep Sea Power & Light 3100 LED lights, a tool skid with an ECA Robotics five-function all-electric manipulator arm, and two parallel spot lasers set at 10 cm in both the video and the still camera frames for scale (Figure 2.1).

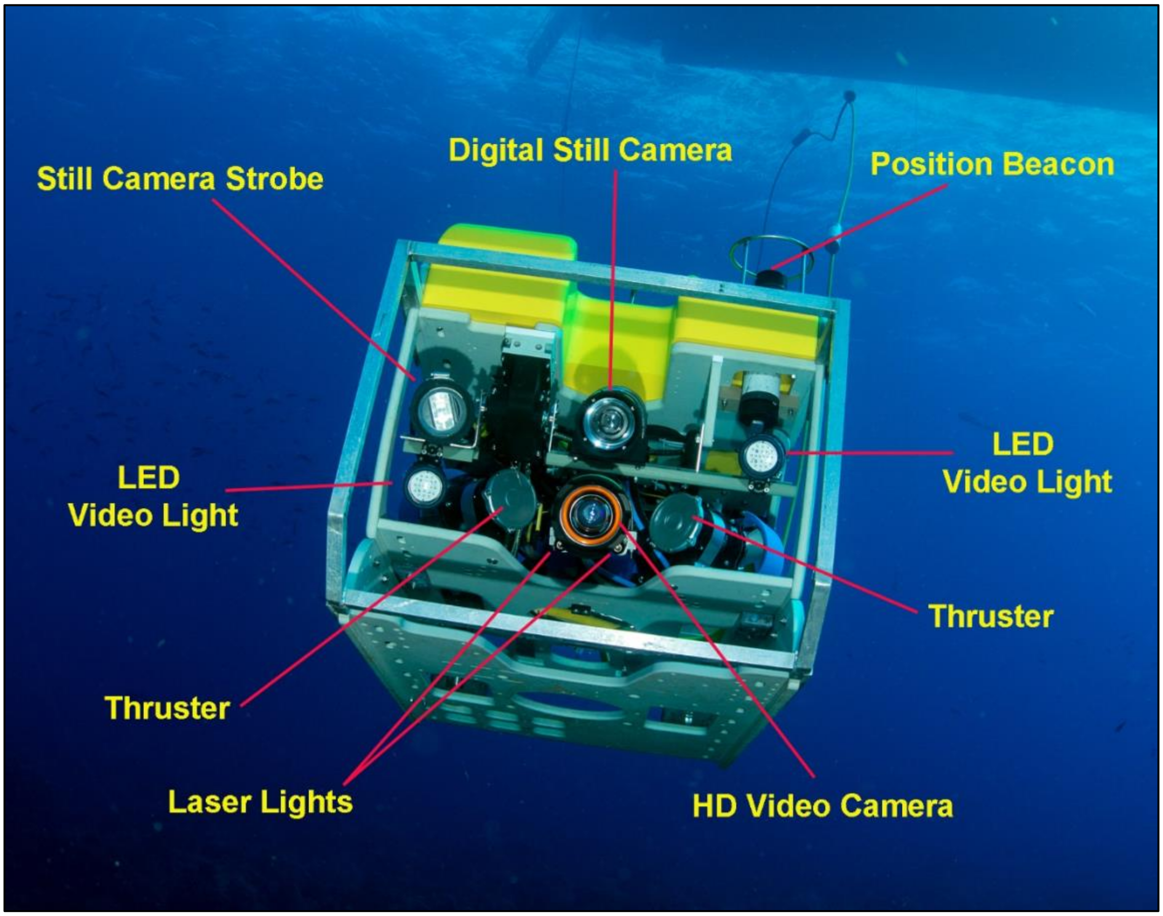


Figure 2.1. Components of Mohawk ROV. Photo: NOAA

In addition to scuba and ROV surveys, scientific fishery acoustic echosounders were deployed during pre- and post-removal surveys. Echosounders transmit high-frequency sound (>38 kHz) that reflects off objects in the water column, such as plankton, fish, the seafloor, and other hard structures. Deployed from a moving vessel, and transmitting over five times per second, individual fish and fish schools can be quickly mapped at high resolution and over large spatial extents to produce estimates of fish densities relative to seafloor habitats and structures, such as HI-A-389-A. These acoustic methods are particularly useful in accounting for schools of fish associated with the platform that are very difficult to enumerate accurately using scuba divers.

Transducers were deployed over the side of the R/V *Manta* using an overboard pole secured to the starboard side of the vessel (Figure 2.2) to document fish densities in the water column surrounding the platform. The Simrad EK60 and EK80 split beam echosounder system operated at a frequency of 38 kHz (only pre-survey) and 120 kHz (pre- and post-survey). The transducers were oriented downward with a nominal beam geometry of 12° and 7°, resulting in a swath width across track of approximately 20% and 12% of the range, or 20 m and 12 m at 100 m depth, respectively (Figure 2.3). A survey of the R/V *Manta* was conducted for precise offset relative to the vessel's Furuno GP-32 GPS antenna and location of the pole mount, which resulted in accurate positioning and visualization of all water column targets, such as fish and the subsurface platform structure.

Figure 2.2. R/V *Manta* polemount and GPS antenna head location used for fishery acoustic surveys. Photo: NOAA

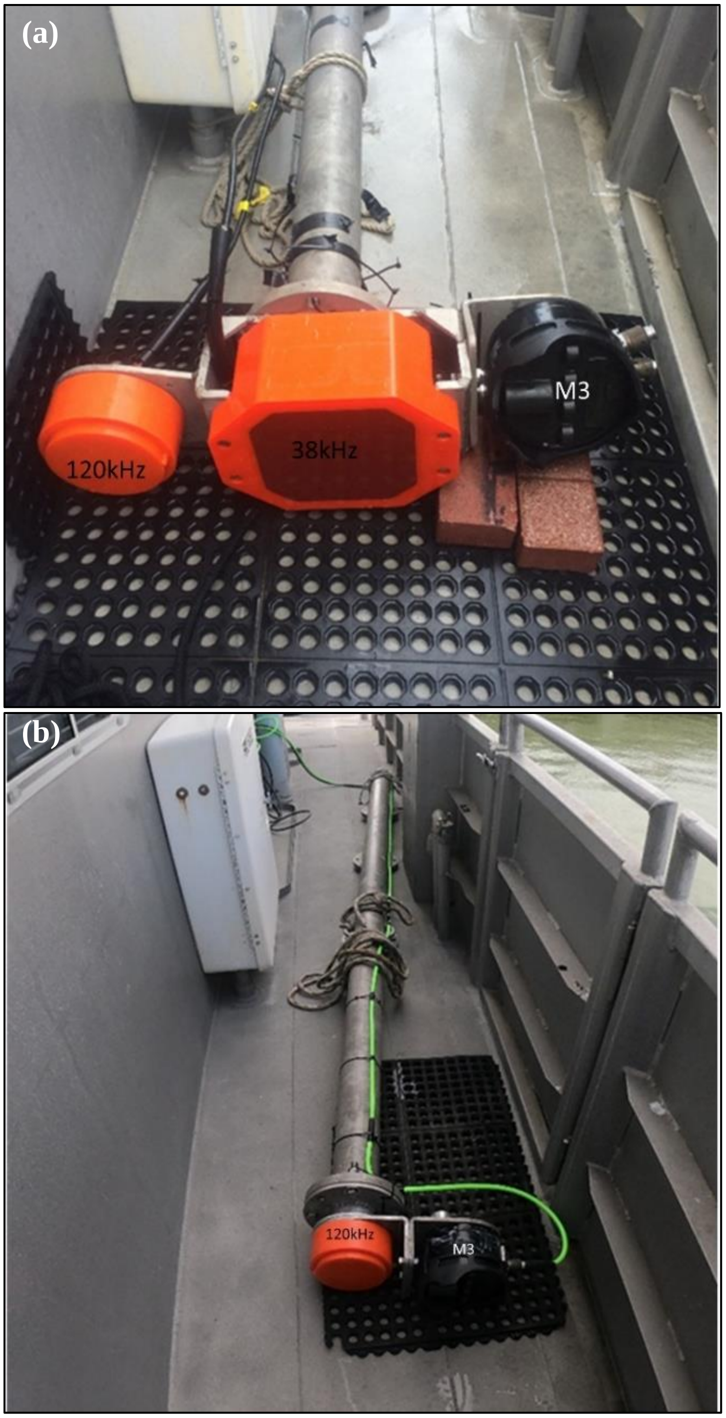


Figure 2.3. (a) Pre-survey sensor setup showing two split beam transducers (120 kHz and 38 kHz) and a multibeam sonar transducer (M3) and (b) survey sensor setup using only a single split beam transducer (120 kHz) along with the multi-beam sonar transducer (M3). Photos: NOAA

For survey purposes, the platform was divided into eight horizontal (H) sections based on depth and the physical characteristics of the structure for horizontal surveys (Figure 2.4, Tables 1.1 and 1.2). Vertical surveys were delineated by eight depth levels between horizontal beams. ROV (July 2015) and scuba (July 2017) surveys were conducted within all eight depth tiers before the removal of the top portion of the platform.

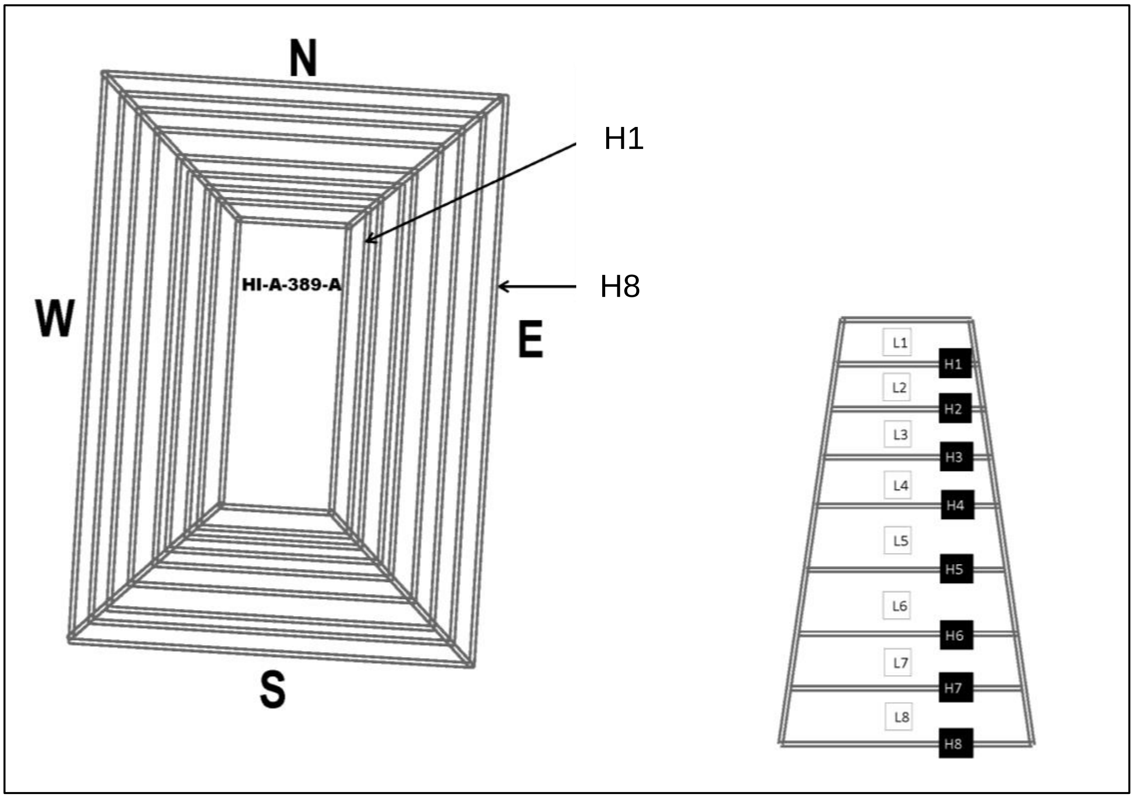


Figure 2.4. HI-A-389-A platform horizontal (H) depth delineations and vertical levels (L) for pre-removal survey purposes. Image: NOAA

Table 2.1. HI-A-389-A dimensions by depth, pre-removal.

Level	Depth (m)	Length (m)	Width (m)
Top	-	38	14
H1	9	43	19
H2	22	46	22
H3	37	50	27
H4	52	54	30
H5	72	60	36
H6	91	66	41
H7	108	70	46
H8	125	75	51

Table 2.2. Distance between horizontal beam levels, pre-removal.

Levels	**Distance (m)**
Surface – H1	9
H1 – H2	13
H2 – H3	15
H3 – H4	15
H4 – H5	20
H5 – H6	20
H6 – H7	17
H7 – H8	17

After the top portion of the platform was removed in July 2018, ROV (August 2019) and scuba (June and October 2019) surveys were completed within the remaining seven depth tiers (Figure 2.5, Tables 2.3 and 2.4). After removal, a three meter yellow spar buoy with solar powered amber light (2 sec flash every 20 seconds), was attached to the top horizontal (H2) beam as an aid to vessel navigation, and to identify the structure as an underwater hazard.

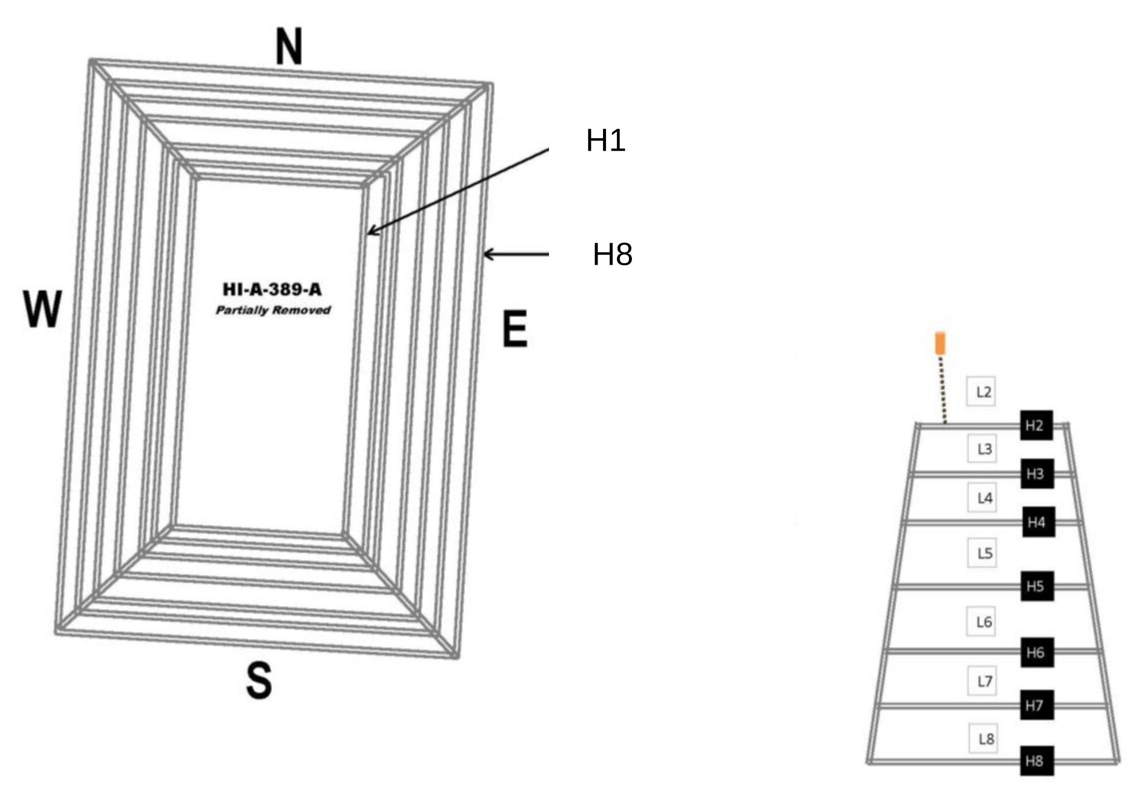


Figure 2.5. HI-A-389-A platform horizontal (H) depth delineations and vertical levels (L) for post-removal survey purposes. Image: NOAA

Table 2.3. HI-A-389-A dimensions by depth, post-removal.

Level	Depth (m)	Length (m)	Width (m)
H2	22	46	22
H3	37	50	27
H4	52	54	30
H5	72	60	36
H6	91	66	41
H7	108	70	46
H8	125	75	51

Table 2.4. Distance between horizontal beam levels, post-removal.

Levels	Distance (m)
H2 – H3	15
H3 – H4	15
H4 – H5	20
H5 – H6	20
H6 – H7	17
H7 – H8	17

Methods Conducted Using Scuba Random Photographic Transects

Field Methods

Random photographic transects consisted of non-overlapping photographs taken along the top, bottom, and each side of horizontal beams along a marked guide tape. Random numbers (in meters) were computer generated according to the dimensions of the platform. Each side and level had specific potential starting points, according to the known dimensions of each segment. L2 east and west sides are the same length and the same numbers could be used, L2 north and south sides are the same length and the same numbers could be used, etc. This ensured that each side (north, south, east, and west) of the platform and each level were sampled at least once. For dive planning and sampling purposes, divers were directed as to which side and level they would be sampling. A unique set of numbers was used for each dive. A measuring tape was temporarily attached to beams by divers using large bungee cords (Figure 2.6). A transect on each horizontal level (H1, H2, H3), side (north, south, east, and west), and beam orientation (top, bottom, inside, and outside) was planned, as well as one survey on a diagonal support structure.

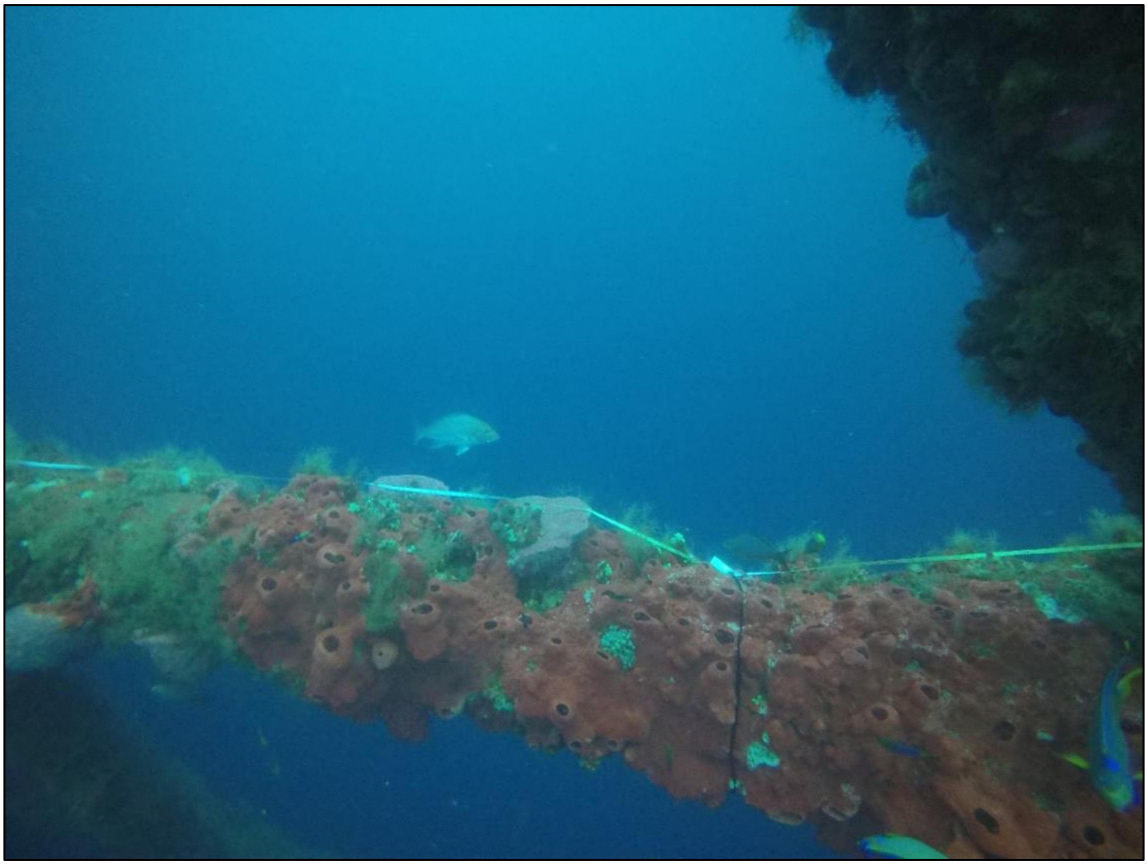


Figure 2.6. Random transect tape installed on horizontal support beam. Photo: John Embesi/CPC

A Canon® Power Shot® G11 digital camera in an Ikelite® housing with standard port, mounted on a 0.625-m t-frame with bubble level, with two Inon® Z240 strobes, was used to capture images along the transects (Figure 2.7). The bubble level mounted to the t-frame center ensured images were taken in a vertical orientation and parallel to the marked guide tape to aid in standardizing the area captured. The mounted camera was placed at pre-marked intervals 80 cm apart on a spooled 15 m measuring tape, producing 16 non-overlapping images along the transect. In some instances, obstructions (support beams, pipes, structural components, etc.) blocked access for the divers to conduct full transects. When this occurred, it was not possible to obtain 16 images, and 8 images were captured. Each still frame image contained 0.25 m^2 coverage of the substrate. This produced a total photographed area of 4 m^2 per transect. The images were then processed to obtain benthic cover using point count software.

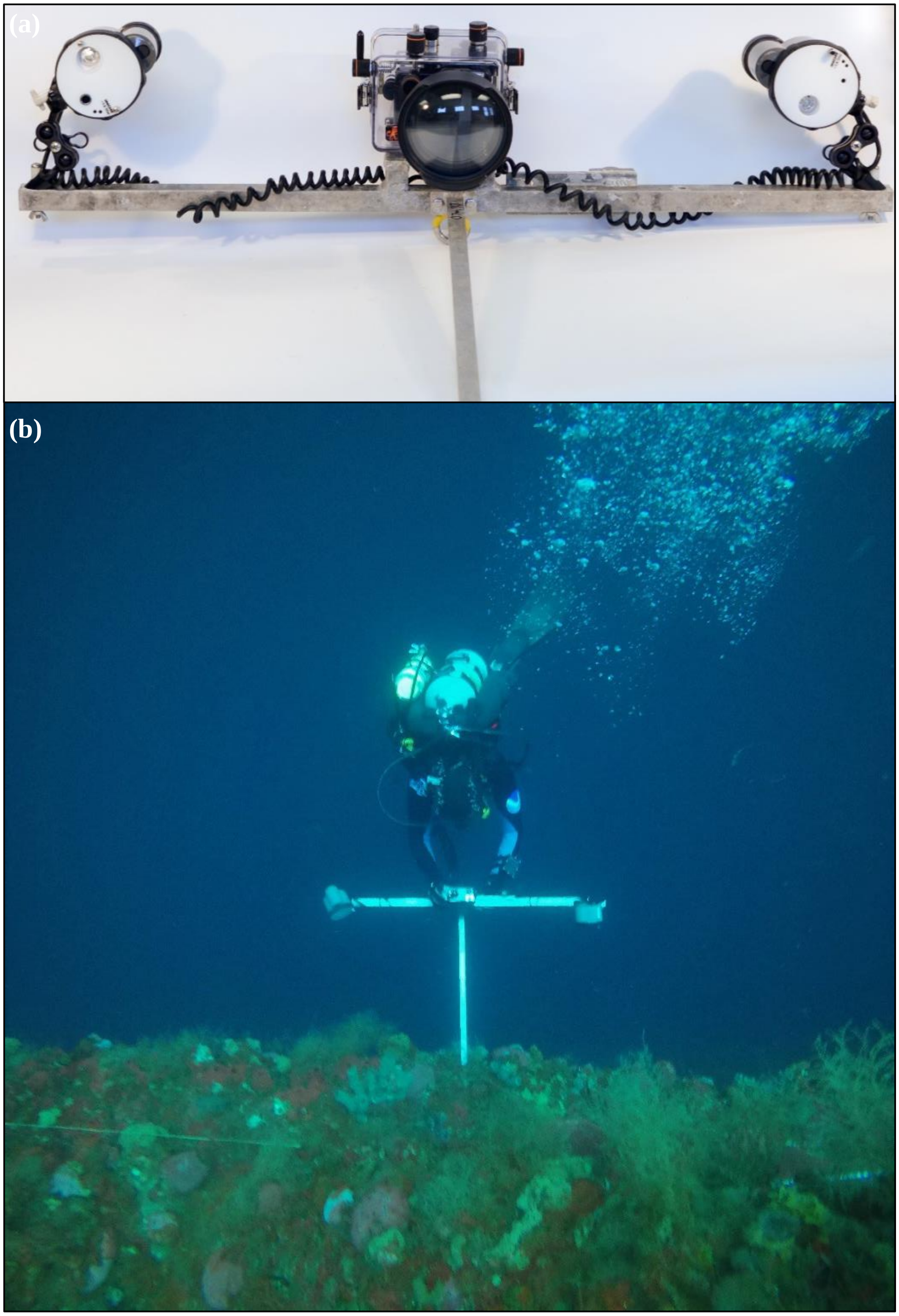


Figure 2.7. (a) T-frame camera setup and (b) diver taking random transect photographs with t-frame along a horizontal support beam. Photos: John Embesi/CPC

Data Processing

Mean percent benthic cover from transect images was analyzed using Coral Point Count with Microsoft® Excel® extensions (CPCe) version 4.1 with a 400 point overlay randomly distributed among all images within a transect (25 spatially random points per image) (Aronson et al. 1994; Kohler and Gill 2006). A customized CPCe code file pertinent to the benthic species on HI-A-389-A was created for species identification. Organisms positioned beneath each random point were identified to the lowest possible taxonomic level, and grouped into 14 primary groups: 1) fire corals, 2) hydroids, 3) octocorals, 4) black corals, 5) stony corals, 6) sponges, 7) encrusting sponges, 8) macroalgae (thick algal turfs covering underlying substrate and algae longer than approximately 3 mm), 9) bivalves 10), barnacles, 11) bare substrate, 12) “other motile organisms” (including fish, urchins, etc.), 13) “other sessile invertebrates” (including anemones, tunicates, zoanthids, etc.), and 14) marine debris. Abiotic features (photostation tags, tape measures, scientific equipment) and points with no data (shadows) were excluded from the analysis.

It should be noted that hydroids, encrusting sponges, macroalgae, and barnacles were not identified to the species level due to the difficulty in making accurate identifications from images. Encrusting sponges were categorized by color (blue, brown, orange, peach, pink, purple, red, white, and yellow), but these colors do not necessarily represent nine species and in fact, various colors may span across multiple species. Other than brown algae (*Dictyota* sp.), most macroalgae identified were grouped into either a generic “algae” group or a turf algae matrix group. Hydroids were grouped into a general hydroids group and barnacles were grouped into a general barnacles group.

Within the CPCe program, additional information about coral and sponge bleaching, organisms overgrown with bivalves, organisms overgrown with algae, organisms overgrown with hydroids, disease or damage, siltation, and organisms attached to debris was also recorded as “notes,” providing additional metadata for each random data point within a transect. Due to the extensive layering and overgrowth of multiple organisms in the fouling community, a point identifying percent cover could also include additional species interactions, captured in this additional note category. For example, if a bivalve was overgrown with sponge, it was identified as a sponge and noted as “bivalve overgrown with” in the CPCe notes category. To illustrate this additional level of identification made in CPCe, point 2 in Figure 2.8 would be identified in CPCe as a bivalve with an “overgrown with algae” note, point 3 would be identified as a hydroid with an “overgrown with bivalve” note, and point 6 would be identified as a zoanthid with an “overgrown with bivalve” note.

Any point that landed on a portion of coral that was white with no visible zooxanthallae was characterized as bleached coral (AGRRA 2012). Any point that landed on a sponge that was white relative to what was considered normal for the species was characterized as bleached sponge. If a coral colony or sponge displayed some bleaching, but the point landed on a healthy area of the organism, the point was characterized as healthy, and no bleaching was noted in CPCe.

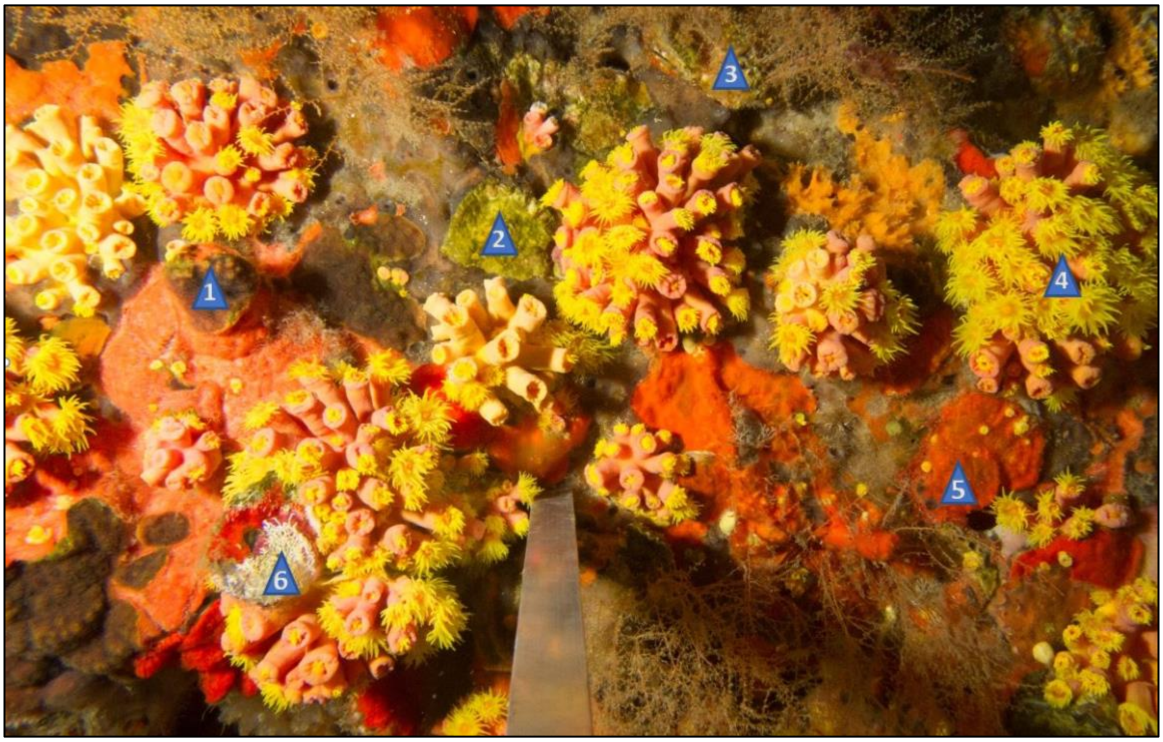


Figure 2.8. Benthic organisms in photo transect image used for CPCe analysis. Photo: John Embesi/CPC

Disease or damage included any point on a recently dead or damaged organism. Any point that landed on organisms or substrate covered in silt was characterized as siltation. Any point that landed on organisms attached to debris was characterized as attached to debris.

Point count analysis was conducted for photos within a transect, and mean percent cover for all groups was determined by averaging all transects by depth per horizontal level (H1, H2, H3). Results are presented as mean percent cover ± standard error.

Consistency for photographic random transect methods was ensured by multiple scientific divers trained on the same systems for correct camera operation. Camera settings and equipment were standardized so that consistent transect images were taken, and equipment checklists were provided in the field to ensure divers had all equipment and were confident with tasks assigned. Random transect photographs were reviewed promptly after images were taken to ensure the quality was sufficient for analysis. After all benthic components were identified in CPCe files, quality assurance/quality control (QA/QC) consisted of a FGBNMS staff member, other than the original CPCe analyzer, independently reviewing all identified points from the random transect photographs for accuracy. Any mistakes were corrected before percent cover analysis was completed.

Statistical Analysis

Benthic community interactions in photographic transects were evaluated with non-parametric distance-based analyses using Primer® version 7.0 (Anderson et al. 2008; Clarke et al. 2014). Euclidean distance resemblance matrices were calculated using square root transformed percent cover data from benthic groups identified in CPCe. Permutational multivariate analysis of variance (PERMANOVA) was based on Euclidean distance resemblance matrices and used to test for benthic community differences and estimate components of variation between horizontal depth levels (Anderson et al. 2008). If significant differences were found, groups or species contributing to observed differences were examined using similarity percentages (SIMPER) to assess the percent contribution of dissimilarity between groups (Clarke et al. 2014).

Differences in benthic communities among survey sides (north, south, east, and west) and orientations (top, bottom, inside, and outside) were assessed using PERMANOVA on square root transformed percent cover data with Euclidean distance similarity matrices. Additional pairwise PERMANOVA tests compared benthic community composition among depths and orientations for levels H1 and H2.

Functional group means by depth were visualized using metric multi-dimensional scaling (MDS) plots, based on Euclidean distance similarity matrices (Anderson et al. 2008; Clarke et al. 2014). Cluster analyses for horizontal level depth groups were performed on Euclidean distance similarity matrices with similarity profiles (SIMPROF) analysis to identify significant (α=0.05) clusters within the data (Clarke et al. 2014). Differences were assessed using PERMANOVA (Clarke et al. 2014).

Differences in pre- and post-removal surveys were assessed using PERMANOVA on square root transformed percent cover data with Euclidean distance similarity matrices. Additional pairwise PERMANOVA tests among depths and survey types were conducted from H2 to H7, since H1 was removed from the structure and surveys were not conducted on H8 during the post-removal cruise.

Repetitive Photostation Images

Field Methods

A total of 27 repetitive photographic stations were established during the pre-removal scuba cruise to observe any changes that may have occurred within the benthic community of these stations after partial platform removal. Repetitive photostations were installed on the second (H2, 22 m water depth) and third (H3, 37 m water depth) horizontal beams of HI-A-389-A, in which the junctions (where horizontal and vertical structures meet) and organisms of interest (e.g. Antipatharia) were prioritized (Figure 2.9). Repetitive photostations were marked by numbered tags and secured to beams with large, industrial zip ties. After each station was located, divers photographed each one in a consistent manner: downward facing and level, with the photographer facing into the structure to facilitate repeatability.

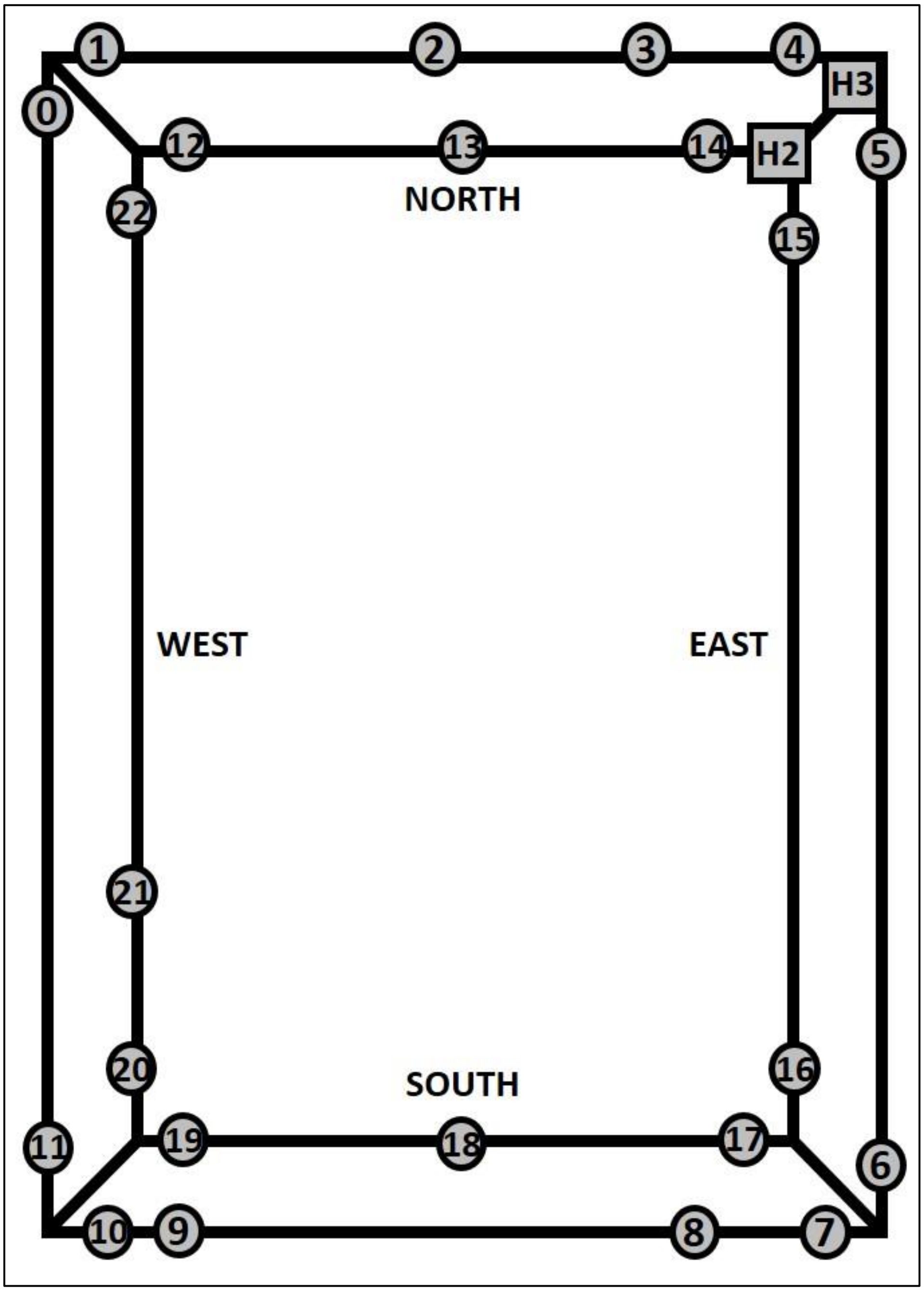


Figure 2.9. Diagram of repetitive photostation locations on levels H2 (22 m) and H3 (37 m) of the HI-A-389-A. Image: Raven Blakeway/CPC

A Canon® Power Shot® G11 digital camera in an Ikelite® housing with standard port, mounted on a 1.5-m t-frame, with two Inon® Z240 strobes, was used to capture images (Figure 2.10). To ensure that the stations were photographed in the same manner each year, the frame was oriented toward the inside of the platform and kept vertical using an attached bullseye bubble level. Images were then qualitatively assessed to determine major changes in the benthic community from 2015 to 2019.

Figure 2.10. Repetitive photostation with camera mounted above aluminum t-frame. Photo: NOAA

Stations were photographed consecutively, and qualitative descriptions were recorded to compare changes in the benthic community from the 2017 pre-removal cruise to the 2019 post-removal cruise. In all cases, the information recorded encompassed changes from 2017 to 2019, as a means to determine the effect, if any, of the removal of the working deck, the top section of the platform jacket, and well conductors on the biological community.

Data Processing

For each station, the photographs from both years were viewed side by side to conduct a comparative analysis. Items noted for each comparison included growth, retention, and loss of organisms or cover, as well as the presence of any new organism(s). While conducting the analysis, consistency in the use of terms was prioritized for ease of interpretation in the results. Each of the terms was defined as:

1. Growth – an increase in size of an organism in 2019 that was present at the station in 2017;
2. Reduction – a decrease in the size or quantity of an organism from 2017 to 2019;
3. Retention – an organism present at the station in 2017 and 2019 with no apparent change in size or status;
4. Loss – an organism was no longer present in 2019 that was present at the station in 2017;
5. Gain – a new organism was present in 2019 that was not present in 2017, or, additional colonies were gained in 2019 of an organism that was present in 2017.

Difficulties arose when comparing photographs from each year, as the length of the T-frame used to take the pictures changed from 2017 to 2019. A longer T-frame was used to take photographs in 2019, thus images had a wider frame of view. To compensate for this difference, and to retain accuracy when comparing photographs, the frame of view for the 2019 photos was reduced based upon the frame of view of 2017 photographs through photo cropping. In addition to this, the cattle tags that were used to mark the stations in 2017 were often overgrown in 2019, making it difficult to discern the station from the photographs in hand. However, points of reference, such as accessory pipes and sponges or coral colonies, assisted with matching the photographs from each year. There were no attempts made to statistically quantify changes between each year due to the lack of consistency between photographs.

Roving Diver Fish Surveys

Field Methods

Roving diver surveys were conducted at each horizontal level and included a portion of horizontal supports (H), vertical supports (V), and diagonal supports (D). Surveys were patterned in a non-repeating fashion so that new areas were covered throughout the survey. The standard roving diver technique (RDT) (Schmitt and Sullivan 1996), where a diver swims freely throughout the dive area, recording every observed fish species and its approximate abundance (single, few 2-10, many 11-100, and abundant >100), was used with the following exceptions: divers stayed on the same level throughout the survey, and the ceiling limit for the survey was one meter below the next higher level (Figure 2.11). Fish observed on a horizontal cylinder structure and one meter below were counted. RDT surveys were standardized at 10 minutes in length. A total of 33 surveys conducted on H1, H2, and H3 were completed during the pre-removal scuba cruise, and a total of 18 were completed in the water column on H1, H2, and H3 during the post-removal scuba cruise. Surveys were conducted at various times throughout the day, from dawn to dusk, to reduce the temporal effect on the data.

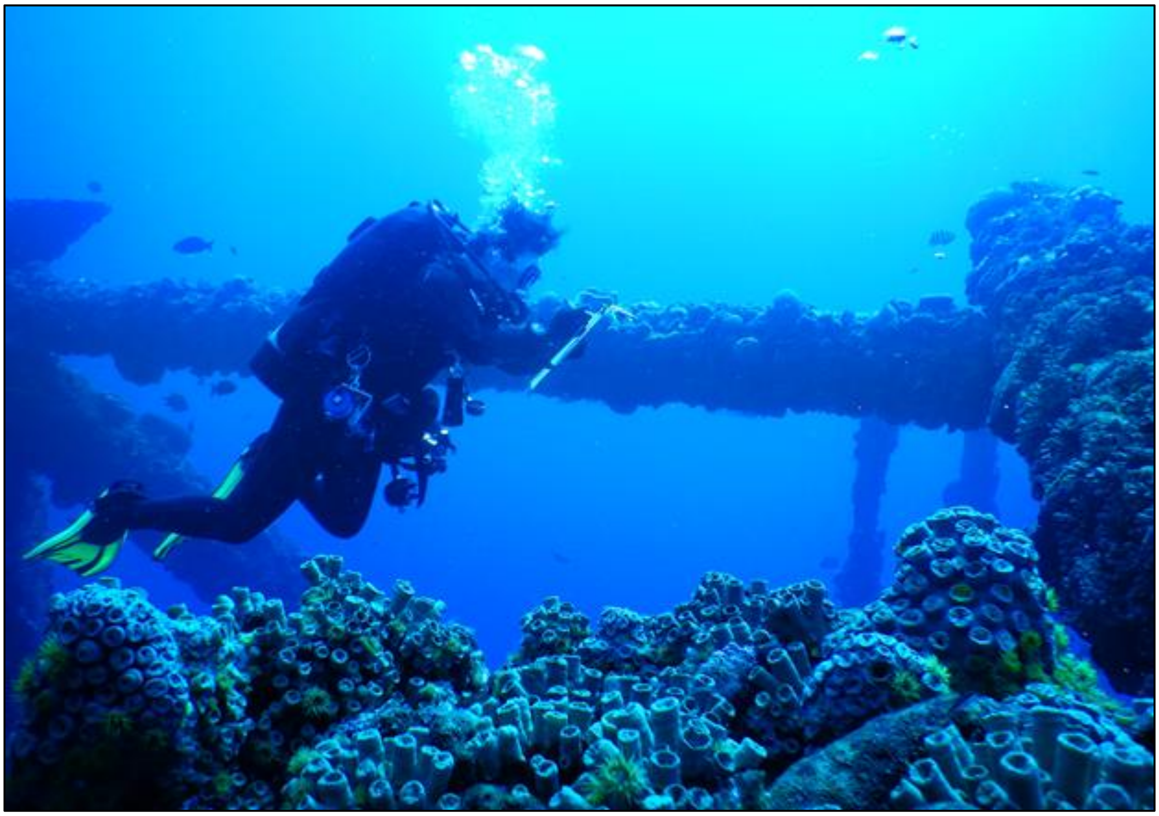


Figure 2.11. Diver conducting roving diver fish survey at HI-A-389-A. Photo: Marissa Nuttall/CPC

Data Processing

Survey data were entered into a Microsoft® Excel® database by each surveyor. Entered data were checked for quality and accuracy prior to processing. For each entry, family and trophic guild were recorded. Species were classified in four primary trophic guilds: herbivores (H), piscivores (P), invertivores (I), and planktivores (PL), based on information provided from FishBase (Froese and Pauly 2019).

Abundance data were used to calculate density index (DI) using abundance categories recorded for observed species (REEF 2019). Multipliers were applied to each of the abundance categories as follows: Single (S), one; Few (F), two; Many (M), three; and Abundant (A), four. DI was calculated using the following equation, where S, F, M, and A equal the total number of surveys in which a given species was observed at each of those four levels:

$$DI = \frac{(S * 1) + (F * 2) + (M * 3) + (A * 4)}{Number\ of\ Surveys\ Species\ was\ Observed}$$

Percent sighting frequency (%SF) was calculated to represent the percentage of surveys, out of all surveys, a particular species was observed. %SF was calculated using the following equation:

$$\%SF = \frac{S + F + M + A}{Number\ of\ Surveys} * 100$$

To provide a singular measure of species abundance, DI and %SF were multiplied (DI*%SF).

Statistical Analysis

All nonparametric analyses for non-normal data were carried out using Primer® version 7.0.

A distance-based test for homogeneity of multivariate dispersion based on deviations from centroids (PERMDISP; Anderson et al. 2006) was performed on presence/absence transformed data in a Jaccard's resemblance matrix with deviations from centroids and 9999 permutations to examine beta diversity.

Cluster analysis with SIMPROF was performed on untransformed DI*%SF data in a Bray-Curtis resemblance matrix with 9999 permutations.

Type III SIMPROF was used to determine the 20 most important species contributing to the community based on untransformed DI*%SF data in a Bray-Curtis resemblance matrix. These results are represented as a shade plot.

PERMANOVA was used to examine differences in species composition between level and removal status based on presence/absence transformed data in a Jaccard's resemblance matrix. One-way PERMANOVA was conducted with unrestricted permutations of raw data, Type I sum of squares, and 9999 permutations. Two-way PERMANOVA was conducted with permutations of residuals under a reduced model, Type III sum of squares, and 9999 permutations.

Cluster and SIMPROF were used to examine significant clusters based on community abundance from DI*%SF data. These results were presented using non-metric multidimensional scaling (nMDS) plots with vector overlay representing variables with Pearson correlation >0.8.

Belt Transect Fish Surveys

Field Methods

Belt transects were used to quantify fish populations. Each perimeter horizontal (H) (north, south, east, and west) was represented at the H1, H2, and H3 levels. The surveys were 12.5 m in length and two meters wide (one meter on each side of center line of the structure) (Figure 2.12).

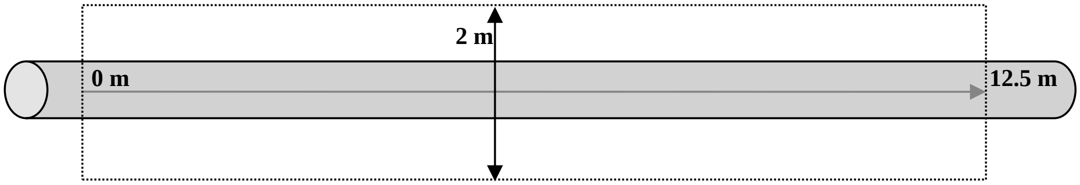


Figure 2.12. Belt transect fish survey schematic for HI-A-389-A. Image: John Embesi/CPC

The upper limit (ceiling) was established at minus one (-1) meter below the next horizontal (H) level. Standard belt transect methods (Roberson et al. 2014; Caldow et al. 2009) were used with the following exceptions: all fish falling within the survey area were recorded, the diver could move off the transect centerline to observe and identify fish as long as they stayed within the two meter transect width, the diver could look forward (no further than the end of 12.5 m transect) but did not look backward to areas already surveyed, and the diver could look around the perimeter and bottom of the cylindrical structure but did not count fish more than 1 m below it (Figure 2.13).

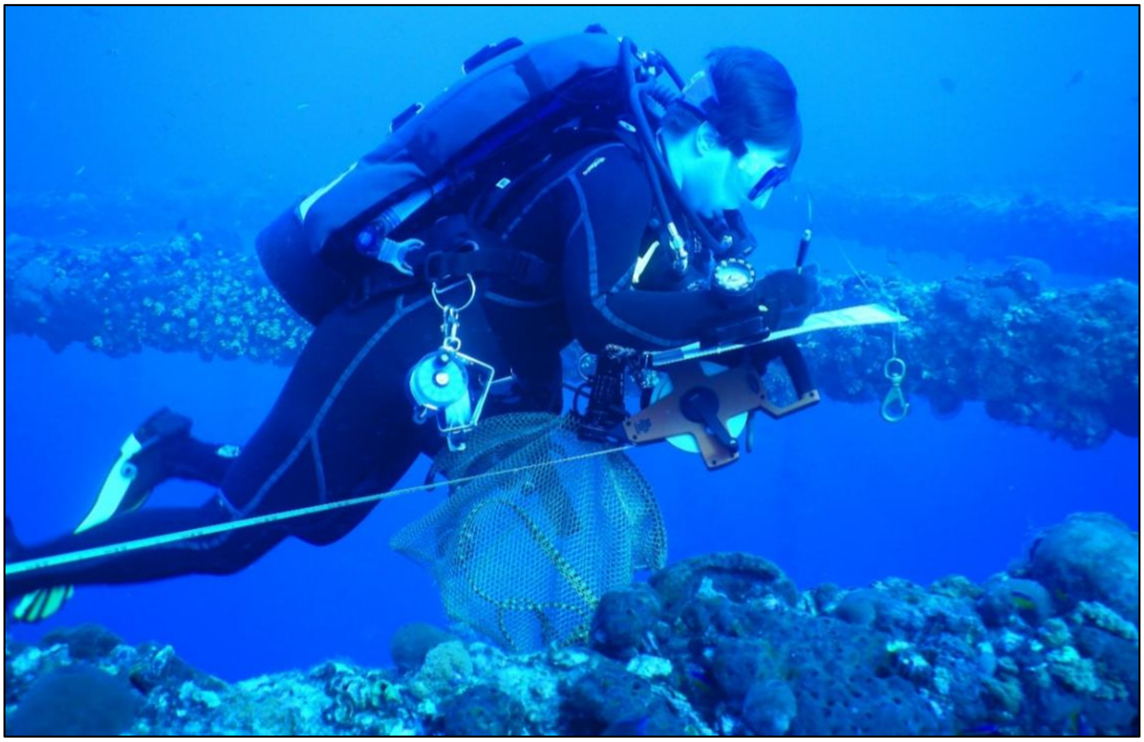


Figure 2.13. Belt transect fish survey at HI-A-389-A. Photo: Marissa Nuttall/CPC

Surveys took approximately seven minutes to complete, and starting points were randomly determined. Random numbers (in meters) were computer-generated according to the dimensions of the platform. Each side and level had specific potential starting points, according to the known dimensions of each segment. L2 east and west sides are the same length and the same numbers could be used, L2 north and south sides are the same length and the same numbers could be used, etc. This ensured that each side (north, south, east, and west) and each level of the platform were sampled at least once. For dive planning and sampling purposes, divers were directed as to which side and level they would be sampling. A unique set of numbers was used for each dive.

Data Processing

As described in Roving Diver Fish Surveys, Data Processing, data were entered into a Microsoft® Excel® database by each surveyor and followed the same checks for quality and accuracy prior to processing. For each entry, family and trophic guild were recorded.

Abundance counts were converted into density per $100m^2$. Biomass was computed using the allometric length-weight conversion formula (Bohnsack and Harper 1988) based on information provided by FishBase (Froese and Pauly 2019). Fish biomass was expressed as grams per 100 m^2. Based on species density and biomass, dominance plots (k-dominance or abundance-biomass comparison curves) were generated using PRIMER®. W-values (difference between the abundance curve and biomass curve) were calculated for each survey (Clarke 1990). This value can range between -1 and 1, where w=1 indicates that the population is dominated by a few large species, and w=-1 indicates that the population is dominated by many small species.

Statistical Analysis

Due to the limited number of samples taken post-removal, no analyses were conducted on these data.

ROV Repetitive Photographic Transects

Field Methods

Repetitive photographic transects were conducted along vertical pilings, horizontal beams, vertical-horizontal junctions, and at the base of the platform to assess community composition. Surveys were conducted with the Mohawk ROV’s forward-facing still camera and two parallel lasers for scale. The ROV camera was a Kongsberg Maritime OE14-408 10 megapixel digital still camera with OE11-442 strobe and two Sidus SS501 50 megawatt green spot lasers set at 10 cm in the still camera frame for scale.

For vertical pilings, transects started at each vertical corner (NE, NW, SE, SW) facing the piling near the seafloor. From H8 to H4, the ROV took non-overlapping photographs every 10 m and from H4 to the surface, the ROV took photographs every 5 m, staying approximately 1.5 m from each corner vertical piling. All four vertical pilings were surveyed during the ROV pre-removal cruise and ROV post-removal cruise, and an additional opportunistic survey on the NW piling was conducted in 2016 following a localized mortality event at EFGB. As the ROV performed the vertical repetitive photographic transects, it stopped at each junction to capture a photograph.

At each horizontal level, the ROV took non-overlapping photographs every 5 m (starting at the corner) on the outward side of the beam. The ROV stayed approximately 1.5 meters from the structure.

At the base of HI-A-389-A, four repetitive photographic transects were completed on the seafloor and two were completed along the gas pipeline during the ROV pre-removal cruise. A radius of 150 m around the center of the base of the platform was used as the focus for the benthic surveys. The surveys consisted of 100 m transects taken 1.5 m off the seafloor using both forward-facing HD video and downward-facing photographs (non-overlapping photographs taken every 5 m).

Data Processing

Photographs were processed to remove silted, shadowed, or out-of-focus images. The size of each image was cropped to 50 x 50 cm in ImageJ using the green spot lasers set at 10 cm apart in the still camera frame for scale, so that the platform structure filled the image. Mean percent cover of the images was analyzed using CPCe, as described in the scuba random photographic transect methods, with 25 spatially random points per image. Point count analysis was conducted for all photos and mean percent cover for primary groups was determined by averaging all photos per transect per horizontal level. Results are presented as mean percent cover ± standard error.

There were no attempts made to process benthic percent cover from seafloor and gas pipeline photographic transect surveys because, upon review after data collection, all photos consisted of mud and no other benthic group categories were identified.

Statistical Analysis

All nonparametric analyses for non-normal data were carried out using Primer® version 7.0 for horizontal photographic transects (see Methods Conducted Using Scuba, Random Photographic Transects, Statistical Analysis).

Benthic community interactions in vertical photographic transects were evaluated with non-parametric distance-based analyses with Primer® version 7.0 (Anderson et al. 2008; Clarke et al. 2014). Euclidean distance resemblance matrices were calculated using square root transformed percent cover data from benthic groups identified in CPCe. PERMANOVA was based on Euclidean distance resemblance matrices and used to test for benthic community differences and estimate components of variation between vertical depths of images (Anderson et al. 2008). If significant differences were found, groups or species contributing to observed differences were examined using SIMPER to assess the percent contribution of dissimilarity between groups (Clarke et al. 2014).

Significant differences in directional vertical pilings (NE, NW, SE, SW) were tested using PERMANOVA on square root transformed percent cover data with Euclidean distance similarity matrices. Additional pairwise PERMANOVA tests between depth and direction were conducted.

Seafloor Random Photographic Transects

Field Methods

At the base of HI-A-389-A, random photographic transects were completed on the seafloor during the ROV pre-removal cruise. A radius of 150 m around the center of the base of the platform was used as the focus for the benthic surveys (Figure 2.14). The surveys consisted of 100 m transects taken 1.5 m off the seafloor using both forward-facing HD video and downward-facing photographs (non-overlapping photographs taken every 5 m). Randomly selected start points were used for each survey.

Data Processing

Photographs were processed to remove silted, shadowed, or out-of-focus images. The size of each image was cropped to 50 x 50 cm in ImageJ using the green spot lasers set at 10 cm apart in the still camera frame for scale. There were no attempts made to statistically quantify benthic percent cover because, upon review after data collection, all photos consisted of mud and no other benthic group categories were identified.

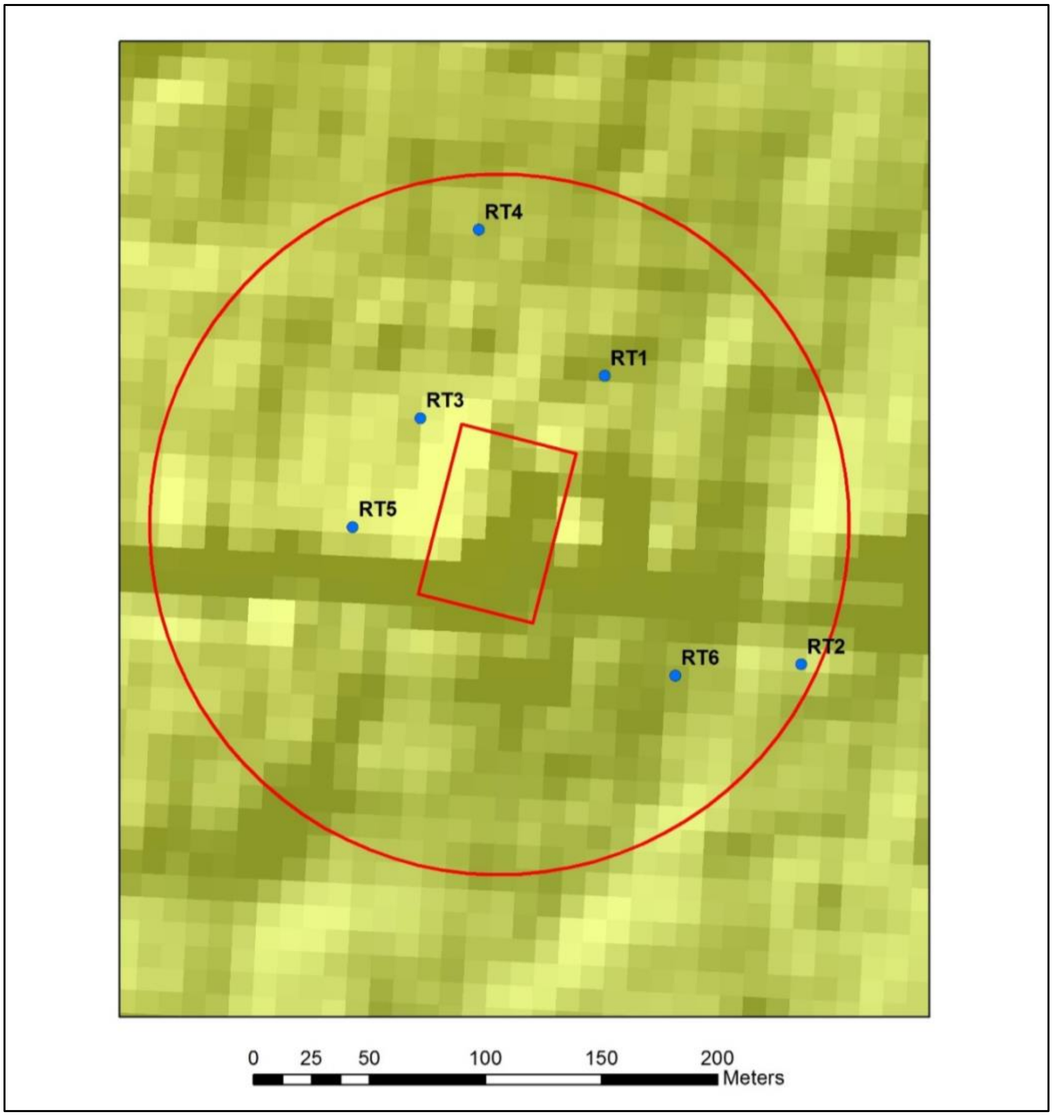


Figure 2.14. Locations of random photographic benthic transects (RT1-RT6) completed on the seafloor during the ROV pre-removal cruise at HI-A-389-A. The red square represents the base of the platform and the circle represents the 150 m survey radius. Image: John Embesi/CPC

Seafloor Random and Repetitive Transect Fish Surveys

Field Methods

To examine fish community composition and changes over time near the seafloor, modified RDT surveys were conducted at random locations in conjunction with the random and repetitive photographic transects on the seafloor (Figure 2.13). The RDT (Schmitt and Sullivan 1996) was modified for use along a 10 minute transect line with the ROV, where observation of fishes was restricted to the field of view of the ROV's high definition video camera. Fish species and abundances were recorded. Each survey represented one sample.

Data Processing

Fish survey data were entered into a Microsoft® Excel® database by the surveyor in real time. Entered data were later checked for quality and accuracy prior to processing by a second person, using high definition video of the survey. Data were processed using the same methods described above Methods Conducted Using Scuba, Belt Transect Fish Surveys, Data Processing.

Statistical Analysis

Data were combined and analyzed with roving ROV fish surveys described below.

Roving ROV Fish Surveys

Field Methods

From H1 to H7, roving fish surveys were conducted using the same modified RDT methods described above. Fish species and abundances were recorded during surveys lasting 10 minutes.

Data Processing

Fish survey data were entered into a Microsoft® Excel® database by the surveyor in real time. Entered data were later checked for quality and accuracy by a second person, prior to processing, using high definition video of the survey. Data were processed using the same methods described in Methods Conducted Using Scuba, Roving Diver Fish Surveys, Data Processing.

Statistical Analysis

See statistical analyses outlined in Methods Conducted Using Scuba, Roving Diver Fish Surveys, Statistcal Analysis.

Fish Acoustics Methods

Fish Acoustic Survey Design

The acoustic surveys were designed to sample the water column in close proximity to the platform and map the distribution of fish in the water column away from the structure. The 2016 pre-removal survey design (Figure 2.15a) was similar to a cloverleaf pattern, with main lines of the survey passing as close as possible to the north, east, south, and west sides of the platform, with large looping turns at corners to allow the research vessel to navigate and approach main lines along the platform. The survey was repeated three times on 1 June (midday, dusk, and night) and twice on 2 June (morning and midday) in

2016. Surveys concluded on 2 June due to deteriorating weather and sea conditions. The 2019 post-removal survey design (Figure 2.15b) resembled a cross-hatch pattern, with lines passing close to the platform, similar to the pre-removal survey design. With the top portion of the platform removed, lines also passed directly over the center of the platform. The survey was repeated two times on 9 October (midday and dusk) and three times on 10 October (morning, midday, and dusk). Surveys were not conducted during night time hours due to limited ship staffing for night time operations.

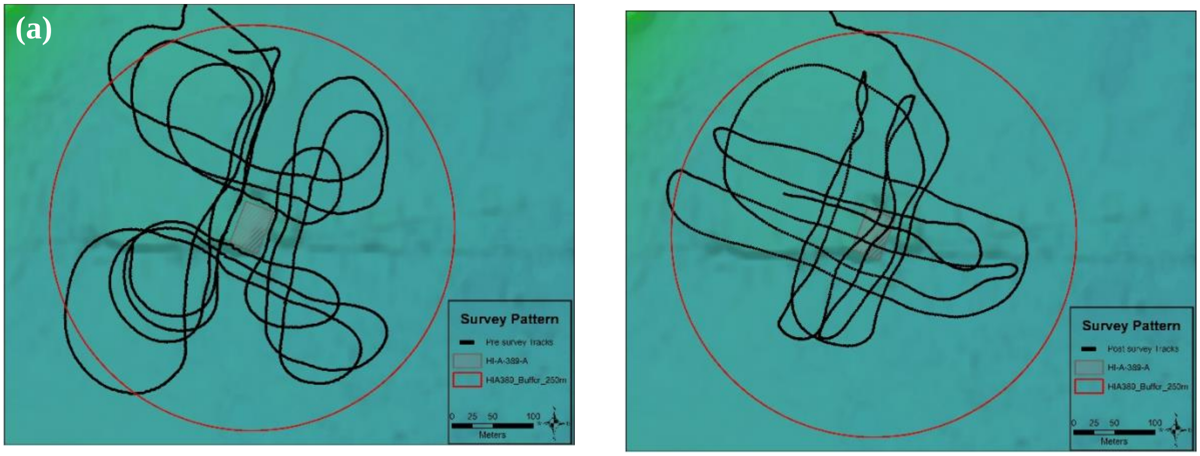


Figure 2.15. Examples of (a) pre- and (b) post-removal fishery acoustic survey designs. Image: NOAA

Data acquisition, pulse transmission, and data viewing were controlled from a workstation operating Simrad EK80 software (version 1.12.2, Simrad Fisheries) and connected by local area network to the general purpose transceiver. Output power, pulse length, and other ping transmission properties are provided in Table 2.5. EK80 data files were logged in 100 megabyte segments. The EK80 system was calibrated using standard techniques (Foote et al. 1987; Demer et al. 2015), with a 38.1 mm tungsten carbide sphere hung below the transducer. The sphere has a known acoustic signature based on sphere diameter, metal type, and environmental conditions. The sphere was systematically moved around the beam cone from forward to aft and port to starboard. The resulting data were used to adjust gain and beam footprint for accurate in situ data collection.

Table 2.5. Acquisition parameters for the Simrad EK60120 kHz split beam echosounder on the R/V *Manta* for HI-A-389-A surveys.

Parameter	Pre Survey 120kHz Frequency	Post Survey 120kHz Frequency
Transducer depth (m)	1.5	1.5
Transmit Power (dB-W)	250	250
Pulse length (µs)	128	128
Sound velocity (nominal, m s^{-1})	1516.24	1545.36
Calibration gain (dB)	25.67	26.01

Data Processing

The 120 kHz split beam echosounder data were processed using Echoview® software (version 10.0.36, Echoview® Ltd.). Each survey was divided into 300 m transects, and each transect was identified as a pass over or near the platform, resulting in 52 transects during the pre-removal survey and 58 transects for the post-removal survey. Post-removal survey data were heave corrected to remove vertical motion caused by sea conditions. The seafloor reflection, surface noise, ship interference, and the platform were delineated and removed to isolate the water column data (Figure 2.16). Backscatter returns from plankton, other non-fish targets, and very small fish were excluded using a combination of masking and thresholding techniques. Two different methods, individual fish tracking and echo integration, were used for deriving the biological density surrounding the HI-A-389-A platform.

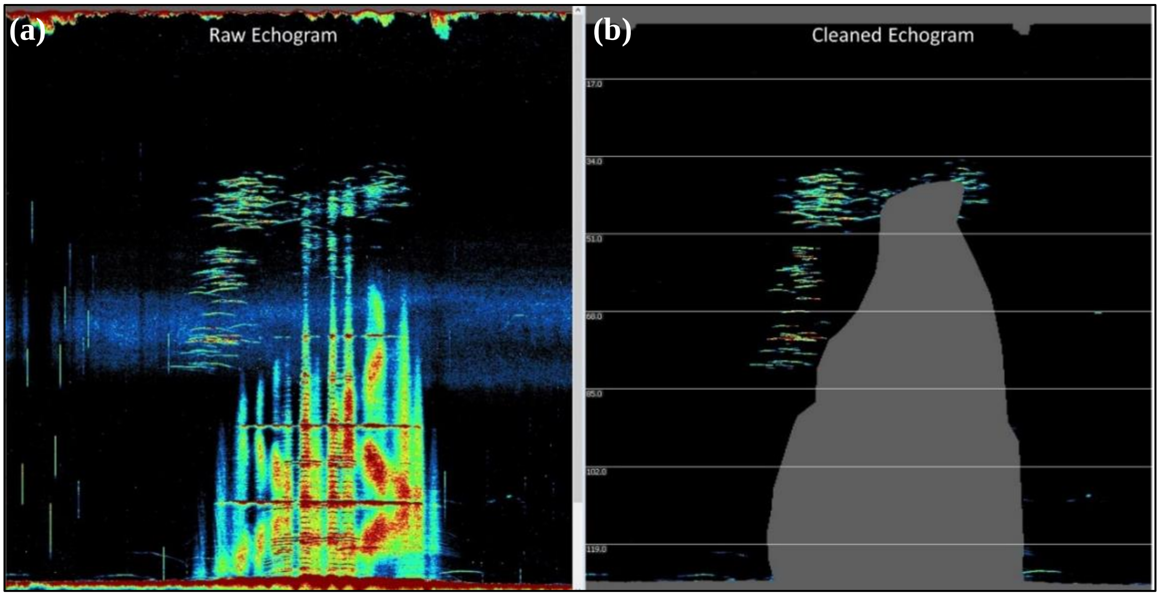


Fig 2.16. Comparison of (a) raw echogram and (b) cleaned echogram with the seafloor, surface noise, platform structure, and midwater scattering layer removed. Image: NOAA

Using the cleaned water column data, individual fish were identified using a single target detection and automated tracking algorithm. The speed of the vessel and rate of ping transmissions resulted in multiple and sequential returns from individual fish. The sequential returns from the fish are referred to as single targets. Thresholding was used on the single targets so only fish greater than -50dB target strength (or about 13 cm total length) were included in the analysis. The split beam transducer detects the range and horizontal position of the target within the beam at each ping using a phase-differential array. The technique for identifying single targets in split beam echosonder data relied upon the data processor’s ability to characterize the shape of the return pulse and to specify an acceptable setting that resulted in quality single targets. The 2D algorithm used range and time patterns from the single targets to search for systematic movements of a fish moving through space (Figure 2.16). The resulting fish identified by the tracking algorithm were stored in a database with a geographic position determined by the ship's GPS, and corrected for relative position of fish within the acoustic beam, depth below the sea surface, and a mean target strength. Individual fish data were exported from Echoview® in CSV format. Open-source statistical programming language R (version 3.4.0) was used to summarize and perform all calculations. The acoustic target strength of all single targets within a detected fish was used to calculate fish size (total length) in centimeters using a generalized acoustic size to fish length relationship derived from the:

$$TL = 10(TS+64.0035)/19.2$$

where TS is target strength measured in dB and TL is calculated length in centimeters (Love 1977). The equation above fits closely with observations of broad classes of fish (Love 1977; Johnston et al. 2016). During the 2019 surveys, there was a persistent mid-water scattering layer. This layer may be composed of plankton or small fish (Figure 2.17). Where the layer was dense, the backscatter may have obscured detection of larger fish. Close scrutiny of this part of the water column still allowed for detection of some fish within this layer.

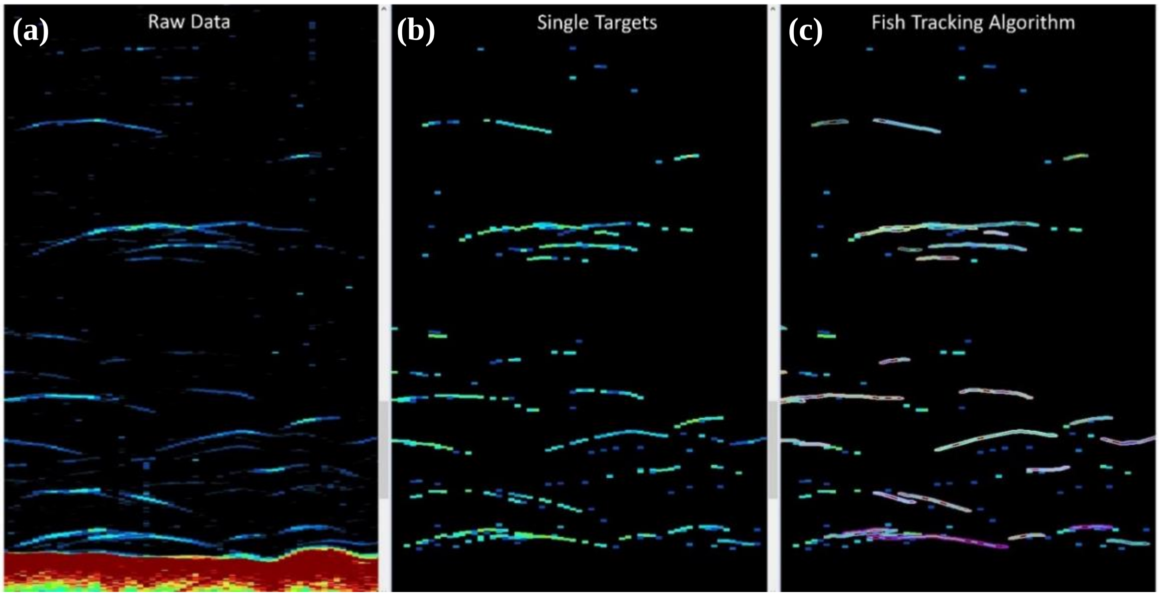


Figure 2.17. Example of fish tracking algorithm showing (a) the raw echogram, (b) thresholded and detected single targets, and (c) targets accumulated into individual fish tracks. Image: NOAA

Echo integration was used to derive fish densities assuming the total reflected backscatter from an ensonified volume of water represents the sum of reflected backscatter from individual fish. The area backscatter coefficient (ABC, m^2m^{-2}) from the cleaned dataset was used to derive densities from discrete volumes of water by transect and depth strata into units of number of fish-m^{-2}. The ABC was exported into depth strata that corresponded to the mean distance between the platform's cross members, similar to the depth strata used in the visual surveys described above. This resulted in eight 17 m depth bins except for the depth bin that included the seafloor. The seafloor and the irregular size of the platform during each transect were accounted for in the ABC measurement by masking the volume occupied by the platform or seafloor by each ping and weighting the bins that have less area sampled. The single targets returns from each fish were used to estimate the mean signal return (in dB) of fish within each depth bin and transect. ABC for each transect and bin was divided by the average fish target strength to produce densities of all fish in each strata and transect.

Statistical Analysis

Summaries of fish sizes and densities for pre- and post-removal surveys by depth strata were calculated using R statistical programming language.

Water Quality

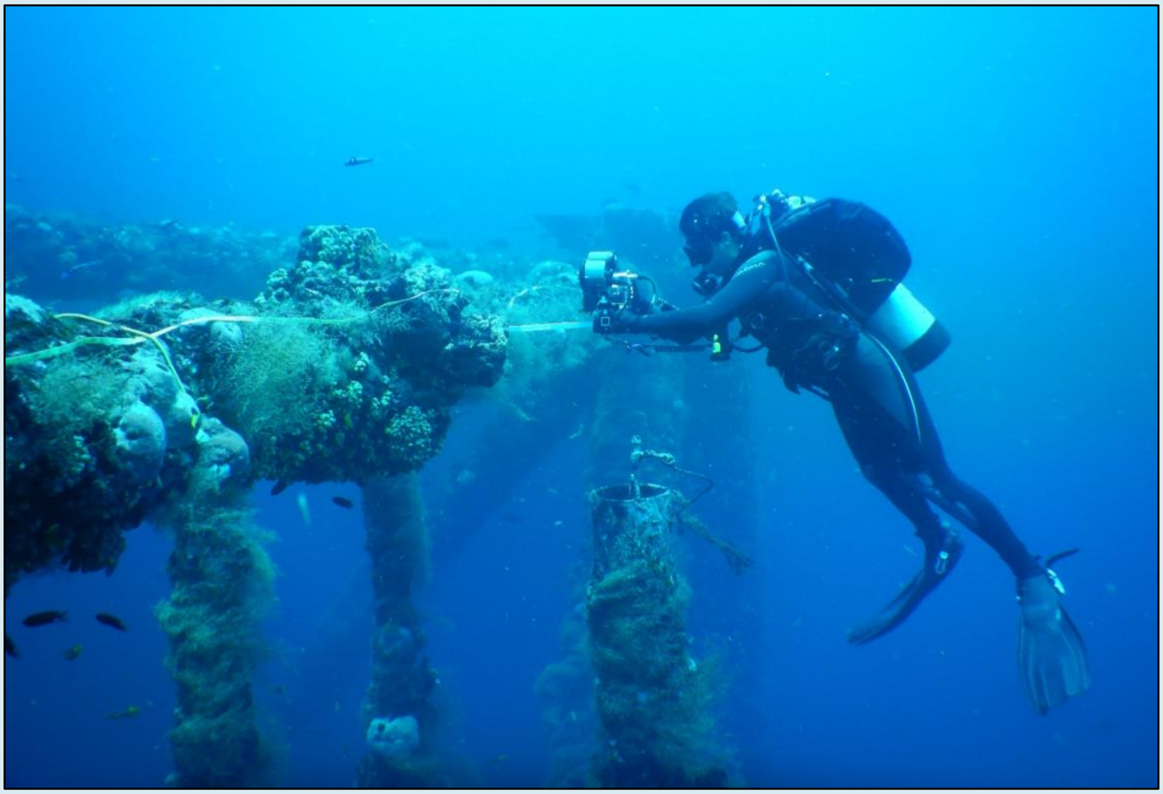
Water Column Profile Field Methods

Water column profiles were opportunistically collected outside of the footprint of the platform from the surface to a depth of approximately 120 meters. To prevent entanglement, the instrument was not lowered all the way to the seafloor. A Sea-Bird® Electronics *19plus* V2 CTD recorded depth, temperature, salinity, pH, turbidity, fluorescence, and dissolved oxygen (DO) every ¼ second. Data were recorded, following an initial surface soaking period, on the downcast phase of each deployment while the CTD was lowered at a rate <1 m/sec. Five water column profiles were obtained between September 2015 and May 2019.

Data Processing

Water column profile data recorded on Sea-Bird® instruments in real time were reviewed after collection to ensure data precision. QA/QC procedures entailed routine equipment calibration and maintenance according to manufacturer recommendations in addition to processing, plotting, and reviewing all data points for accuracy and precision. Data were organized by parameter and plotted to visualize water column characteristics according to depth for each profile taken.

Chapter 3: Benthic Surveys



NOAA diver conducts a post-removal photographic transect on the outside of a horizontal support beam.
Photo: Jimmy MacMillan/CPC

Photographic Transects on Horizontal Beams

Pre-Removal Horizontal Beam Benthic Results

Table 3.1 summarizes completed surveys on the bottom, inside, outside, and top orientations of horizontal beams in photographic transects taken by divers, and ROV transects completed on the outside orientation only (to avoid entanglement with the structure) on all sides (east, west, north, and south). Due to unfavorable weather conditions and strong currents, all planned photographic surveys on horizontal beams were not completed during scuba and ROV operations. Because of the limited number of scuba surveys completed at H3 (attributable to limited time in the field), scuba and ROV surveys were combined at this level to ensure enough data points for analysis. Poor visibility and strong currents did not allow for the completion of ROV surveys on all four sides at the deeper horizontal levels (H7 and H8). The east and south sides were surveyed at H7, and only the east side was surveyed on H8. Only one diagonal transect was completed during scuba operations on the south side of H2 due to a lack of time in the field. This transect was omitted from analysis because no comparative diagonal data were collected from other levels. A total of 39 photographic transects were completed by scuba divers, and a total of 29 horizontal surveys were completed with the ROV.

Table 3.1. Completed pre-removal surveys on the bottom, inside, outside, and top (B, I, O, T) of the sides of horizontal beams in photographic transects taken by divers. ROV photographic transects on the sides of the structure were only done using an outside orientation to avoid entanglement.

Survey Method by Horizontal Level and Depth (m)	East	West	North	South
Scuba - H1 (9 m)	B, I, O, T	B, I, O, T	B, I, O, T	B, I, O, T
Scuba - H2 (22 m)	B, I, O, T	B, I, O, T	B, I, O, T	I, O, T
Scuba - H3 (37 m)	-	-	B, I, O, T	-
ROV - H3 (37 m)	O	O	O	O
ROV - H4 (52 m)	O	O	O	O
ROV - H5 (72 m)	O	O	O	O
ROV - H6 (91 m)	O	O	O	O
ROV - H7 (108 m)	O	-	-	O
ROV - H8 (125 m)	O	-	-	-

Mean percent cover varied among the 14 groups considered during CPCe analysis among depths (Table 3.2). Macroalgae had the highest cover on H1 (42%), hydroids had the highest cover on H2 (35%), sponge had the highest cover on H3 and H4 (40% and 39%, respectively), encrusting sponge had the highest cover on H5 (31%), other sessile invertebrates, including anemones, tunicates, zoanthids, etc., had the highest cover on H6 and H7 (48% and 61%, respectively), and bare substrate had the highest cover on H8 (88%) (Figure 3.1).

Table 3.2. Mean percent cover ± SE of benthic groups identified in CPCe pre-removal analysis on depth-delineated horizontal beams from H1 to H8: 1) fire coral, 2) stony coral, 3) hydroids, 4) sponges, 5) encrusting sponges, 6) macroalgae, 7) bivalves, 8) barnacles, 9) black corals 10) octocorals, 11) other motile organisms (including fish, urchins, etc.), 12) other sessile invertebrates (anemones, bryozoans, tube worms, tunicates, and zoanthids), 13) bare substrate, and 14) marine debris. The components of these benthic groups are further broken down throughout this report section.

Level (Depth m)	Fire coral	Stony coral	Hydroids	Sponge	Encrusting sponge	Macroalgae	Bivalves	Barnacles	Black corals	Octocorals	Other motile organisms	Other sessile invertebrates	Bare substrate	Marine debris
H1 (9 m)	0.63 ± 0.28	8.94 ± 2.75	8.42 ± 1.13	11.15 ± 1.66	17.05 ± 2.39	42.42 ± 4.85	0.66 ± 0.19	0.07 ± 0.03	0.00	0.00	0.15 ± 0.07	3.21 ± 0.54	7.26 ± 0.98	0.05 ± 0.05
H2 (22 m)	0.00	2.55 ± 0.91	34.71 ± 2.60	25.61 ± 1.70	17.29 ± 2.49	12.18 ± 3.22	2.19 ± 0.50	0.02 ± 0.02	0.00	0.00	0.30 ± 0.08	2.78 ± 0.76	2.36 ± 0.75	0.00
H3 (37 m)	0.00	9.03 ± 3.66	16.99 ± 2.81	40.38 ± 3.51	11.30 ± 0.93	15.23 ± 2.72	0.98 ± 0.32	0.06 ± 0.05	1.29 ± 0.77	0.00	0.23 ± 0.13	2.93 ± 0.68	1.62 ± 0.74	0.00
H4 (52 m)	0.00	18.04 ± 3.73	5.18 ± 1.53	38.66 ± 1.99	14.06 ± 1.58	18.09 ± 0.88	0.50 ± 0.21	0.00	0.00	0.00	0.93 ± 0.50	0.79 ± 0.27	3.70 ± 0.75	0.07 ± 0.07
H5 (72 m)	0.00	2.14 ± 0.44	14.99 ± 2.30	21.51 ± 2.56	30.53 ± 2.65	14.50 ± 2.35	1.70 ± 0.43	0.00	6.61 ± 2.54	0.00	0.48 ± 0.16	2.92 ± 1.01	4.61 ± 0.26	0.00
H6 (91 m)	0.00	6.47 ± 0.91	4.33 ± 1.79	0.51 ± 0.11	28.48 ± 5.32	6.78 ± 2.81	1.40 ± 0.46	0.00	0.59 ± 0.59	2.35 ± 2.22	0.64 ± 0.56	47.61 ± 10.53	0.85 ± 0.46	0.00
H7 (108 m)	0.00	6.22 ± 0.15	3.00 ± 1.82	0.21 ± 0.15	4.08 ± 1.06	14.91 ± 6.60	3.54 ± 1.29	0.00	0.32 ± 0.08	0.43 ± 0.30	0.43 ± 0.00	61.27 ± 12.22	5.58 ± 3.95	0.00
H8 (125 m)	0.00	0.00	0.00	0.00	0.00	12.5	0.00	0.00	0.00	0.00	0.00	0.00	87.5	0.00

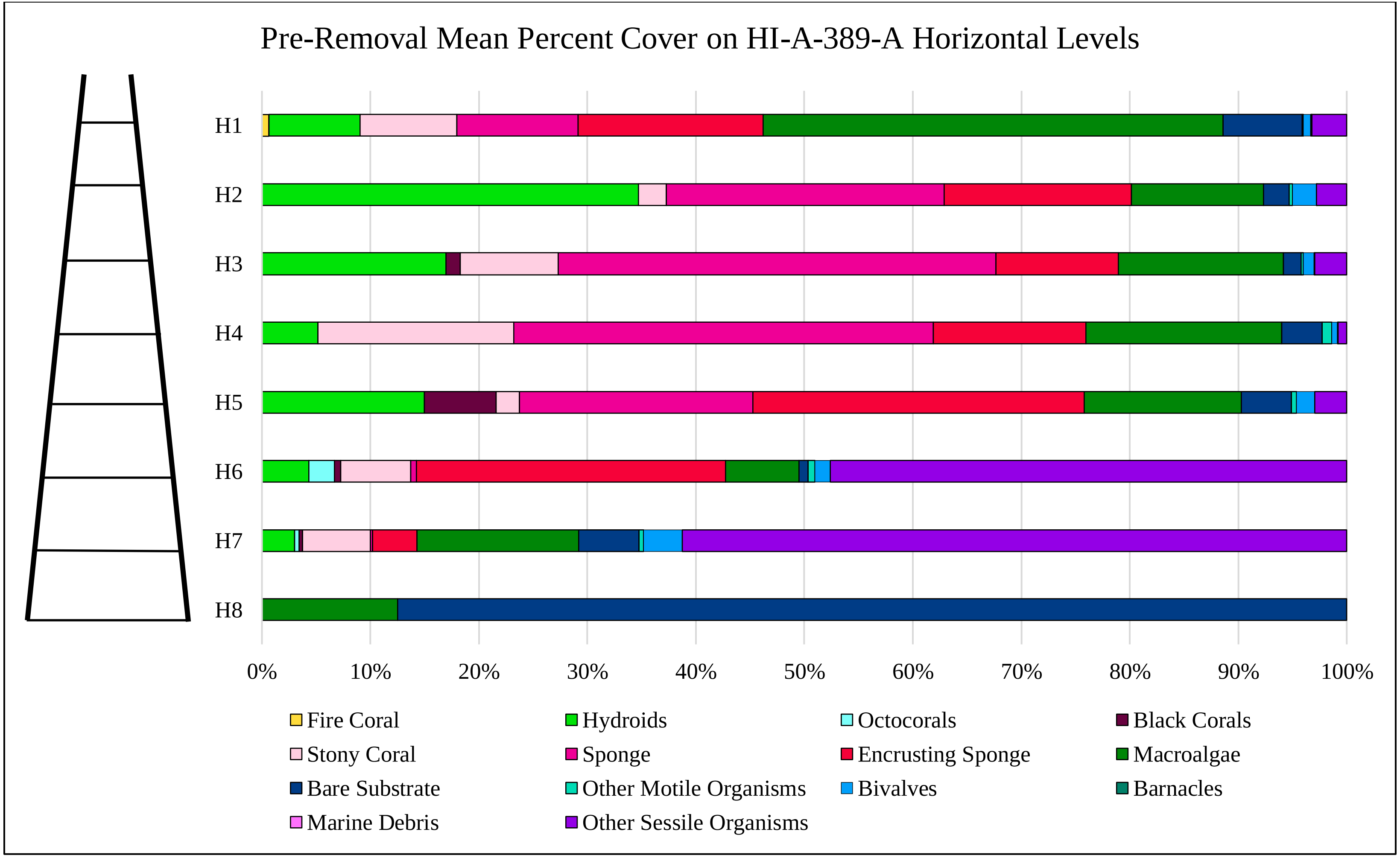


Figure 3.1. Percent composition of benthic cover groups per horizontal level (H1-H8) identified in CPCe pre-removal analysis. The outline of HI-A-389-A to the left of the stacked bar graph helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m).

Within the CPCe program, an additional note category for species interactions necessitated by the layered nature of the fouling community is listed in Table 3.3. Bivalve overgrowth was most abundant on H1 and was common on all horizontal levels except H8. Organisms overgrown with algae and hydroids were most abundant on H2, organisms covered with silt were most abundant on H8, bleached coral and sponge was most abundant on H3, and other disease or damage and debris represented less than 1% of benthic cover among all horizontal levels.

Table 3.3. Pre-removal mean percent cover ± SE of noted interaction types for benthic organisms identified in CPCe on depth-delineated horizontal beams from H1 to H8.

Level (Depth m)	Overgrown with bivalve	Overgrown with algae	Overgrown with hydroid	Silted	Bleached	Other disease or damage	Attached to debris
H1 (9 m)	83.02 ± 2.39	2.34 ± 0.70	0.75 ± 0.33	0.00	0.05 ± 0.05	0.31 ± 0.18	0.00
H2 (22 m)	42.98 ± 3.31	4.98 ± 1.29	18.91 ± 2.94	0.00	0.40 ± 0.20	0.09 ± 0.06	0.00
H3 (37 m)	37.14 ± 4.80	1.50 ± 0.49	4.64 ± 0.97	0.00	5.53 ± 2.43	0.00	0.00
H4 (52 m)	10.15 ± 4.29	0.48 ± 0.19	0.00	0.00	0.18 ± 0.18	0.18 ± 0.18	0.00
H5 (72 m)	33.65 ± 5.35	0.28 ± 0.24	0.00	0.00	0.00	0.00	0.10 ± 0.10
H6 (91 m)	39.32 ± 7.88	0.19 ± 0.19	0.00	0.19 ± 0.12	0.00	0.00	0.05 ± 0.05
H7 (108 m)	25.86 ± 4.17	0.00	0.00	4.94 ± 2.88	0.00	0.00	0.00
H8 (125 m)	0.00	0.00	0.00	100	0.00	0.00	0.00

Mean percent cover of the most common species within the 14 groupings outlined in the CPCe analysis throughout the various depth levels were further investigated.

Fire coral (*Millepora alcicornis*), a type of hydrocoral, was only observed on H1 (0.63 ± 0.28%).

Stony corals (Scleractinia that build hard skeletons) were found on levels H1 to H7, but were most abundant on H4, due to the percent cover of orange cup coral (*Tubastraea* sp.) (17.98 ± 3.77%) (Table 3.2). It is important to note that *Tubastraea* sp., an invasive ahermatypic cup coral native to the Indo Pacific, was the most abundant coral species observed from H1 to H5. Very few native coral species, such as ten-ray star coral (*Madracis decactis*) (found from H1 to H3) and symmetrical brain coral (*Pseudodiploria strigosa*) (H1 only), were detected on the structure (Table 3.4).

Table 3.4. Mean percent cover ± SE of stony corals identified in CPCe pre-removal analysis on depth delineated horizontal beams from H1 to H8.

Level (Depth m)	***Madracis decactis***	***Pseudodiploria strigosa***	***Tubastraea* sp.**	**Colonial cup coral**	***Oculina* sp.**
H1 (9 m)	0.02 ± 0.02	0.02 ± 0.02	8.90 ± 2.76	0.00	0.00
H2 (22 m)	0.04 ± 0.04	0.00	2.50 ± 0.89	0.02 ± 0.02	0.00
H3 (37 m)	0.18 ± 0.12	0.00	8.81 ± 3.62	0.00	0.00
H4 (52 m)	0.00	0.00	17.98 ± 3.77	0.07 ± 0.07	0.00
H5 (72 m)	0.00	0.00	1.03 ± 0.49	0.08 ± 0.08	1.04 ± 0.67
H6 (91 m)	0.00	0.00	0.00	0.26 ± 0.26	6.21 ± 2.73
H7 (108 m)	0.00	0.00	0.00	0.00	6.22 ± 0.15
H8 (125 m)	0.00	0.00	0.00	0.00	0.00

Figure 3.2. *Tubastraea* sp. on HI-A-389-A. Photo: G.P. Schmahl/NOAA

Hydroids (solitary or colonial hydrozoans in polyp form) were found on levels H1 to H7, but were most abundant on H2 (Table 3.2). This benthic category was grouped together and not broken out by species in CPCe due to the difficulty in making accurate identifications from images.

Sponges were found on levels H1 to H7, but were most abundant on H3 and H4 (Table 3.2). The most common species of sponge observed in surveys were branching vase sponge (*Callyspongia vaginalis*), *Dictyonella ruetzleri*, *Ircinia* sp., stinker sponge (*Ircinia felix*), black-ball sponge (*Ircinia strobilina*), touch-me-not sponge (*Neofibularia nolitangere*), and unidentified sponges (Table 3.5).

Table 3.5. Mean percent cover ± SE of sponges identified in CPCe pre-removal analysis on depth-delineated horizontal beams from H1 to H8.

Level (Depth m)	***Callyspongia vaginalis***	***Dictyonella ruetzleri***	***Ircinia* sp.**	***Ircinia felix***	***Ircinia strobilina***	***Neofibularia nolitangere***	**Unidentified sponge**
H1 (9 m)	0.00	0.07 ± 0.05	4.78 ± 1.20	3.53 ± 0.98	0.08 ± 0.04	0.18 ± 0.12	1.95 ± 0.64
H2 (22 m)	0.22 ± 0.19	5.96 ± 1.05	8.40 ± 0.90	0.87 ± 0.31	1.67 ± 0.44	2.50 ± 1.57	4.36 ± 1.01
H3 (37 m)	0.49 ± 0.22	2.98 ± 0.73	4.78 ± 0.91	0.40 ± 0.40	1.28 ± 0.93	26.24 ± 2.96	1.29 ± 0.45
H4 (52 m)	0.46 ± 0.31	0.50 ± 0.21	4.12 ± 1.41	0.72 ± 0.72	2.09 ± 1.28	29.14 ± 2.87	1.57 ± 0.65
H5 (72 m)	0.00	0.13 ± 0.13	5.08 ± 0.80	0.00	0.10 ± 0.10	14.42 ± 3.41	1.44 ± 0.64
H6 (91 m)	0.00	0.00	0.16 ± 0.16	0.00	0.00	0.00	0.35 ± 0.15
H7 (108 m)	0.00	0.00	0.00	0.00	0.00	0.00	0.21 ± 0.15
H8 (125 m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Encrusting sponges were found on levels H1 to H7, but were most abundant on H5 and H6 (Table 3.2). Encrusting sponges observed in surveys were most commonly orange or yellow.

Macroalgae was found on levels H1 to H8, but was most abundant on H1 (Table 3.2).

Bivalves were found on levels H1 to H7, but were most abundant on H7 (Table 3.2). The bivalves identified were the coon oyster (*Dendrostrea frons*), jewel box oyster (*Chama* sp.), scalloped bivalve (Pectinidae), Atlantic thorny oyster (*Spondylus americanus*), and unidentified bivalve (Bivalvia) (Table 3.6). In many cases, while bivalves were present, they were not captured in percent cover data because they were overgrown with another organism. These species interactions with bivalves are identified in Table 3.3.

Table 3.6. Mean percent cover ± SE of bivalves identified in CPCe pre-removal analysis on depth-delineated horizontal beams from H1 to H8.

Level (Depth m)	***Dendrostrea frons***	***Chama* sp.**	**Pectinidae**	***Spondylus americanus***	**Bivalvia**
H1 (9 m)	0.00	0.02 ± 0.02	0.12 ± 0.04	0.02 ± 0.02	0.51 ± 0.21
H2 (22 m)	0.00	0.00	0.16 ± 0.08	0.00	2.03 ± 0.49
H3 (37 m)	0.00	0.00	0.20 ± 0.11	0.06 ± 0.06	0.72 ± 0.33
H4 (52 m)	0.00	0.00	0.00	0.07 ± 0.07	0.43 ± 0.22
H5 (72 m)	0.03 ± 0.03	0.00	0.08 ± 0.08	0.10 ± 0.10	1.48 ± 0.54
H6 (91 m)	0.00	0.00	0.00	0.00	1.40 ± 0.46
H7 (108 m)	0.00	0.00	0.00	0.00	3.54 ± 1.29
H8 (125 m)	0.00	0.00	0.00	0.00	0.00

Barnacles were found on levels H1, H2, and H3 (Table 3.2).

Black corals (soft deep-water corals) were found on level H3 and levels H5 to H7, but were most abundant on H5 (Table 3.2). The black corals observed in surveys were *Antipathes furcata*, Antipathidae, black coral sea fan, *Plumapathes pennacea*, *Stichopathes* sp., and *Tanacetipathes* sp. (Table 3.7). It should be noted that many species of black coral sea fans cannot be identified visually from photographs, and thus are binned into a multi-species category.

Table 3.7. Mean percent cover ± SE of black corals identified in CPCe pre-removal analysis on depth-delineated horizontal beams from H1 to H8.

Level (Depth m)	*Antipathes furcata*	*Antipathidae*	Black coral sea fan	*Plumapathes pennacea*	*Stichopathes* sp.	*Tanacetipathes* sp.
H1 (9 m)	0.00	0.00	0.00	0.00	0.00	0.00
H2 (22 m)	0.00	0.00	0.00	0.00	0.00	0.00
H3 (37 m)	0.00	0.00	0.00	1.29 ± 0.77	0.00	0.00
H4 (52 m)	0.00	0.00	0.00	0.00	0.00	0.00
H5 (72 m)	0.14 ± 0.08	0.41 ± 0.41	5.88 ± 2.47	0.00	0.08 ± 0.08	0.10 ± 0.10
H6 (91 m)	0.20 ± 0.20	0.05 ± 0.05	0.29 ± 0.29	0.00	0.00	0.00
H7 (108 m)	0.00	0.21 ± 0.15	0.11 ± 0.03	0.00	0.00	0.00
H8 (125 m)	0.00	0.00	0.00	0.00	0.00	0.00

Octocorals (organisms formed of colonial polyps with eight-fold symmetry) were only observed on levels H6 and H7 (Table 3.2). On H6, *Muricea pendula* (2.28 ± 0.81%) and *Nicella* sp. (0.06 ± 0.02%) were the two species of octocoral observed. On H7, *Diodogorgia nodulifera* (0.43 ± 0.11%) was the only species observed.

Other motile organisms (including fish, urchins, fire worms, annelids, arthropods, etc.) were found on levels H1 to H7, but were most abundant on H4 (Table 3.2).

Other sessile invertebrates (including anemones, bryozoans, tubeworms, tunicates, and zoanthids) were found on levels H1 to H7, but were most abundant on H7 followed by H6 (Table 3.2). Anemones, bryozoans, tunicates, and zoanthids were the most common organisms observed in this group (Table 3.8).

Bare substrate (exposed metal) was present on all horizontal levels, but was most prevalent on H8 (Table 3.2).

Table 3.8. Mean percent cover ± SE of other sessile invertebrates in CPCe pre-removal analysis on depth-delineated horizontal beams from H1 to H8.

Level (Depth m)	Anemone	Bryozoan	Tubeworm	Tunicate	Zoanthid
H1 (9 m)	0.00	0.89 ± 0.27	0.00	2.18 ± 0.41	0.14 ± 0.14
H2 (22 m)	0.00	0.61 ± 0.20	0.00	2.16 ± 0.64	0.02 ± 0.02
H3 (37 m)	0.00	0.63 ± 0.25	0.07 ± 0.05	2.13 ± 0.49	0.10 ± 0.10
H4 (52 m)	0.00	0.46 ± 0.27	0.00	0.33 ± 0.04	0.00
H5 (72 m)	0.00	1.51 ± 1.20	0.17 ± 0.17	0.27 ± 0.12	0.98 ± 0.65
H6 (91 m)	0.06 ± 0.06	0.00	0.06 ± 0.06	0.19 ± 0.19	47.29 ±10.69
H7 (108 m)	0.00	0.00	0.00	0.21 ± 0.15	61.05 ± 38.01
H8 (125 m)	0.00	0.00	0.00	0.00	0.00

Marine debris was observed on levels H1 and H4 from CPCe primary group analysis (Table 3.2), and on H5 and H6 from interaction notes CPCe analysis (Table 3.3). The type of debris observed was braided rope entangled around the structure on H1 (south beam), monofilament fishing line with hooks and lure entangled around the structure on H4 (west beam) (Figure 3.3), and monofilament fishing line on H5 and H6.

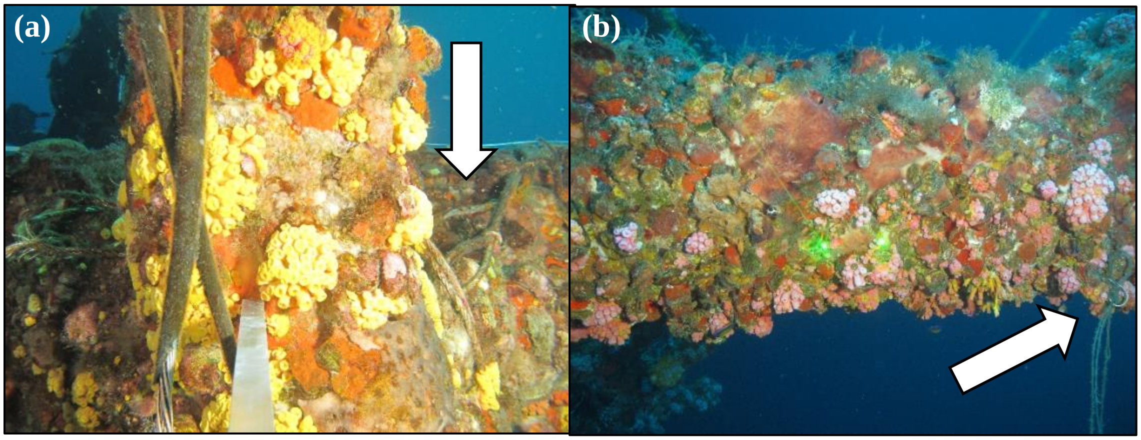


Figure 3.3. Marine debris found in CPCe pre-removal analysis on depth-delineated horizontal beams. Arrows point to (a) entangled rope observed on the H1 south beam and (b) entangled fishing hooks and line observed on the H4 west beam. Photos: NOAA (left), NOAA/UNCW-UVP (right)

PERMANOVA analysis comparing benthic groups by horizontal level revealed significant differences, suggesting that the benthic community of HI-A-389-A differed by depth (Table 3.9).

Table 3.9. PERMANOVA results comparing benthic groups by horizontal level depth in pre-removal analysis. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Depth	786	7	12.84	**0.001**
Res	402	46		
Total	1189	53		

Hierarchical cluster analysis with SIMPROF tests detected several significant clusters among the various horizontal depths (Figure 3.4). In general, horizontal beams from level H1 clustered together, H2 through H5 clustered together, H6 and H7 formed a significant cluster, and H8 differed significantly from all other levels. SIMPER analysis further identified that, on average, the greatest contributor to the observed dissimilarity of H1 and all other levels was macroalgae. Sponges and encrusting sponges were the primary contributors to the clustering of levels H2 through H5. The greatest contributor to the observed clustering of H6 and H7 and dissimilarity from all other levels was the other sessile invertebrates group. The amount of bare substrate observed on the H8 horizontal beams separated that level from all the other levels in the cluster analysis.

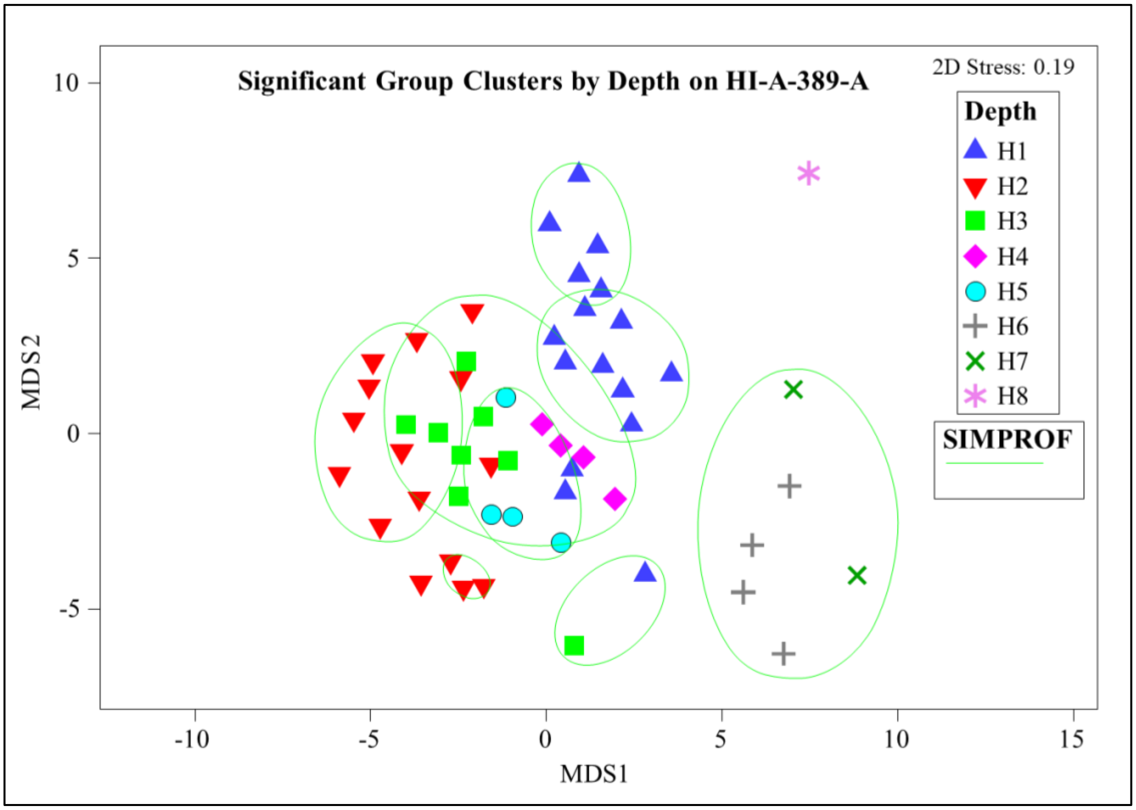


Figure 3.4. MDS plot of significant group clusters by horizontal level depth on HI-A-389-A from pre-removal surveys. The ovals are SIMPROF groups representing significant clusters.

When comparing benthic communities observed during pre-removal surveys among depths and sides (east, west, north, and south) of HI-A-389-A, PERMANOVA analysis still only revealed a significant difference among horizontal depth levels, suggesting the directional sides of the platform did not differ significantly (Table 3.10).

Table 3.10. PERMANOVA results comparing pre-removal benthic communities on HI-A-389-A by horizontal depth level and location (east, west, north, south sides). Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Depth	47109	7	13.57	**0.001**
Direction (E, W, N, S)	1270	3	0.85	0.559
Depth x Direction	6274	16	0.79	0.803
Res	13387	27		
Total	72622	53		

To further investigate survey methods, scuba surveys on H1 and H2 were completed in different orientations (bottom, inside, outside, and top) of the horizontal beams in photographic transects on all four sides of HI-A-389-A. When comparing pre-removal benthic communities on HI-A-389-A by depth and orientation, PERMANOVA analysis revealed a significant difference among both depths and orientations, suggesting that the orientation of surveys on beams resulted in observation of different benthic communities on H1 and H2 (Table 3.11).

Table 3.11. PERMANOVA results comparing pre-removal benthic communities on HI-A-389-A by depth (H1 and H2) and orientation. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Depth	14591	1	47.02	**0.001**
Orientation	7973	3	8.56	**0.001**
Depth x Orientation	792	3	0.85	0.511
Res	7137	23		
Total	30693	30		

Hierarchical cluster analysis with SIMPROF tests detected several significant clusters between H1 and H2 (Figure 3.5). Pairwise tests between depth and orientation for pairs of levels by the factor orientation on H1 detected significant differences in the benthic community between surveys from the top and all other sides (Table 3.12). Significant differences in the benthic community between surveys from the top and the bottom, and from the top and the inside, were detected on H2 (Table 3.13).

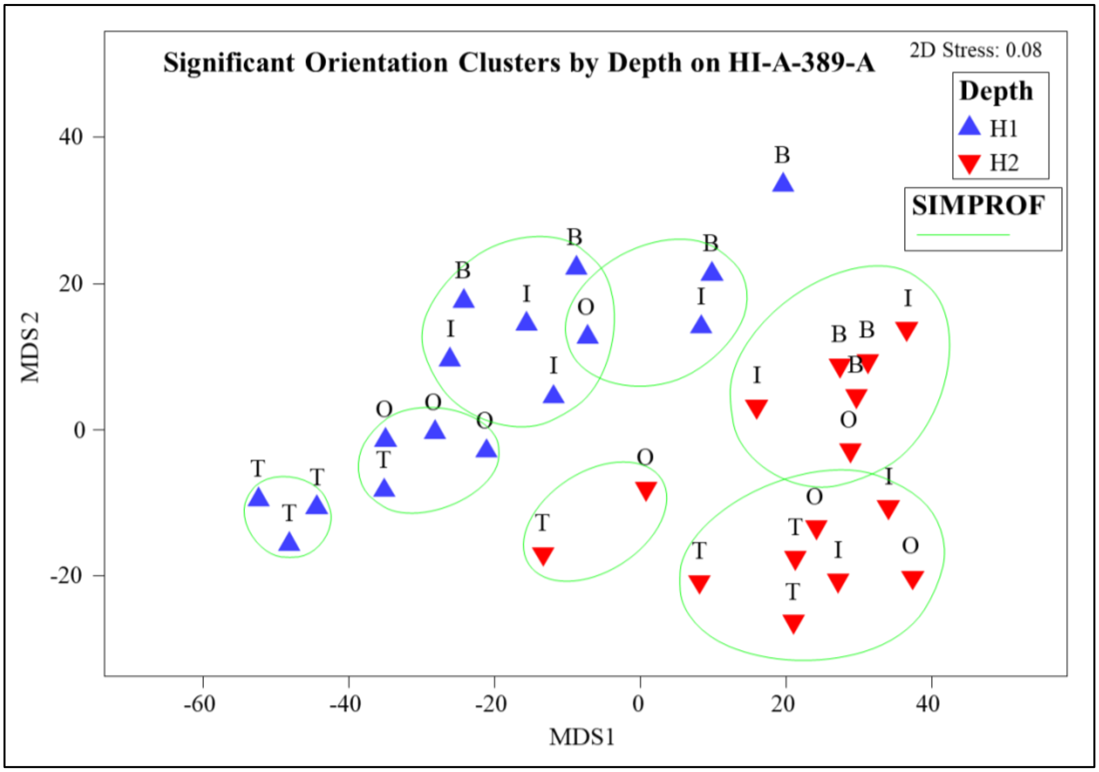


Figure 3.5. MDS plot of significant orientation clusters by depth (H1 and H2) on HI-A-389-A from pre-removal surveys. The ovals are SIMPROF groups representing significant clusters.

Table 3.12. PERMANOVA pairwise test results for significant differences in pre-removal benthic communities among orientations on H1 at HI-A-389-A. Bold text denotes significant value.

Groups	t	Unique perms	P (perm)
B, I	1.1824	35	0.225
B, O	1.9239	35	0.058
B, T	3.8194	35	**0.033**
I, O	1.5069	35	0.177
I, T	4.2038	35	**0.031**
O, T	2.8878	35	**0.032**

Table 3.13. PERMANOVA pairwise test results for significant differences in pre-removal benthic communities among orientations on H2 at HI-A-389-A. Bold text denotes significant value.

Groups	t	Unique perms	P (perm)
B, I	1.3952	35	0.140
B, O	1.6878	35	0.071
B, T	2.7549	35	**0.029**
I, O	1.110	35	0.384
I, T	1.7913	35	**0.027**
O, T	1.2318	35	0.288

Post-Removal Horizontal Beam Benthic Results

After the top portion of HI-A-389-A (H1) was removed in July 2018, ROV and scuba surveys were completed within the remaining seven depth tiers (H2 to H8). Due to unfavorable weather conditions and strong currents, not all photographic surveys used to document percent cover on horizontal beams were completed during scuba and ROV operations. Table 3.14 summarizes completed surveys on the bottom, inside, outside, and top (B, I, O, T) orientations of horizontal beams. Photographic transects were taken by divers on all orientations when possible, and ROV transects were completed on the outside orientation only (to avoid entanglement on the structure). Transects were conducted on all sides (east, west, north, and south) of HI-A-389-A when possible. Due to the lack of scuba surveys completed on the H3 south beam (due to limited time in the field), ROV surveys of the H3 south beam were used for analysis. Strong current did not allow for ROV surveys on horizontal beams on the east side of the platform. Poor visibility, creating an entanglement risk, did not allow for the completion of ROV surveys on any sides of the deepest horizontal level (H8). A total of 35 photographic transects were completed by scuba divers, and a total of 18 horizontal surveys were completed among platform levels utilizing the ROV.

Table 3.14. Completed post-removal surveys on the bottom, inside, outside, and top (B, I, O, T) of the horizontal beams, including photographic transects taken by divers and ROV transects. ROV photographic transects on the sides of the structure were only done on the outside orientation to avoid entanglement.

Survey method by Horizontal Level and Depth (m)	East	West	North	South
SCUBA - H2 (22 m)	B, I, O, T	B, I, O, T	B, I, O, T	I, O, T
SCUBA - H3 (37 m)	B, I, O, T	B, I, O, T	B, I, O, T	-
ROV - H3 (37 m)	-	O	O	O
ROV - H4 (52 m)	-	O	O	O
ROV - H5 (72 m)	-	O	O	O
ROV - H6 (91 m)	-	O	O	O
ROV - H7 (108 m)	-	O	O	O
ROV - H8 (125 m)	-	-	-	-

Mean percent cover varied among the 14 groups considered in the CPCe analysis throughout the various depths (Table 3.15). Macroalgae was the most abundant type of cover observed on H2 (29%), sponge had the highest cover on H3, H4, and H5 (31%, 52%, and 27% respectively), encrusting sponge had the highest cover on H6 (32%), and other sessile invertebrates had the highest cover on H7 (27%) (Figure 3.6).

Table 3.15. Mean percent cover ± SE of benthic groups identified in CPCe post-removal analysis on depth delineated-horizontal beams from H2 to H7: 1) fire coral, 2) stony coral, 3) hydroids, 4) sponges, 5) encrusting sponges, 6) macroalgae, 7) bivalves, 8) barnacles, 9) black corals 10) octocorals, 11) other motile organisms, 12) other sessile invertebrates, 13) bare substrate, and 14) marine debris. No surveys were conducted on H8. The components of these benthic groups are further broken down throughout this report section.

Level (Depth m)	Fire coral	Stony coral	Hydroids	Sponge	Encrusting sponge	Macroalgae	Bivalves	Barnacles	Black corals	Octocorals	Other motile organisms	Other sessile invertebrates	Bare substrate	Marine debris
H2 (22 m)	0.01 ± 0.01	5.32 ± 1.19	16.13 ± 1.44	22.08 ± 1.44	20.77 ± 2.30	29.06 ± 3.78	0.12 ± 0.05	0.00	0.00	0.08 ± 0.08	0.09 ± 0.03	2.97 ± 0.43	3.35 ± 0.53	0.00
H3 (37 m)	0.06 ± 0.04	12.69 ± 3.74	8.33 ± 1.86	30.66 ± 3.41	22.27 ± 2.40	17.38 ± 2.49	0.48 ± 0.20	0.00	0.40 ± 0.40	0.00	0.16 ± 0.07	3.44 ± 0.68	4.14 ± 0.52	0.00
H4 (52 m)	0.00	7.06 ± 1.71	1.07 ± 0.99	51.94 ± 7.81	15.65 ± 2.97	16.36 ± 4.18	1.97 ± 1.31	0.00	0.00	0.00	0.23 ± 0.15	1.22 ± 0.44	4.47 ± 1.26	0.03 ± 0.03
H5 (72 m)	0.00	1.04 ± 0.32	0.76 ± 0.13	27.27 ± 0.71	23.99 ± 2.31	26.60 ± 8.06	8.15 ± 7.13	0.00	6.37 ± 2.86	0.00	0.57 ± 0.05	1.89 ± 0.81	3.36 ± 0.70	0.00
H6 (91 m)	0.00	10.86 ± 1.48	0.09 ± 0.09	0.81 ± 0.49	31.50 ± 7.74	9.46 ± 4.30	20.21 ± 14.96	0.00	0.46 ± 0.46	1.03 ± 0.77	0.31 ± 0.26	20.15 ± 11.13	5.11 ± 2.70	0.00
H7 (108 m)	0.00	4.26 ± 1.75	0.87 ± 0.47	0.27 ± 0.27	2.53 ± 0.71	18.47 ± 9.71	26.80 ± 5.95	0.00	0.03 ± 0.03	0.00	0.19 ± 0.11	27.27 ± 7.98	19.19 ± 6.67	0.13 ± 0.06
H8 (125 m)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

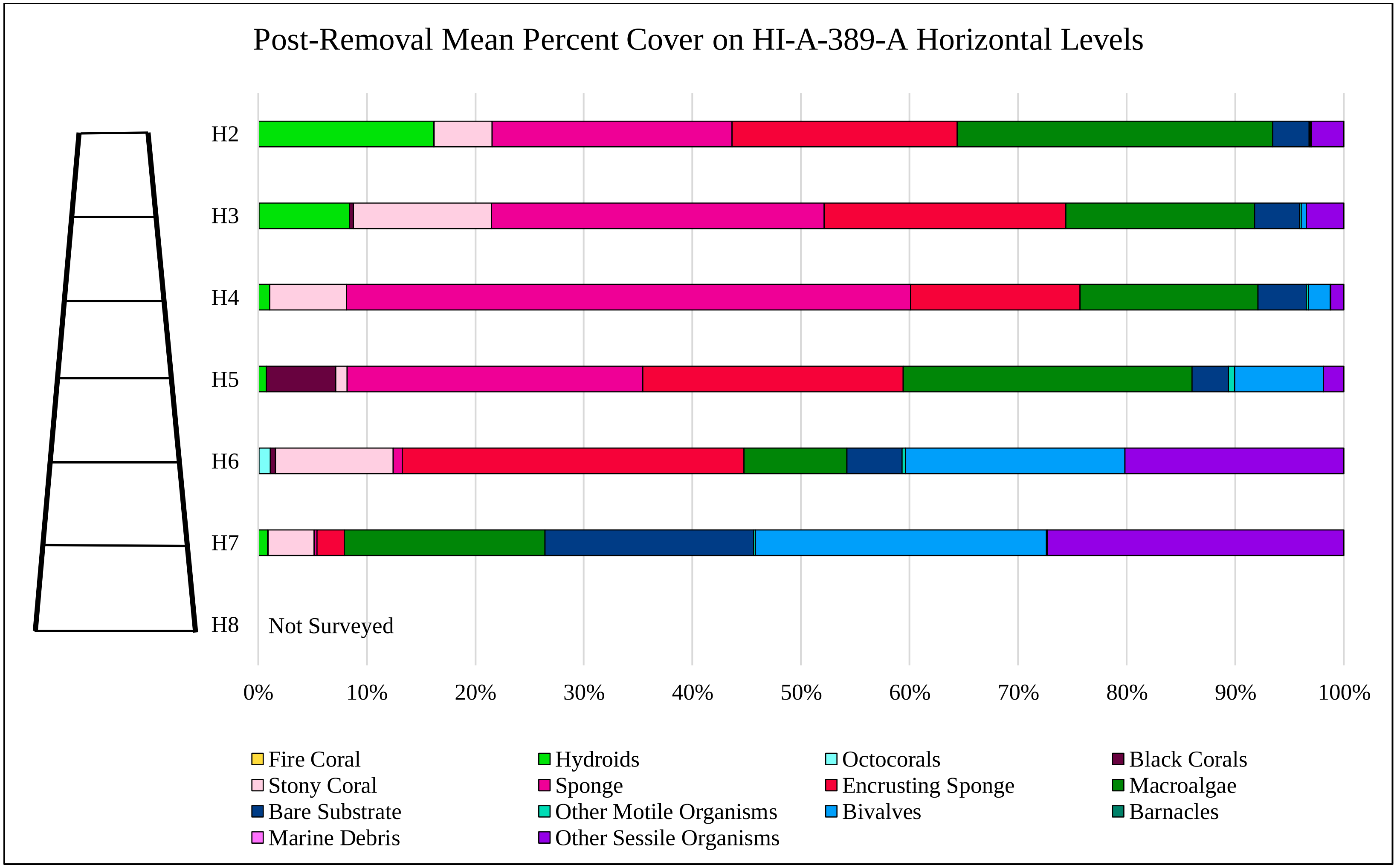


Figure 3.6. Percent composition of benthic cover groups per horizontal level (H2-H7) identified in CPCe post-removal analysis. The outline of HI-A-389-A to the left of the stacked bar graph helps to visually represent the depth delineations of the horizontal beams below the surface: H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m). No surveys were conducted on H8.

Within the CPCe additional note category for species interactions, organisms overgrown with hydroids were most abundant on H2, organisms overgrown with bivalves were most abundant on H5 and H6, organisms covered with silt were most abundant on H7, bleached coral and sponge was most abundant on H5 (Table 3.16). Other disease or damage and debris were less than 1% among all horizontal levels (Table 3.16).

Table 3.16. Post-removal mean percent cover ± SE of noted interaction types for benthic organisms identified in CPCe on depth-delineated horizontal beams from H2 to H7. No surveys were conducted on H8.

Level (Depth m)	Overgrown with bivalve	Overgrown with algae	Overgrown with hydroid	Silted	Bleached	Other disease or damage	Attached to debris
H2 (22 m)	4.74 ± 0.58	7.75 ± 0.56	25.29 ± 2.87	0.00	1.40 ± 0.39	0.08 ± 0.04	0.00
H3 (37 m)	13.07 ± 1.70	8.10 ± 1.17	12.87 ± 1.98	0.00	4.56 ± 1.77	0.04 ± 0.03	0.02 ± 0.02
H4 (52 m)	35.63 ± 8.47	5.50 ± 2.33	0.56 ± 0.34	0.00	4.61 ± 1.31	0.20 ± 0.16	0.00
H5 (72 m)	42.40 ± 12.92	10.67 ± 7.08	0.34 ± 0.10	0.15 ± 0.15	9.49 ± 3.53	0.02 ± 0.02	0.00
H6 (91 m)	46.44 ± 15.07	1.78 ± 0.77	0.03 ± 0.03	18.65 ± 14.37	0.59 ± 0.59	0.00	0.00
H7 (108 m)	23.62 ± 10.50	1.00 ± 0.92	0.09 ± 0.05	36.76 ± 20.93	0.00	0.00	0.00

Mean percent cover of the most common species within the 14 groups outlined in the CPCe analysis throughout the various depth levels were further investigated.

Fire coral was observed on H2 (0.01 ± 0.01%) and H3 (0.06 ± 0.04%).

Stony corals were found on levels H2 to H7, but were most abundant on H3 (Table 3.15). It is important to note that the most common coral species observed from H2 to H5 was *Tubastraea* sp. Very few native coral species, such as *Madracis decactis* (found on H2, H3, and H5) and lesser starlet coral (*Siderastrea radians*) (H3 only), were detected on the structure (Table 3.17).

Hydroids were found on levels H2 to H7, but were most abundant on H2 (Table 3.15).

Table 3.17. Mean percent cover ± SE of stony corals identified in CPCe post-removal analysis on depth-delineated horizontal beams from H2 to H7. No surveys were conducted on H8.

Level (Depth m)	***Madracis decactis***	***Tubastraea* sp.**	**Colonial cup coral**	***Siderastrea radians***	***Oculina* sp.**
H2 (22 m)	0.32 ± 0.20	5.00 ± 1.21	0.00	0.00	0.00
H3 (37 m)	0.40 ± 0.20	8.53 ± 2.40	0.19 ± 0.09	3.54 ± 3.54	0.04 ± 0.04
H4 (52 m)	0.00	7.06 ± 1.71	0.00	0.00	0.00
H5 (72 m)	0.05 ± 0.05	0.81 ± 0.38	0.11 ± 0.08	0.00	0.07 ± 0.07
H6 (91 m)	0.00	0.09 ± 0.09	0.06 ± 0.06	0.00	10.71 ± 7.61
H7 (108 m)	0.00	0.00	0.00	0.00	4.25 ± 3.53

Sponges were found on levels H2 to H7, but were most abundant on H3 and H4 (Table 3.15). The most common species of sponge observed in surveys were *Callyspongia vaginalis*, *Dictyonella ruetzleri*, *Ircinia* sp., *Ircinia felix*, *Ircinia strobilina*, *Neofibularia nolitangere*, and unidentified sponges (Table 3.18).

Table 3.18. Mean percent cover ± SE of sponges identified in CPCe post-removal analysis on depth-delineated horizontal beams from H2 to H7. No surveys were conducted on H8.

Level (Depth m)	***Callyspongia vaginalis***	***Dictyonella ruetzleri***	***Ircinia* sp.**	***Ircinia felix***	***Ircinia strobilina***	***Neofibularia nolitangere***	**Unidentified sponge**
H2 (22 m)	0.12 ± 0.07	5.70 ± 0.74	9.95 ± 1.09	1.90 ± 0.65	1.14 ± 0.38	2.24 ± 1.22	0.57 ± 0.15
H3 (37 m)	0.26 ± 0.13	6.12 ± 1.04	8.96 ± 1.25	0.29 ± 0.17	0.27 ± 0.21	11.50 ± 3.61	0.69 ± 0.21
H4 (52 m)	0.34 ± 0.34	2.78 ± 0.98	3.67 ± 1.81	0.10 ± 0.10	2.94 ± 1.40	39.52 ± 12.46	2.29 ± 1.91
H5 (72 m)	0.00	0.42 ± 0.23	3.44 ± 0.96	0.00	0.11 ± 0.08	18.98 ± 1.12	4.13 ± 0.94
H6 (91 m)	0.00	0.03 ± 0.03	0.03 ± 0.03	0.00	0.00	0.00	0.66 ± 0.57
H7 (108 m)	0.00	0.00	0.00	0.00	0.00	0.00	0.27 ± 0.27

Encrusting sponges were found on levels H2 to H7, but were most abundant on H6 (Table 3.15). Orange encrusting sponges were the most common encrusting sponges observed in surveys and were present from H2 to H7.

Macroalgae was found on levels H2 to H7, but was most abundant on H2 (Table 3.15).

Bivalves were found on levels H2 to H7, but were most abundant on H7 (Table 3.15). The bivalves identified were Pectinidae, *Spondylus americanus*, and unidentified bivalve (Table 3.19).

Table 3.19. Mean percent cover ± SE of bivalves identified in CPCe post-removal analysis on depth-delineated horizontal beams from H2 to H7. No surveys were conducted on H8.

Level (Depth m)	**Pectinidae**	***Spondylus americanus***	**Unidentified bivalve**
H2 (22 m)	0.02 ± 0.02	0.01 ± 0.01	0.08 ± 0.04
H3 (37 m)	0.02 ± 0.02	0.00	0.46 ± 0.20
H4 (52 m)	0.00	0.00	1.97 ± 1.31
H5 (72 m)	0.00	0.10 ± 0.10	8.15 ± 7.13
H6 (91 m)	0.00	0.00	20.21 ± 14.96
H7 (108 m)	0.00	0.00	26.80 ± 5.95

Black corals were found on levels H5 to H7, but were most abundant on H5 (Table 3.15). The black corals observed in surveys were *Antipathes furcata*, Antipathidae, black coral sea fan, and *Tanacetipathes* sp. (Table 3.20).

Table 3.20. Mean percent cover ± SE of black corals identified in CPCe post-removal analysis on depth-delineated horizontal beams from H2 to H7. No surveys were conducted on H8.

Level (Depth m)	***Antipathes furcata***	**Antipathidae**	**Black coral sea fan**	***Tanacetipathes* sp.**
H2 (22 m)	0.00	0.00	0.00	0.00
H3 (37 m)	0.00	0.00	0.00	0.00
H4 (52 m)	0.00	0.00	0.00	0.00
H5 (72 m)	0.02 ± 0.02	0.56 ± 0.56	5.61 ± 3.19	0.18 ± 0.18
H6 (91 m)	0.00	0.37 ± 0.37	0.09 ± 0.09	0.00
H7 (108 m)	0.00	0.03 ± 0.03	0.00	0.00

Octocorals were only observed on levels H2 and H6 (Table 3.15). *Chironephthya caribaea* (0.08 ± 0.08%) was the only species observed on H2. Alcyoniidae (0.18 ±

0.18%), *Hypnogorgia*/*Muricea pendula* (0.79 ± 0.79%), and *Thesea rubra* (0.06 ± 0.06%) were observed in surveys on H6.

Other motile organisms were found on levels H2 to H7, but were most abundant on H5 (Table 3.15).

Other sessile invertebrates were found on levels H2 to H7, but were most abundant on H7 (Table 3.15). Anemones, bryozoans, tunicates, and zoanthids were the most common organisms observed in this group (Table 3.21).

Table 3.21. Mean percent cover ± SE of other sessile invertebrates in CPCe post-removal analysis on depth-delineated horizontal beams from H2 to H7. No surveys were conducted on H8.

Level (Depth m)	Anemone	Bryozoan	Tubeworm	Tunicate	Zoanthid
H2 (22 m)	0.00	0.75 ± 0.20	0.01 ± 0.01	2.20 ± 0.31	0.01 ± 0.01
H3 (37 m)	0.08 ± 0.08	1.09 ± 0.29	0.00	1.30 ± 0.28	1.01 ± 0.59
H4 (52 m)	0.00	0.61 ± 0.22	0.00	0.61 ± 0.22	0.00
H5 (72 m)	0.00	0.28 ± 0.16	0.00	0.19 ± 0.19	1.42 ± 0.80
H6 (91 m)	0.00	0.09 ± 0.09	0.00	0.00	20.06 ±10.63
H7 (108 m)	0.00	0.00	0.00	0.00	27.27 ± 7.98

Bare substrate (exposed metal beams) was present on all horizontal levels, but was most prevalent on H7 (Table 3.15).

Marine debris was observed on levels H4 and H7 from CPCe primary group analysis (Table 3.15), and on H3 from CPCe analysis of interaction notes (Table 3.16). The types of debris observed were monofilament fishing line entangled around the structure on H4 (west beam) and braided rope entangled around the structure on H7 (west and south beams) (Figure 3.7).

Barnacles were not observed in any surveys.

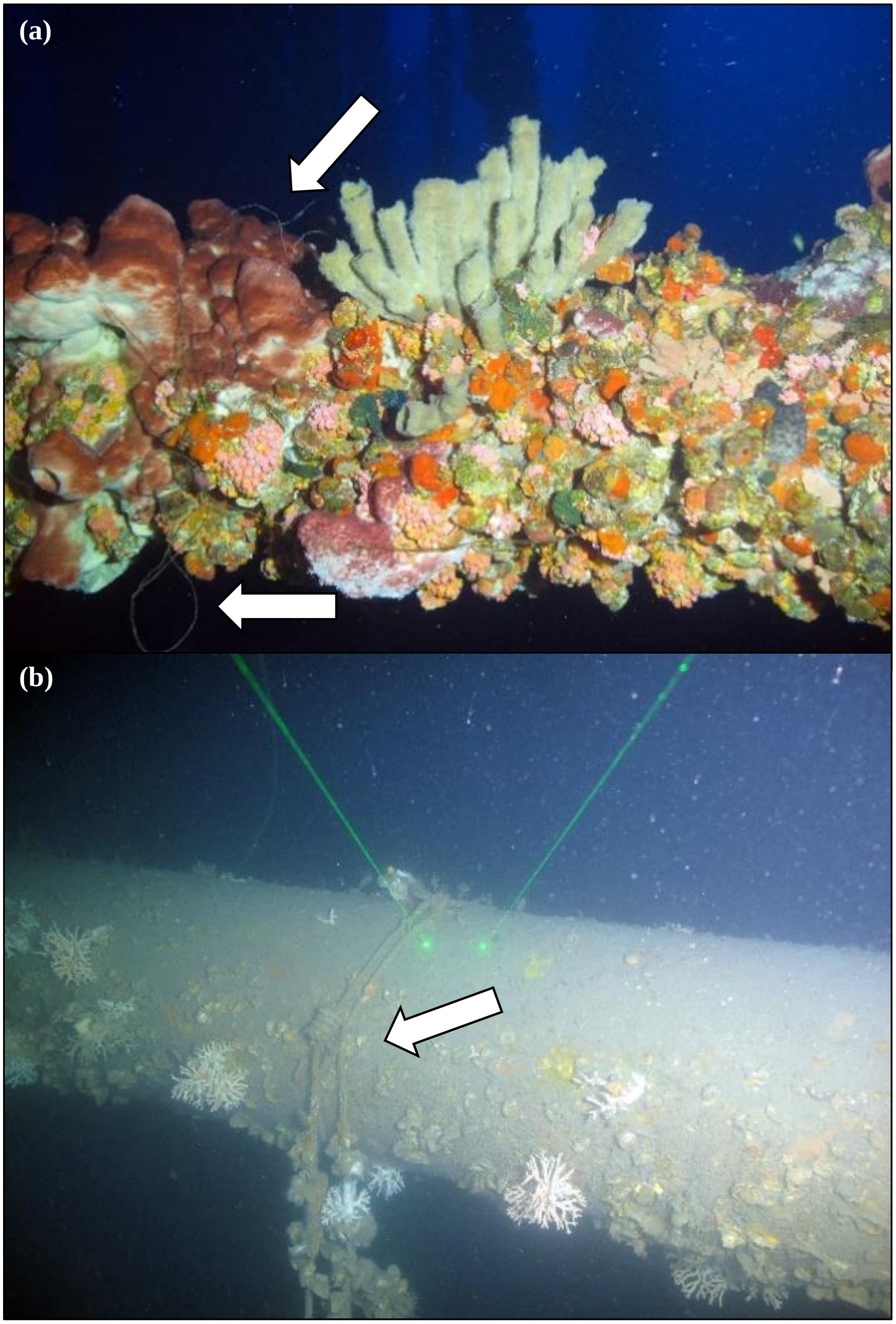


Figure 3.7. Marine debris found in CPCe post-removal analysis on depth-delineated horizontal beams. Arrows point to (a) entangled fishing line observed on the H4 west beam and (b) entangled rope observed on the H7 south beam. Photos: NOAA/UNCW-UVP

PERMANOVA analysis comparing benthic groups by horizontal level revealed significant differences, suggesting that the benthic community of HI-A-389-A differed by depth in post-removal surveys (Table 3.22).

Table 3.22. PERMANOVA results comparing benthic groups by horizontal level depth in post-removal analysis. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Depth	478	5	9.56	**0.001**
Res	440	44		
Total	918	49		

Hierarchical cluster analysis with SIMPROF tests detected several significant clusters among the various horizontal depths (Figure 3.8). In general, beams from level H2 through H5 clustered together, and H6 and H7 formed a significant cluster. SIMPER analysis identified that, on average, the greatest contributor to the observed dissimilarity between the clusters of H2 through H5 and all other levels was sponges, and the greatest contributor to the observed dissimilarity between the cluster of H6 and H7 and all other levels was bivalves.

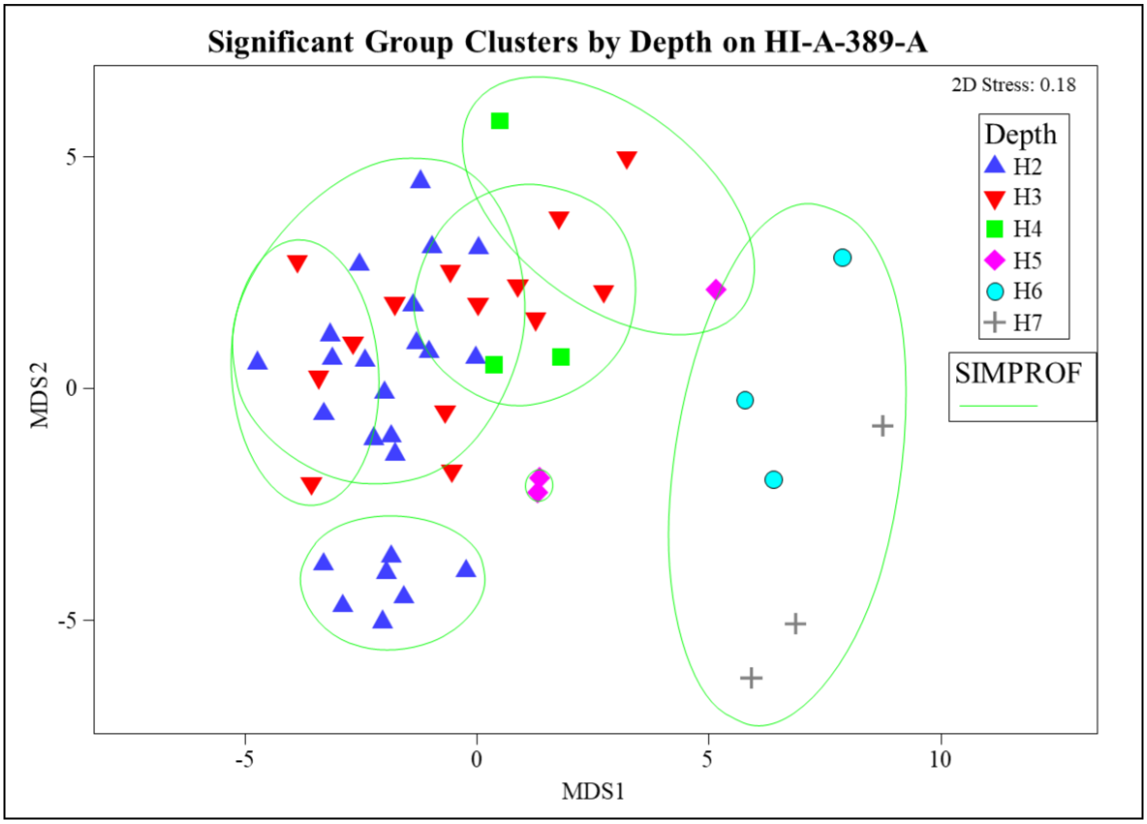


Figure 3.8. MDS plot of significant group clusters by horizontal level depth on HI-A-389-A from post-removal surveys. The ovals are SIMPROF groups representing significant clusters.

When comparing depths and the side of post-removal surveys (west, north, and south sides) on HI-A-389-A, PERMANOVA analysis only revealed a significant difference among horizontal depth levels, suggesting that the directional sides of the platform did not have an effect on benthic community composition (Table 3.23).

Table 3.23. PERMANOVA results comparing horizontal depth level and location (west, north, south sides) of post-removal surveys on HI-A-389-A. The east side of the platform was not surveyed. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Depth	471	5	10.85	**0.001**
Direction (W, N, S)	90	3	3.45	0.252
Depth x Direction	115	11	1.20	0.257
Res	260	30		
Total	918	49		

To further investigate survey methods, scuba photographic transects on H2 and H3 were completed on different orientations (bottom, inside, outside, and top) of the horizontal beams on all four sides of HI-A-389-A. PERMANOVA analysis revealed that the post-removal benthic community varied between depths and among survey orientations for H2 and H3 (Table 3.24).

Table 3.24. PERMANOVA results comparing depth (H2 and H3) and orientation of post-removal surveys on HI-A-389-A. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Depth	3119	1	15.53	**0.001**
Orientation	6629	1	7.31	**0.001**
Res	14938	35		
Total	24686	37		

Pairwise tests between depth and orientation for pairs of levels by the factor orientation on H2 detected significant differences in the benthic community among all orientations (Table 3.25). There were no significant differences in the benthic community among the beam orientations on H3.

Table 3.25. PERMANOVA pairwise test results for significant differences in the HI-A-389-A post-removal benthic community among orientations. Bold text denotes significant value.

Groups	t	Unique perms	P (perm)
B, I	2.610	411	**0.005**
B, O	2.110	407	**0.007**
B, T	5.460	420	**0.002**
I, O	1.555	411	**0.016**
I, T	2.436	401	**0.015**
O, T	4.181	415	**0.002**

Comparison of Pre- and Post-Removal Horizontal Beam Benthic Results

Pre-removal surveys were conducted on levels H1 to H8 in 2015 and 2017 and post-removal surveys were conducted on levels H2 to H7 in 2019 (Figure 3.9).

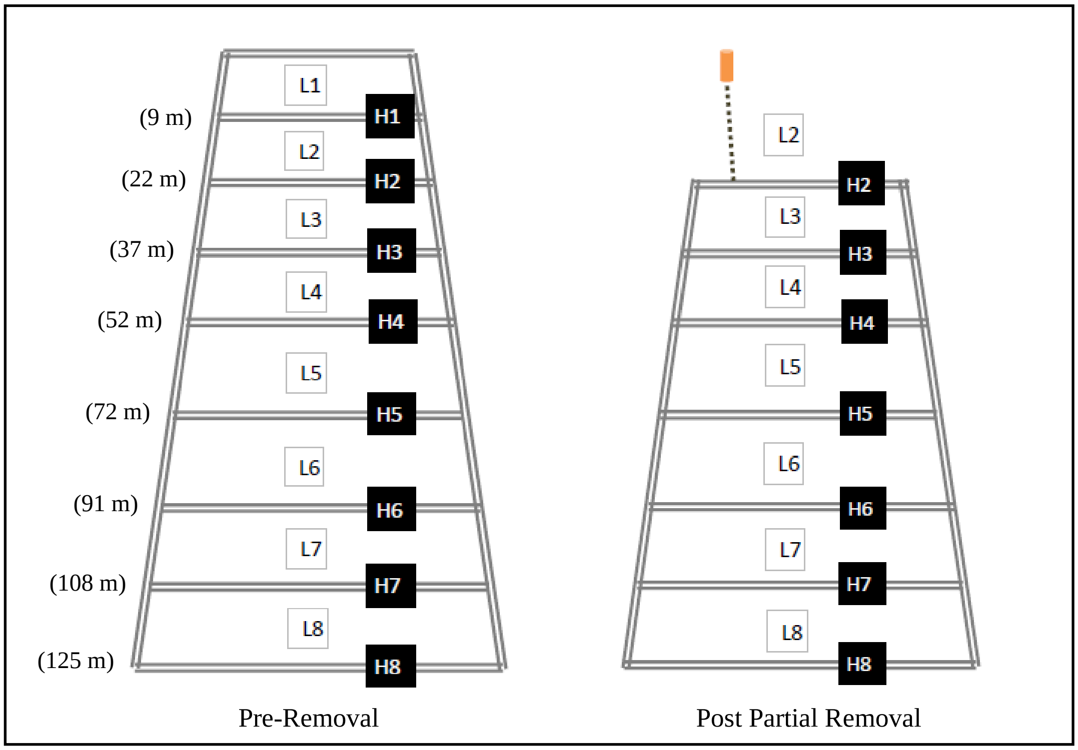


Figure 3.9. HI-A-389-A platform horizontal (H) depth delineations and vertical levels (L) for pre-removal and post-removal surveys. Image: NOAA

Mean percent cover varied among the 14 groups in the CPCe analysis throughout the different levels of the platform between the pre- and post-removal surveys (Table 3.26). Macroalgae had the highest cover of any group on H1 (42%), hydroids had the highest cover on H2 pre-removal (35%) and macroalgae had the highest cover post-removal (29%), sponge had the highest cover on H3 both pre-removal (40%) and post-removal

(31%), sponge had the highest cover on H4 both pre-removal (39%) and post-removal (52%), encrusting sponge had the highest cover on H5 pre-removal (31%) and sponge had the highest cover post-removal (27%), other sessile invertebrates had the highest cover on H6 pre-removal (48%) and encrusting sponge had the highest cover post-removal (32%), other sessile invertebrates had the highest cover on H7 pre-removal (61%) and post-removal (27%), and bare substrate had the highest cover on H8 pre-removal (88%) (Figure 3.10). During post-removal surveys, H8 was not surveyed due to poor visibility and entanglement hazards for the ROV.

On average, stony and fire coral cover increased post-removal on H2 and H3, while stony coral cover decreased post-removal on levels H4, H5, and H7. Percent cover of hydroids decreased across all levels (H2-H7) post-removal, percent cover of black coral also decreased on levels H3, and H5 through H7. Sponge and bivalve cover declined on the upper two levels (H2 and H3), while the deeper levels (H4-H7) experienced an increase in percent cover of sponges and bivalves. Encrusting sponge, macroalgae, and bare substrate percent cover increased on all levels post-removal. Percent cover of other sessile invertebrate and other motile organisms increased on the upper levels (H2-H4), but decreased on H5 (Figure 3.10).

Table 3.26. Mean percent cover and change of benthic groups identified in CPCe pre-removal and post-removal analysis on depth-delineated horizontal beams from H1 to H8: 1) fire coral, 2) stony coral, 3) hydroids, 4) sponges, 5) encrusting sponges, 6) macroalgae, 7) bivalves, 8) barnacles, 9) black corals 10) octocorals, 11) other motile organisms, 12) other sessile invertebrates, 13) bare substrate, and 14) marine debris. No post-removal surveys were conducted on H8. Change between pre- and post-removal percent cover values for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level	Fire coral	Stony coral	Hydroids	Sponge	Encrusting sponge	Macroalgae	Bivalves	Barnacles	Black corals	Octocorals	Other motile organisms	Other sessile invertebrates	Bare substrate	Marine debris
Pre-Removal H1	0.63	8.94	8.42	11.15	17.05	42.42	0.66	0.07	0.00	0.00	0.15	3.21	7.26	0.05
Pre-Removal H2	0.00	2.55	34.71	25.61	17.29	12.18	2.19	0.02	0.00	0.00	0.30	2.78	2.36	0.00
Post-Removal H2	0.01	5.32	16.13	22.08	20.77	29.06	0.12	0.00	0.00	0.08	0.09	2.97	3.35	0.00
Change H2	*+0.01*	*+2.77*	*-18.58*	*-3.53*	*+3.48*	*+16.88*	*-2.07*	*-0.02*	*0.00*	*+0.08*	*-.21*	*+0.19*	*+0.99*	*0.00*
Pre-Removal H3	0.00	9.03	16.99	40.38	11.30	15.23	0.98	0.06	1.29	0.00	0.23	2.93	1.62	0.00
Post-Removal H3	0.06	12.69	8.33	30.66	22.27	17.38	0.48	0.00	0.40	0.00	0.16	3.44	4.14	0.00
Change H3	*+0.06*	*+3.66*	*-8.66*	*-9.72*	*+10.97*	*+2.15*	*-0.5*	*-0.06*	*-0.89*	*0.00*	*-0.07*	*+0.51*	*+2.52*	*0.00*
Pre-Removal H4	0.00	18.04	5.18	38.66	14.06	18.09	0.50	0.00	0.00	0.00	0.93	0.79	3.70	0.07
Post-Removal H4	0.00	7.06	1.07	51.94	15.65	16.36	1.97	0.00	0.00	0.00	0.23	1.22	4.47	0.03
Change H4	*0.00*	*-10.98*	*-4.11*	*+13.28*	*+1.59*	*-1.73*	*+1.47*	*0.00*	*0.00*	*0.00*	*-0.70*	*+0.43*	*+0.77*	*-0.04*
Pre-Removal H5	0.00	2.14	14.99	21.51	30.53	14.50	1.70	0.00	6.61	0.00	0.48	2.92	4.61	0.00
Post-Removal H5	0.00	1.04	0.76	27.27	23.99	26.60	8.15	0.00	6.37	0.00	0.57	1.89	3.36	0.00
Change H5	*0.00*	*-1.1*	*-14.23*	*+5.76*	*-6.54*	*+12.10*	*+6.45*	*0.00*	*-0.24*	*0.00*	*+0.09*	*-1.03*	*-1.25*	*0.00*
Pre-Removal H6	0.00	6.47	4.33	0.51	28.48	6.78	1.40	0.00	0.59	2.35	0.64	47.61	0.85	0.00
Post-Removal H6	0.00	10.86	0.09	0.81	31.50	9.46	20.21	0.00	0.46	1.03	0.31	20.15	5.11	0.00
Change H6	*0.00*	*+4.39*	*-4.24*	*+0.30*	*+3.02*	*+2.68*	*+18.81*	*0.00*	*-0.13*	*-1.32*	*-0.33*	*-27.46*	*+4.26*	*0.00*
Pre-Removal H7	0.00	6.22	3.00	0.21	4.08	14.91	3.54	0.00	0.32	0.43	0.43	61.27	5.58	0.00
Post-Removal H7	0.00	4.26	0.87	0.27	2.53	18.47	26.80	0.00	0.03	0.00	0.19	27.27	19.19	0.13
Change H7	*0.00*	*-1.96*	*-2.13*	*+0.06*	*-1.55*	*+3.56*	*+23.26*	*0.00*	*-0.29*	*-0.43*	*-0.24*	*-34.0*	*+13.61*	*+0.13*
Pre-Removal H8	0.00	0.00	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00	87.50	0.00
Post-Removal H8	Not surveyed													

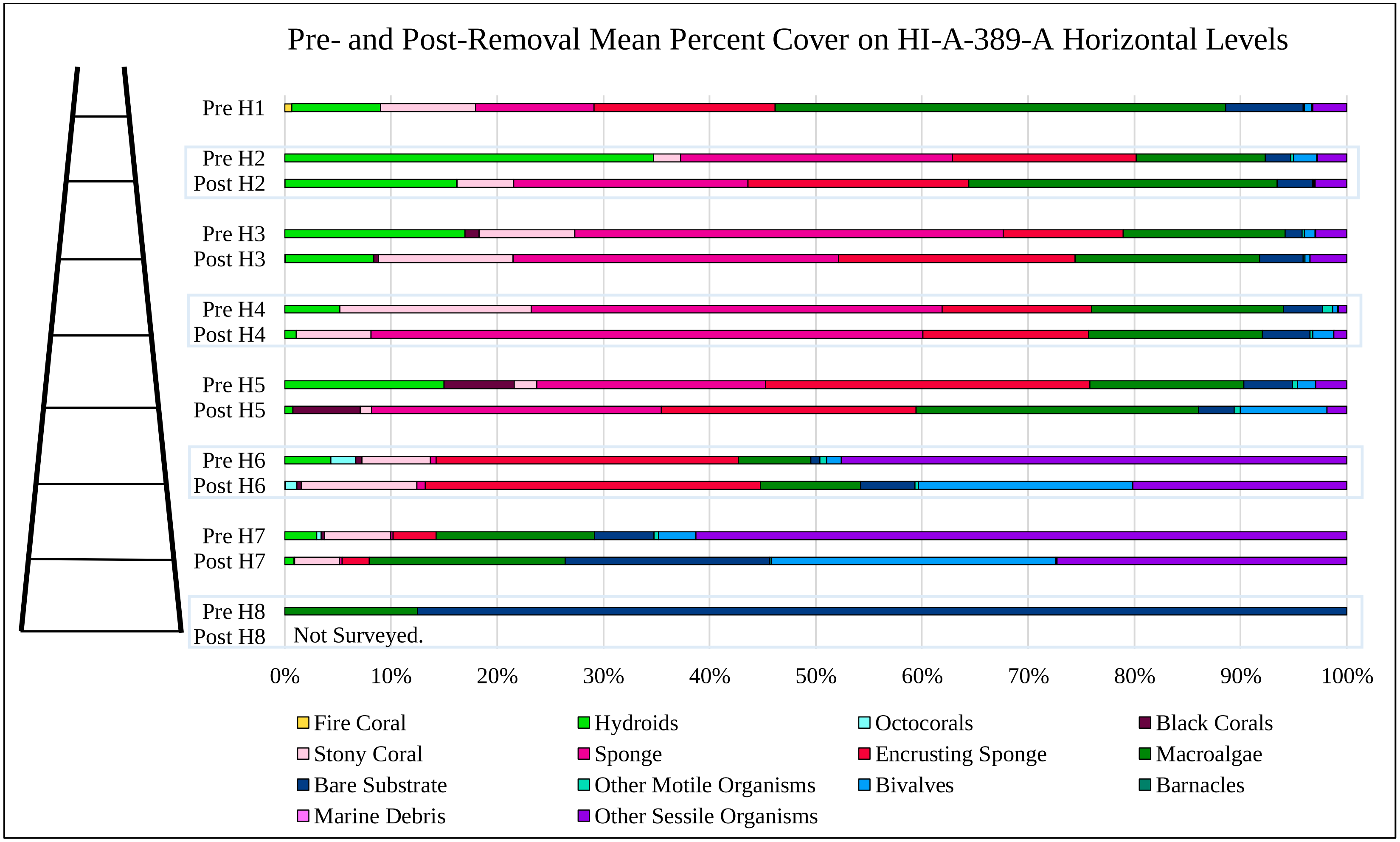


Figure 3.10. Percent composition of benthic cover groups per horizontal level (H1-H8) identified in CPCe pre-removal and post-removal analyses. Outline of HI-A-389-A to the left of the stacked bar graph helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m). No post-removal surveys were conducted on H8. Light blue boxes aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Cover of bivalve overgrowth (from the CPCe additional note category for species interactions) decreased on the upper two levels, H2 and H3, but increased on levels H4 through H6, and decreased on H7 (Table 3.27). Organisms overgrown with algae and hydroids increased on all levels (H2-H7) after the top portion of the HI-A-389-A platform was removed. There was an increase in percent cover of organisms that were silted on the deeper levels (H5-H7) post-removal, while no organisms observed on levels H2-H4 were silted pre- or post-removal. Cover of bleached organisms increased in post-removal surveys; sponges and corals were the primary organisms impacted. Overall there was a slight increase in percent cover of other disease or damage post-removal on levels H3 through H5 (Table 3.27).

Table 3.27. Pre-removal and post-removal mean percent cover of noted interaction types for benthic organisms identified in CPCe on depth-delineated horizontal beams from H1 to H8. No post-removal surveys were conducted on H8. Calculated change between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level	Overgrown with bivalve	Overgrown with algae	Overgrown with hydroid	Silted	Bleached	Other disease or damage	Attached to debris
Pre-Removal H1	83.02	2.34	0.75	0.00	0.05	0.31	0.00
Pre-Removal H2	42.98	4.98	18.91	0.00	0.40	0.09	0.00
Post-Removal H2	4.74	7.75	25.29	0.00	1.40	0.08	0.00
Change H2	*-38.24*	*+2.77*	*+6.38*	*0.00*	*+1.0*	*-0.01*	*0.00*
Pre-Removal H3	37.14	1.50	4.64	0.00	5.53	0.00	0.00
Post-Removal H3	13.07	8.10	12.87	0.00	4.56	0.04	0.02
Change H3	*-24.07*	*+6.60*	*+8.23*	*0.00*	*-0.97*	*+0.04*	*+0.02*
Pre-Removal H4	10.15	0.48	0.00	0.00	0.18	0.18	0.00
Post-Removal H4	35.63	5.50	0.56	0.00	4.61	0.20	0.00
Change H4	*+25.48*	*+5.02*	*+0.56*	*0.00*	*+4.43*	*+0.02*	*0.00*
Pre-Removal H5	33.65	0.28	0.00	0.00	0.00	0.00	0.10
Post-Removal H5	42.40	10.67	0.34	0.15	9.49	0.02	0.00
Change H5	*+8.75*	*+10.39*	*+0.34*	*+0.15*	*+9.49*	*+0.02*	*-0.10*
Pre-Removal H6	39.32	0.19	0.00	0.19	0.00	0.00	0.05
Post-Removal H6	46.44	1.78	0.03	18.65	0.59	0.00	0.00
Change H6	*+7.12*	*+1.59*	*+0.03*	*+18.46.*	*+0.59*	*0.00*	*-0.05*
Pre-Removal H7	25.86	0.00	0.00	4.94	0.00	0.00	0.00
Post-Removal H7	23.62	1.00	0.09	36.76	0.00	0.00	0.00
Change H7	*-2.24*	*+1.00*	*+0.09*	*+31.82*	*0.00*	*0.00*	*0.00*
Pre-Removal H8	0.00	0.00	0.00	100.00	0.00	0.00	0.00

Mean percent cover of the most abundant species within the 14 groups outlined in the CPCe analysis throughout the various depth levels was further investigated to assess differences between post- and pre-removal surveys.

Fire coral was only observed on H1 (0.63 ± 0.28%) in pre-removal surveys. In post-removal surveys, fire coral was observed on H2 (0.01 ± 0.01%) and H3 (0.06 ± 0.04%).

Stony corals were found on levels H1 to H7, but were most abundant on H4 in pre-removal surveys and H3 in post-removal surveys (Table 3.26). The predominant coral species observed during transects of horizontal beams in both pre- and post-removal surveys was *Tubastraea* sp. Native coral species, such as *Madracis decactis*, *Oculina* sp., and colonial cup coral were found in pre- and post-removal surveys. *Pseudodiploria strigosa* was found in pre-removal surveys (H1 only), and *Siderastrea radians* was found in post-removal surveys (H3 only) (Table 3.28).

Table 3.28. Pre-removal and post-removal mean percent cover ± SE of stony corals identified on depth-delineated horizontal beams from H1 to H8. No post-removal surveys were conducted on H8. Change between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level	*Madracis decactis*	*Pseudodiploria strigosa*	*Tubastraea* sp.	Colonial cup coral	*Siderastrea radians*	*Oculina* sp.
Pre-Removal H1	0.02 ± 0.02	0.02 ± 0.02	8.90 ± 2.76	0.00	0.00	0.00
Pre-Removal H2	0.04 ± 0.04	0.00	2.50 ± 0.89	0.02 ± 0.02	0.00	0.00
Post-Removal H2	0.32 ± 0.20	0.00	5.00 ± 1.21	0.00	0.00	0.00
Change H2	*+ 0.28*	*0.00*	*+ 2.50*	*- 0.02*	*0.00*	*0.00*
Pre-Removal H3	0.18 ± 0.12	0.00	8.81 ± 3.62	0.00	0.00	0.00
Post-Removal H3	0.40 ± 0.20	0.00	8.53 ± 2.40	0.19 ± 0.09	3.54 ± 3.54	0.04 ± 0.04
Change H3	*+ 0.22*	*0.00*	*- 0.28*	*+ 0.19*	*+ 3.54*	*+ 0.04*
Pre-Removal H4	0.00	0.00	17.98 ± 3.77	0.07 ± 0.07	0.00	0.00
Post-Removal H4	0.00	0.00	7.06 ± 1.71	0.00	0.00	0.00
Change H4	*0.00*	*0.00*	*- 10.92*	*- 0.07*	*0.00*	*0.00*
Pre-Removal H5	0.00	0.00	1.03 ± 0.49	0.08 ± 0.08	0.00	1.04 ± 0.67
Post-Removal H5	0.05 ± 0.05	0.00	0.81 ± 0.38	0.11 ± 0.08	0.00	0.07 ± 0.07
Change H5	*+ 0.05*	*0.00*	*- 0.22*	*+ 0.03*	*0.00*	*- 0.97*
Pre-Removal H6	0.00	0.00	0.00	0.26 ± 0.26	0.00	6.21 ± 2.73
Post-Removal H6	0.00	0.00	0.09 ± 0.09	0.06 ± 0.06	0.00	10.71 ± 7.61
Change H6	*0.00*	*0.00*	*+ 0.09*	*- 0.20*	*0.00*	*+ 4.50*

Level	***Madracis decactis***	***Pseudodiploria strigosa***	***Tubastraea* sp.**	**Colonial cup coral**	***Siderastrea radians***	***Oculina* sp.**
Pre-Removal H7	0.00	0.00	0.00	0.00	0.00	6.22 ± 0.15
Post-Removal H7	0.00	0.00	0.00	0.00	0.00	4.25 ± 3.53
Change H7	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*- 1.97*
Pre-Removal H8	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal H8	NA	NA	NA	NA	NA	NA

Hydroids were found on levels H1 to H7, but were most abundant on H2 in both pre-and post-removal surveys (Table 3.26). On all horizontal levels, hydroid percent cover decreased from pre-removal surveys to post-removal surveys.

Sponges were found on levels H1 to H7, but were most abundant on H3 in pre-removal surveys and H4 in post-removal surveys (Table 3.26). On H2, sponge percent cover decreased from pre-removal surveys to post-removal surveys, but increased in post-removal surveys on levels H4 to H7. *Neofibularia nolitangere* was the species that contributed most to the increase in percent cover from pre- to post-removal surveys (Table 3.29).

Table 3.29. Pre-removal and post-removal mean percent cover ± SE of sponges identified on depth-delineated horizontal beams from H1 to H8. No post-removal surveys were conducted on H8. Calculated change between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level	***Callyspongia vaginalis***	***Dictyonella ruetzleri***	***Ircinia* sp.**	***Ircinia felix***	***Ircinia strobilina***	***Neofibularia nolitangere***	**Unidentified sponge**
Pre-Removal H1	0.00	0.07 ± 0.05	4.78 ± 1.20	3.53 ± 0.98	0.08 ± 0.04	0.18 ± 0.12	1.95 ± 0.64
Pre-Removal H2	0.22 ± 0.19	5.96 ± 1.05	8.40 ± 0.90	0.87 ± 0.31	1.67 ± 0.44	2.50 ± 1.57	4.36 ± 1.01
Post-Removal H2	0.12 ± 0.07	5.70 ± 0.74	9.95 ± 1.09	1.90 ± 0.65	1.14 ± 0.38	2.24 ± 1.22	0.57 ± 0.15
Change H2	*- 0.01*	*- 0.26*	*+ 1.55*	*+ 1.03*	*- 0.53*	*- 0.26*	*- 3.79*
Pre-Removal H3	0.49 ± 0.22	2.98 ± 0.73	4.78 ± 0.91	0.40 ± 0.40	1.28 ± 0.93	26.24 ± 2.96	1.29 ± 0.45
Post-Removal H3	0.26 ± 0.13	6.12 ± 1.04	8.96 ± 1.25	0.29 ± 0.17	0.27 ± 0.21	11.50 ± 3.61	0.69 ± 0.21
Change H3	*- 0.23*	*+ 3.14*	*+ 4.18*	*- 0.11*	*- 1.01*	*- 14.74*	*- 0.6*
Pre-Removal H4	0.46 ± 0.31	0.50 ± 0.21	4.12 ± 1.41	0.72 ± 0.72	2.09 ± 1.28	29.14 ± 2.87	1.57 ± 0.65

Level	***Callyspongia vaginalis***	***Dictyonella ruetzleri***	***Ircinia* sp.**	***Ircinia felix***	***Ircinia strobilina***	***Neofibularia nolitangere***	**Unidentified sponge**
Post-Removal H4	0.34 ± 0.34	2.78 ± 0.98	3.67 ± 1.81	0.10 ± 0.10	2.94 ± 1.40	39.52 ± 12.46	2.29 ± 1.91
Change H4	*- 0.12*	*+2.28*	*- 0.45*	*- 0.62*	*+ 0.85*	*+ 10.38*	*+ 0.72*
Pre-Removal H5	0.00	0.13 ± 0.13	5.08 ± 0.80	0.00	0.10 ± 0.10	14.42 ± 3.41	1.44 ± 0.64
Post-Removal H5	0.00	0.42 ± 0.23	3.44 ± 0.96	0.00	0.11 ± 0.08	18.98 ± 1.12	4.13 ± 0.94
Change H5	*0.00*	*+ 0.29*	*- 1.64*	*0.00*	*+ 0.01*	*+ 4.56*	*+ 2.69*
Pre-Removal H6	0.00	0.00	0.16 ± 0.16	0.00	0.00	0.00	0.35 ± 0.15
Post-Removal H6	0.00	0.03 ± 0.03	0.03 ± 0.03	0.00	0.00	0.00	0.66 ± 0.57
Change H6	*0.00*	*+ 0.03*	*- 0.13*	*0.00*	*0.00*	*0.00*	*+ 0.31*
Pre-Removal H7	0.00	0.00	0.00	0.00	0.00	0.00	0.21 ± 0.15
Post-Removal H7	0.00	0.00	0.00	0.00	0.00	0.00	0.27 ± 0.27
Change H7	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*+ 0.06*
Pre-Removal H8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal H8	NA	NA	NA	NA	NA	NA	NA

Encrusting sponges were found on levels H1 to H7, but were most abundant on H5 in pre-removal surveys and H6 in post-removal surveys (Table 3.26). Encrusting sponge percent cover increased from pre- to post-removal surveys on H2 to H4 and decreased from pre- to post-removal surveys on H5 to H7.

Macroalgae was found on levels H1 to H8, but was most abundant on H1 in pre-removal surveys and H2 in post-removal surveys (Table 3.26). Macroalgae percent cover increased from pre- to post-removal surveys on H2, H3, and H5 to H7, and decreased from pre- to post-removal surveys on H4.

Bivalves were found on levels H1 to H7, but were most abundant on H7 in both pre- and post-removal surveys (Table 3.26). Bivalve percent cover decreased from pre- to post-removal surveys on H2 and H3 and increased from pre- to post-removal surveys on H4 to H7. Unidentified bivalves were the greatest contributor to the overall increase in percent bivalve cover from pre- to post-removal surveys (Table 3.30).

Table 3.30. Pre-removal and post-removal mean percent cover ± SE of bivalves identified on depth-delineated horizontal beams from H1 to H8. No post-removal surveys were conducted on H8. Calculated change between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level	***Dendrostrea frons***	***Chama* sp.**	**Pectinidae**	***Spondylus americanus***	**Bivalvia**
Pre-Removal H1	0.00	0.02 ± 0.02	0.12 ± 0.04	0.02 ± 0.02	0.51 ± 0.21
Pre-Removal H2	0.00	0.00	0.16 ± 0.08	0.00	2.03 ± 0.49
Post-Removal H2	0.00	0.00	0.02 ± 0.02	0.01 ± 0.01	0.08 ± 0.04
Change H2	*0.00*	*0.00*	*- 0.14*	*+ 0.01*	*- 1.95*
Pre-Removal H3	0.00	0.00	0.20 ± 0.11	0.06 ± 0.06	0.72 ± 0.33
Post-Removal H3	0.00	0.00	0.02 ± 0.02	0.00	0.46 ± 0.20
Change H3	*0.00*	*0.00*	*- 0.18*	*- 0.06*	*- 0.26*
Pre-Removal H4	0.00	0.00	0.00	0.07 ± 0.07	0.43 ± 0.22
Post-Removal H4	0.00	0.00	0.00	0.00	1.97 ± 1.31
Change H4	*0.00*	*0.00*	*0.00*	*- 0.07*	*+ 1.54*
Pre-Removal H5	0.03 ± 0.03	0.00	0.08 ± 0.08	0.10 ± 0.10	1.48 ± 0.54
Post-Removal H5	0.00	0.00	0.00	0.10 ± 0.10	8.15 ± 7.13
Change H5	*- 0.03*	*0.00*	*- 0.08*	*0.00*	*+ 6.67*
Pre-Removal H6	0.00	0.00	0.00	0.00	1.40 ± 0.46
Post-Removal H6	0.00	0.00	0.00	0.00	20.21 ± 14.96
Change H6	*0.00*	*0.00*	*0.00*	*0.00*	*+ 18.81*
Pre-Removal H7	0.00	0.00	0.00	0.00	3.54 ± 1.29
Post-Removal H7	0.00	0.00	0.00	0.00	26.80 ± 5.95
Change H7	*0.00*	*0.00*	*0.00*	*0.00*	*23.26*
Pre-Removal H8	0.00	0.00	0.00	0.00	0.00
Post-Removal H8	NA	NA	NA	NA	NA

Barnacles were found on levels H1, H2, and H3 in pre-removal surveys, but were not observed in post-removal surveys (Table 3.26).

Black corals were found on level H3 and levels H5 to H7 in pre-removal surveys and on levels H5 to H7 in post-removal surveys. They were most abundant on H5 in both pre- and post-removal surveys (Table 3.26). Overall, mean percent cover of black corals decreased from pre-removal surveys to post-removal surveys. Black coral sea fans contributed most to the overall decrease in cover from pre- to post-removal surveys (Table 3.31).

Table 3.31. Pre-removal and post-removal mean percent cover ± SE of black corals identified on depth-delineated horizontal beams from H1 to H8. Calculated change between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level	***Antipathes furcata***	***Antipathidae***	**Black coral sea fan**	***Plumapathes pennacea***	***Stichopathes* sp.**	***Tanacetipathes* sp.**
Pre-Removal H1	0.00	0.00	0.00	0.00	0.00	0.00
Pre-Removal H2	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal H2	0.00	0.00	0.00	0.00	0.00	0.00
Change H2	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Pre-Removal H3	0.00	0.00	0.00	1.29 ± 0.77	0.00	0.00
Post-Removal H3	0.00	0.00	0.00	0.00	0.00	0.00
Change H3	*0.00*	*0.00*	*0.00*	*- 1.29*	*0.00*	*0.00*
Pre-Removal H4	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal H4	0.00	0.00	0.00	0.00	0.00	0.00
Change H4	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Pre-Removal H5	0.14 ± 0.08	0.41 ± 0.41	5.88 ± 2.47	0.00	0.08 ± 0.08	0.10 ± 0.10
Post-Removal H5	0.02 ± 0.02	0.56 ± 0.56	5.61 ± 3.19	0.00	0.00	0.18 ± 0.18
Change H5	*- 0.12*	*+ 0.15*	*- 0.27*	*0.00*	*- 0.08*	*+ 0.08*
Pre-Removal H6	0.20 ± 0.20	0.05 ± 0.05	0.29 ± 0.29	0.00	0.00	0.00
Post-Removal H6	0.00	0.37 ± 0.37	0.09 ± 0.09	0.00	0.00	0.00
Change H6	*- 0.20*	*+ 0.32*	*- 0.20*	*0.00*	*0.00*	*0.00*
Pre-Removal H7	0.00	0.21 ± 0.15	0.11 ± 0.03	0.00	0.00	0.00
Post-Removal H7	0.00	0.03 ± 0.03	0.00	0.00	0.00	0.00
Change H7	*0.00*	*- 0.18*	*- 0.11*	*0.00*	*0.00*	*0.00*
Pre-Removal H8	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal H8	NA	NA	NA	NA	NA	NA

Octocorals were observed on H6 and H7 in pre-removal surveys and H2 and H6 in post-removal surveys (Table 3.26). *Chironephthya caribaea* (0.08 ± 0.08%) was the only species observed on H2 (post-removal surveys). During pre-removal surveys, *Hypnogorgia/Muricea pendula* (2.28 ± 0.81%) and *Nicella* sp. (0.06 ± 0.02%) were the two species of octocoral observed on H6, while Alcyoniidae (0.18 ± 0.18%), *Hypnogorgia/Muricea pendula* (0.79 ± 0.79%), and *Thesea rubra* (0.06 ± 0.06%) were observed on this level in post-removal surveys. On H7, *Diodogorgia nodulifera* (0.43 ± 0.11%) was the only species observed in pre-removal surveys. *Hypnogorgia/Muricea pendula* was the only species observed in both pre- and post-removal surveys, and percent cover of this species decreased from pre- to post-removal surveys on H6.

Other sessile invertebrates were found on levels H1 to H7, but were most abundant on H7 in both pre- and post-removal surveys (Table 3.26). Percent cover increased from pre- to post-removal surveys on H2 to H4 and decreased from pre- to post-removal surveys on H5 to H7. Zoanthids contributed most to the decrease in cover from pre- to post-removal surveys (Table 3.32).

Table 3.32. Pre-removal and post-removal mean percent cover ± SE of other sessile invertebrates group on depth-delineated horizontal beams from H1 to H8. Calculated change between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level	Anemone	Bryozoan	Tubeworm	Tunicate	Zoanthid
Pre-Removal H1	0.00	0.89 ± 0.27	0.00	2.18 ± 0.41	0.14 ± 0.14
Pre-Removal H2	0.00	0.61 ± 0.20	0.00	2.16 ± 0.64	0.02 ± 0.02
Post-Removal H2	0.00	0.75 ± 0.20	0.01 ± 0.01	2.20 ± 0.31	0.01 ± 0.01
Change H2	*0.00*	*+ 0.14*	*+ 0.01*	*+ 0.04*	*- 0.01*
Pre-Removal H3	0.00	0.63 ± 0.25	0.07 ± 0.05	2.13 ± 0.49	0.10 ± 0.10
Post-Removal H3	0.08 ± 0.08	1.09 ± 0.29	0.00	1.30 ± 0.28	1.01 ± 0.59
Change H3	*+ 0.08*	*+ 0.46*	*- 0.07*	*- 0.83*	*+ 0.91*
Pre-Removal H4	0.00	0.46 ± 0.27	0.00	0.33 ± 0.04	0.00
Post-Removal H4	0.00	0.61 ± 0.22	0.00	0.61 ± 0.22	0.00
Change H4	*0.00*	*+ 0.15*	*0.00*	*+ 0.28*	*0.00*
Pre-Removal H5	0.00	1.51 ± 1.20	0.17 ± 0.17	0.27 ± 0.12	0.98 ± 0.65
Post-Removal H5	0.00	0.28 ± 0.16	0.00	0.19 ± 0.19	1.42 ± 0.80
Change H5	*0.00*	*- 1.23*	*- 0.17*	*- 0.08*	*+ 0.44*
Pre-Removal H6	0.06 ± 0.06	0.00	0.06 ± 0.06	0.19 ± 0.19	47.29 ±10.69
Post-Removal H6	0.00	0.09 ± 0.09	0.00	0.00	20.06 ±10.63
Change H6	*- 0.06*	*+ 0.09*	*- 0.06*	*- 0.19*	*- 27.23*
Pre-Removal H7	0.00	0.00	0.00	0.21 ± 0.15	61.05 ± 38.01
Post-Removal H7	0.00	0.00	0.00	0.00	27.27 ± 7.98
Change H7	*0.00*	*0.00*	*0.00*	*- 0.21*	*- 33.78*
Pre-Removal H8	0.00	0.00	0.00	0.00	0.00
Post-Removal H8	NA	NA	NA	NA	NA

Other motile organisms were found on levels H1 to H7, but were most abundant on H4 in pre-removal surveys and H5 in post-removal surveys (Table 3.26). From H2 to H4 and H6 to H7, mean percent cover decreased from pre- to post-removal surveys, and on H5, mean percent cover increased from pre- to post-removal surveys.

Bare substrate was present on all horizontal levels, but was most prevalent on H8 in pre-removal surveys and H7 in post-removal surveys (Table 3.26). With the exception of H5, mean percent cover of bare substrate increased from pre-removal surveys to post-removal surveys.

Marine debris was observed on levels H1 and H4 in pre-removal surveys and H4 and H7 in post-removal surveys (Table 3.26). Monofilament fishing line entangled around the structure on H4 in pre-removal surveys was still present in post-removal surveys.

PERMANOVA analysis comparing benthic groups in pre-removal and post-removal surveys revealed significant differences, suggesting that the benthic community of HI-A-389-A changed between pre-removal and post-removal surveys (Table 3.33). SIMPER analysis identified that the greatest contributor to the overall observed dissimilarity between pre- and post-removal surveys was hydroids (15%).

Table 3.33. PERMANOVA results comparing mean percent cover of benthic groups from pre- and post-removal survey analysis. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Survey	86	1	4.42	**0.003**
Res	1670	85		
Total	1745	86		

Pairwise tests between depth and pre- and post-removal surveys detected significant differences in the benthic community on H2 to H5, but not H6 and H7 (Table 3.34), suggesting significant changes in the benthic community occurred on level H5 and above.

Table 3.34. PERMANOVA pairwise test results for significant differences between pre- and post-removal surveys from H2 to H7 at HI-A-389-A. Bold text denotes significant value.

Groups	t	Unique perms	P (perm)
H2 - Pre, Post	3.1979	999	**0.001**
H3 - Pre, Post	1.7717	997	**0.022**
H4 - Pre, Post	1.7559	35	**0.032**
H5 - Pre, Post	1.9906	35	**0.033**
H6 - Pre, Post	1.6276	35	0.073
H7 - Pre, Post	1.4465	10	0.191

When HI-A-389-A benthic communities were compared among depths and directional sides (east, west, north, and south sides) pre- and post-removal, no significant differences were found. This suggests that the directional side of the platform did not make a significant difference in the overall benthic community in pre- or post-removal surveys.

To further investigate the effect of beam characteristics on the benthic community, orientation (bottom, inside, outside, and top) of scuba photographic transect surveys on H2 were compared between pre- and post-removal surveys. There were not enough surveys completed on H3 for statistical comparison. PERMANOVA analysis revealed a significant difference in the benthic community between pre- and post-removal surveys and among beam orientations on H2 (Table 3.35).

Table 3.35. PERMANOVA results comparing pre- and post-removal surveys and orientation on H2. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Survey	95	1	20.08	**0.001**
Orientation	160	3	11.26	**0.001**
Survey x Orientation	19	3	1.33	0.228
Res	147	31		
Total	435	38		

Pairwise tests between surveys and orientation on H2 detected significant differences in the benthic community between surveys and all sides, suggesting there was a significant difference in the benthic community on all sides of horizontal beams from the time pre-removal surveys were conducted to the time post-removal surveys were conducted (Table 3.36).

Table 3.36. PERMANOVA pairwise test results for significant differences of orientation from pre- and post-removal surveys on H2 at HI-A-389-A. Bold text denotes significant value.

Groups	t	Unique perms	P (perm)
Bottom - Pre, Post	2.2657	84	**0.015**
Inside - Pre, Post	2.5869	205	**0.006**
Outside - Pre, Post	1.9705	210	**0.011**
Top - Pre, Post	2.9317	207	**0.010**

Photographic Transects on Vertical Pilings

Pre-Removal Vertical Piling Benthic Results

All four vertical photo transect surveys were completed during the ROV pre-removal cruise. An additional opportunistic transect was completed on the NW vertical piling in 2016 following a localized mortality event occurring at EFGB. Surveys along the vertical pilings were delineated by eight depth levels (Figure 2.4):

- Level 1 (L1) - the surface to H1 (0 m to 9 m),
- Level 2 (L2) - H1 to H2 (9.1 m to 22 m),
- Level 3 (L3) - H2 to H3 (22.1 m to 37 m),
- Level 4 (L4) - H3 to H4 (37.1 m to 52 m),
- Level 5 (L5) - H4 to H5 (52.1 m to 72 m),
- Level 6 (L6) - H5 to H6 (72.1 m to 91 m),
- Level 7 (L7) - H6 to H7 (91.1 m to 108 m), and
- Level 8 (L8) - H7 to H8 (108.1 m to 125 m).

Mean percent cover varied among the benthic groups outlined in the CPCe analysis throughout the various depths (Table 3.37). Encrusting sponge was the most abundant type of cover observed on Level 1 (25%), Level 2 (30%), and Level 3 (30%), sponge was most abundant on Level 4 (33%), macroalgae was most abudnant on Level 5 (34%), encrusting sponge was most abundant on H6 and H7 (57% and 53%, respectively), and other sessile invertebrates were most abundant on Level 8 (42%) (Figure 3.11).

Table 3.37. Mean percent cover ± SE of benthic groups identified in CPCe pre-removal analysis on depth-delineated vertical pilings from L1 to L8: 1) fire coral, 2) stony coral, 3) hydroids, 4) sponges, 5) encrusting sponges, 6) macroalgae, 7) bivalves, 8) barnacles, 9) black corals 10) octocorals, 11) other motile organisms (including fish, urchins, etc.), 12) other sessile invertebrates (anemones, bryozoans, tube worms, tunicates, and zoanthids), 13) bare substrate, and 14) marine debris. The components of these benthic groups are further broken down throughout this report section.

Level (L) (Depth m)	Fire coral	Stony coral	Hydroids	Sponge	Encrusting sponge	Macroalgae	Bivalves	Barnacles	Black corals	Octocorals	Other motile organisms	Other sessile invertebrates	Bare substrate	Marine debris
L1 (0 m to 9 m)	18.63 ± 14.22	0.00	6.25 ± 6.25	10.26 ± 4.27	24.50 ± 12.79	19.27 ± 10.59	12.02 ± 8.57	0.00	0.00	0.00	0.84 ± 0.84	0.00	8.22 ± 5.45	0.00
L2 (9.1 m to 22 m)	0.00	0.00	27.96 ± 7.01	13.93 ± 3.79	29.77 ± 7.61	21.52 ± 7.73	2.73 ± 1.69	0.00	0.00	0.00	0.81 ± 0.55	0.00	3.27 ± 1.32	0.00
L3 (22.1 m to 37 m)	0.00	0.30 ± 0.30	19.73 ± 4.81	28.69 ± 7.36	30.11 ± 5.94	15.72 ± 3.99	0.62 ± 0.42	0.00	0.00	0.00	0.64 ± 0.43	0.00	4.20 ± 2.04	0.00
L4 (37.1 m to 52 m)	0.00	0.00	13.01 ± 4.32	32.82 ± 10.37	21.64 ± 4.67	22.70 ± 5.20	0.74 ± 0.50	0.00	0.00	0.00	0.00	0.00	9.09 ± 3.28	0.00
L5 (52.1 m to 72 m)	0.00	0.00	12.66 ± 3.91	21.23 ± 6.45	22.72 ± 4.09	33.93 ± 9.15	0.46 ± 0.46	0.00	1.33 ± 1.33	0.00	0.46 ± 0.46	0.00	7.20 ± 1.70	0.00
L6 (72.1 m to 91 m)	0.00	1.30 ± 0.66	5.22 ± 3.48	3.72 ± 1.97	57.31 ± 6.42	19.49 ± 5.47	0.42 ± 0.42	0.00	4.67 ± 2.84	0.00	0.00	0.00	7.86 ± 1.86	0.00
L7 (91.1 m to 108 m)	0.00	1.76 ± 0.83	0.00	0.00	52.95 ± 14.51	9.15 ± 4.18	2.43 ± 1.86	0.00	0.00	0.00	0.00	23.43 ± 15.43	10.27 ± 6.97	0.00
L8 (108.1 m to 125 m)	0.00	2.31 ± 2.09	0.00	0.00	3.65 ± 2.28	39.20 ± 13.05	1.41 ± 0.92	0.46 ± 0.42	0.00	0.00	0.00	41.78 ± 14.97	11.19 ± 8.73	0.00

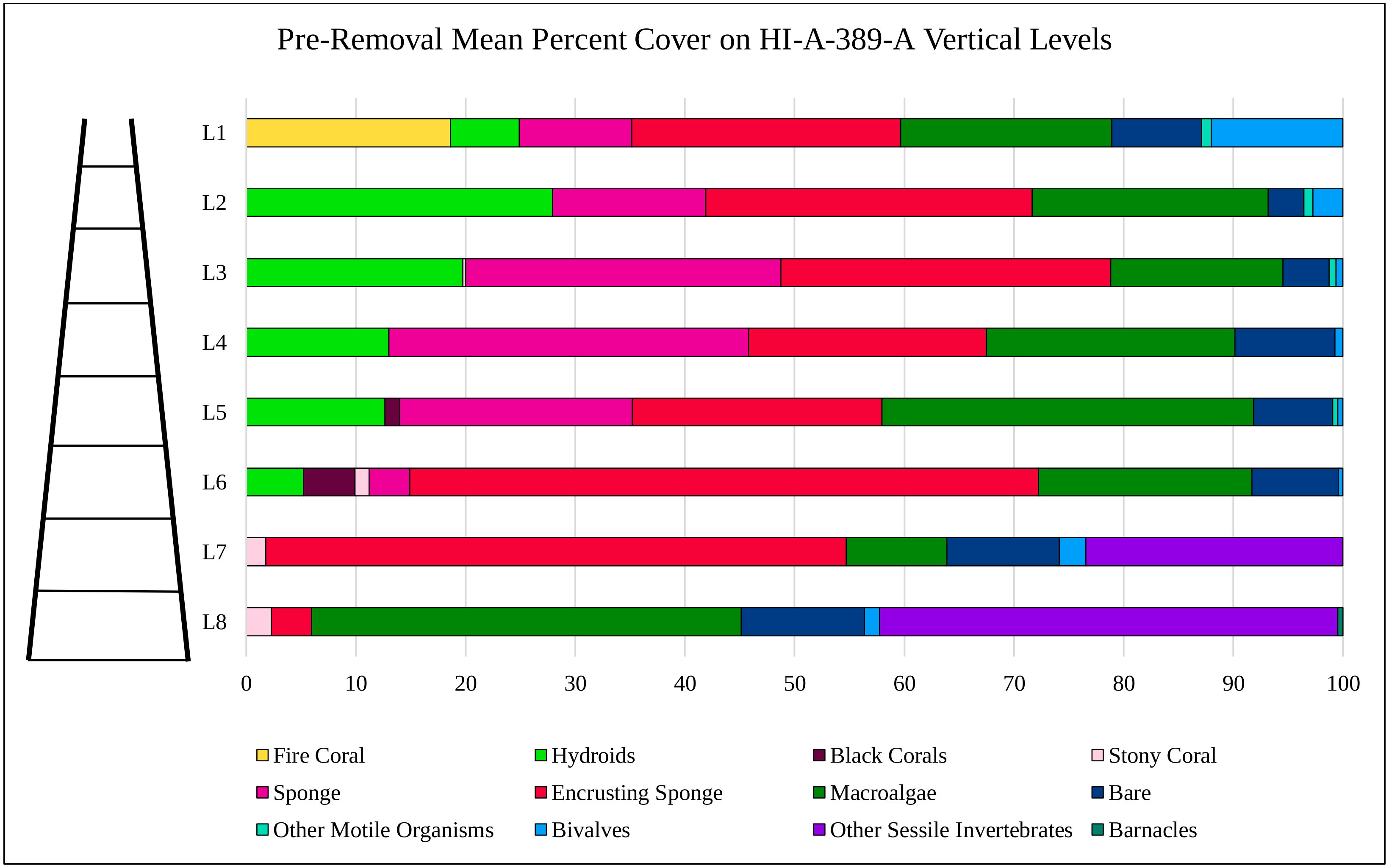


Figure 3.11. Percent composition of benthic cover groups at vertical levels (L1-L8) identified in CPCe pre-removal analysis. Outline of HI-A-389-A to the left of the stacked bar graph helps to visually represent the depth delineations of the level between horizontal beams below the surface.

Due to the layered nature of the fouling community, an additional note category was added in CPCe to document species interactions (Table 3.38). Bivalve overgrowth was observed on all levels, and was most abundant on L7. Organisms covered with silt were observed on L8.

Table 3.38. Mean percent cover ± SE of noted interaction types for benthic organisms identified in CPCe on depth-delineated vertical pilings from L1 to L8.

Level (L) (Depth m)	Over grown with bivalve	Over grown with algae	Over grown with hydroid	Silted	Bleached	Other disease or damage	Attached to debris
L1 (0 m to 9 m)	25.50 ± 6.83	0.00	0.00	0.00	0.00	0.00	0.00
L2 (9.1 m to 22 m)	17.69 ± 4.24	0.00	0.00	0.00	0.00	0.00	0.00
L3 (22.1 m to 37 m)	14.15 ± 4.31	0.00	0.00	0.00	0.00	0.00	0.00
L4 (37.1 m to 52 m)	20.49 ± 4.44	0.00	0.00	0.00	0.00	0.00	0.00
L5 (52.1 m to 72 m)	18.66 ± 3.23	0.00	0.00	0.00	0.00	0.00	0.00
L6 (72.1 m to 91 m)	40.70 ± 7.72	0.00	0.00	0.00	0.00	0.00	0.00
L7 (91.1 m to 108 m)	47.39 ± 9.59	0.00	0.00	0.00	0.00	0.00	0.00
L8 (108.1 m to 125 m)	27.11 ± 10.82	0.00	0.00	31.04 ± 13.89	0.00	0.00	0.00

Millepora alcicornis was observed on L1 (18.63 ± 14.22) and was only present on the southwest vertical piling (Figure 3.12).

Stony corals were found on L3 and L6 to L8, but were most abundant on L8 (Table 3.37). *Madracis decactis* (0.30 ± 0.30%) was the only species observed on L3 and *Oculina* sp. was the only stony coral observed on L6 (1.30 ± 0.66%), L7 (1.76 ± 0.83%), and L8 (2.31 ± 2.09%). One patch of *Madracis decactis* was on the northeast vertical piling and *Oculina* sp. was observed on all four vertical pilings (Figure 3.12). No *Tubastraea* sp. were observed on vertical pilings.

Hydroids were found on levels L1 to L6, but were most abundant on L2 (Table 3.37). Hydroids were observed on all four vertical pilings, but were lowest in abundance on the northeast piling (Figure 3.12).

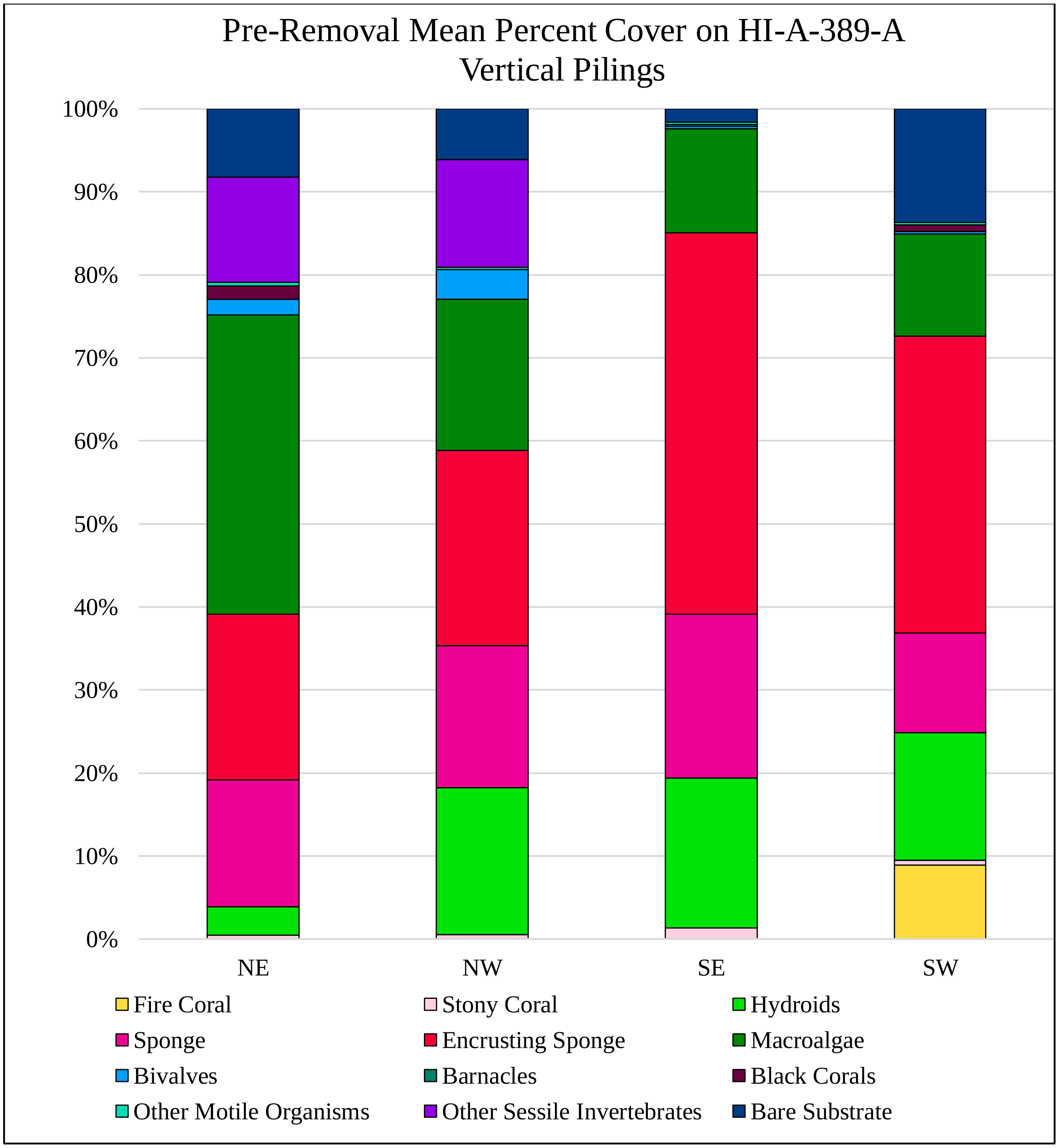


Figure 3.12. Percent composition of benthic cover groups on HI-A-389-A vertical pilings (northeast, northwest, southeast, and southwest) as identified in CPCe pre-removal analysis.

Sponges were found on L1 to L6, but were most abundant on L4 (Table 3.39). The most common species of sponge observed in surveys were *Geodia gibberosa*, *Ircinia* sp., *Ircinia strobilina*, *Neofibularia nolitangere*, *Aiolochroia crassa*, *Suberites* sp., and unidentified sponges. *N. nolitangere* occurred more frequently than other species, with high abundance at L3, L4, and L5. Sponges were observed on all four vertical pilings, but were most abundant on the southeast piling (Figure 3.12).

Table 3.39. Mean percent cover ± SE of sponges identified in CPCe pre-removal analysis on depth-delineated vertical pilings from L1 to L8.

Level (L) (Depth m)	***Geodia gibberosa***	***Ircinia* sp.**	***Ircinia strobilina***	***Neofibularia nolitangere***	***Aiolochroia crassa***	***Suberites* sp.**	**Unidentified sponge**
L1 (0 m to 9 m)	0.00	0.00	0.00	0.79 ± 0.79	0.00	0.84 ± 0.84	7.84 ± 3.99
L2 (9.1 m to 22 m)	0.42 ± 0.42	0.44 ± 0.44	0.44 ± 0.44	2.00 ± 1.67	0.40 ± 0.40	5.25 ± 3.93	4.32 ± 1.88
L3 (22.1 m to 37 m)	1.02 ± 1.02	0.34 ± 0.34	0.89 ± 0.89	13.93 ± 7.70	1.24 ± 0.71	0.32 ± 0.32	3.19 ± 1.30
L4 (37.1 m to 52 m)	0.00	0.00	1.06 ± 0.75	25.88 ± 11.29	1.75 ± 0.97	0.00	0.00
L5 (52.1 m to 72 m)	0.00	1.33 ± 1.33	0.00	13.40 ± 6.40	2.51 ± 1.73	0.00	1.91 ± 1.47
L6 (72.1 m to 91 m)	0.00	0.00	0.00	1.60 ± 1.60	0.83 ± 0.83	0.00	1.29 ± 0.92
L7 (91.1 m to 108 m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L8 (108.1 m to 125 m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Encrusting sponges were found on L1 to L8, but were most abundant on L6 (Table 3.37). Encrusting sponges were observed on all four vertical pilings, but were most abundant on the southeast piling (Figure 3.12).

Macroalgae was found on L1 to L8, but was most abundant on L8 (Table 3.37). Macroalgae was observed on all four vertical pilings, but was most abundant on the northeast piling (Figure 3.12).

Bivalves were found on L1 to L8, but were most abundant on L8 (Table 3.37). Bivalves were observed on all four vertical pilings, but were most abundant on the northwest piling (Figure 3.12).

Barnacles were observed on L8 (Table 3.37), but were only present on the southeast vertical piling (Figure 3.12).

Black corals were found on L5 and L6, but were most abundant on L6 (Table 3.37). The black corals observed in surveys were the black coral sea fan on L5 (1.33 ± 1.33%) and L6 (2.50 ± 2.50%) and Antipathidae on L6 (2.17 ± 1.75%). Antipathidae were on the northeast vertical piling and black coral sea fans were observed on the northeast and southwest vertical pilings (Figure 3.12).

Other motile organisms were found on L1 to L3 and L5, but were most abundant on L1 (Table 3.37). Other motile organisms were observed on all four vertical pilings, but were most abundant on the northeast piling (Figure 3.12).

Other sessile invertebrates were found on L7 and L8, and were most abundant on L8 (Table 3.37). Zoanthids were the only other sessile invertebrates identified on L7 (23.43 ± 15.43) and L8 (41.78 ± 14.97). Zoanthids were only present on the northeast and northwest vertical pilings (Figure 3.12).

Bare substrate was present on all levels, but was most prevalent on L8 (Table 3.37). Bare substrate was observed on all four vertical pilings, but was most abundant on the southwest piling (Figure 3.12).

No octocorals or marine debris were observed on the vertical pilings.

Hierarchical cluster analysis detected numerous significant clusters among the various vertical depth levels; however, the clusters overlapped greatly and did not produce clear groupings among the levels. PERMANOVA analysis comparing benthic groups by depth on vertical pilings revealed significant differences, suggesting that the benthic community of HI-A-389-A differed by depth. Significant differences also existed among the four pilings (Table 3.40).

Table 3.40. PERMANOVA results comparing benthic groups by depth and direction of vertical pilings in pre-removal analysis. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Depth	403	1	10.11	**0.001**
Direction	422	3	3.53	**0.001**
Res	2987	75		
Total	3811	79		

Pairwise tests detected significant differences between the benthic community on the northeast piling and all other vertical pilings, as well as a significant difference between the northwest and southeast pilings (Table 3.41). Mean macroalgae percent cover was the primary contributor (46.33%) to the observed dissimilarity of the northeast piling to all other pilings based on SIMPER analysis, and encrusting sponge percent cover was the primary contributor (21.58%) to the observed dissimilarity between the northwest and southeast pilings.

Table 3.41. PERMANOVA pairwise test results for differences in the benthic community among vertical pilings from pre-removal surveys on HI-A-389-A. Bold text denotes significant value.

Groups	t	Unique perms	P (perm)
NE, NW	1.8313	9948	**0.008**
NE, SE	2.8467	9944	**0.001**
NE, SW	2.2359	9944	**0.005**
NW, SE	1.6653	9942	**0.020**
NW, SW	1.1654	9942	0.218
SE, SW	1.1958	9950	0.197

Opportunistic Vertical Pile Survey Results after EFGB Localized Mortality Event

After pre-removal surveys were conducted in July 2015 and June 2016, a localized mortality event was documented at EFGB in July 2016, affecting approximately 2.6% of the coral reef (Johnston et al. 2019). Within this area, up to 82% of the coral colonies, along with numerous invertebrates, including sponges, sea urchins, crustaceans, and mollusks, succumbed to partial or total mortality. Within the affected area, the impact was highly stratified, and while the mortality event likely resulted from a combination of stressors, localized low DO was implicated as the primary contributing factor (Johnston et al. 2019). After documentation of the localized event, an opportunistic ROV photographic transect on the NW vertical piling of HI-A-389-A was conducted on September 13, 2016 to assess the platform for similar types of mortality. Diver obervations were also conducted in August 2016. Results include qualitative observations since only one transect was opportunistically completed without replication to facilitate comparison.

While there was no definitive evidence of the broad impacts that may have been directly related to the EFGB 2016 localized mortality event, the following observations were made:

- On the ROV transect at 35 m, a section of piling (approximately 1 m x 2.4 m) lost an area of sponge (Figure 3.13a), leaving behind a stark white area of mollusk shells and patches of bleached and damaged sponge tissue. Sponge loss also occurred on H3, approximately 1.5 m away from the piling. The affected area was approximately 1 m^2 and appeared to have been affected in a similar way as the area on the vertical piling.

- This observation is consistent with impacts seen by divers on HI-A-389-A on August 26, 2016 and August 27, 2016, although the August observations suggested more widespread impacts. Dives were conducted to a depth of approximately 30 m. From that depth, impacts were observed at deeper depths and down the risers. In figure Figure 3.13b, *C. vaginalis* was dead and stark white in color, but the sponge structure was still erect, indicating recent mortality.

Figure 3.13c shows bare area, white bivalves, and bleached and daamaged sponge tissue similar to what was observed in the ROV transect. In Figure 3.13d, sponge tissue is disintegrated, leaving behind the branches, and areas of finely branched calcareous algae were observed on affected sponges.

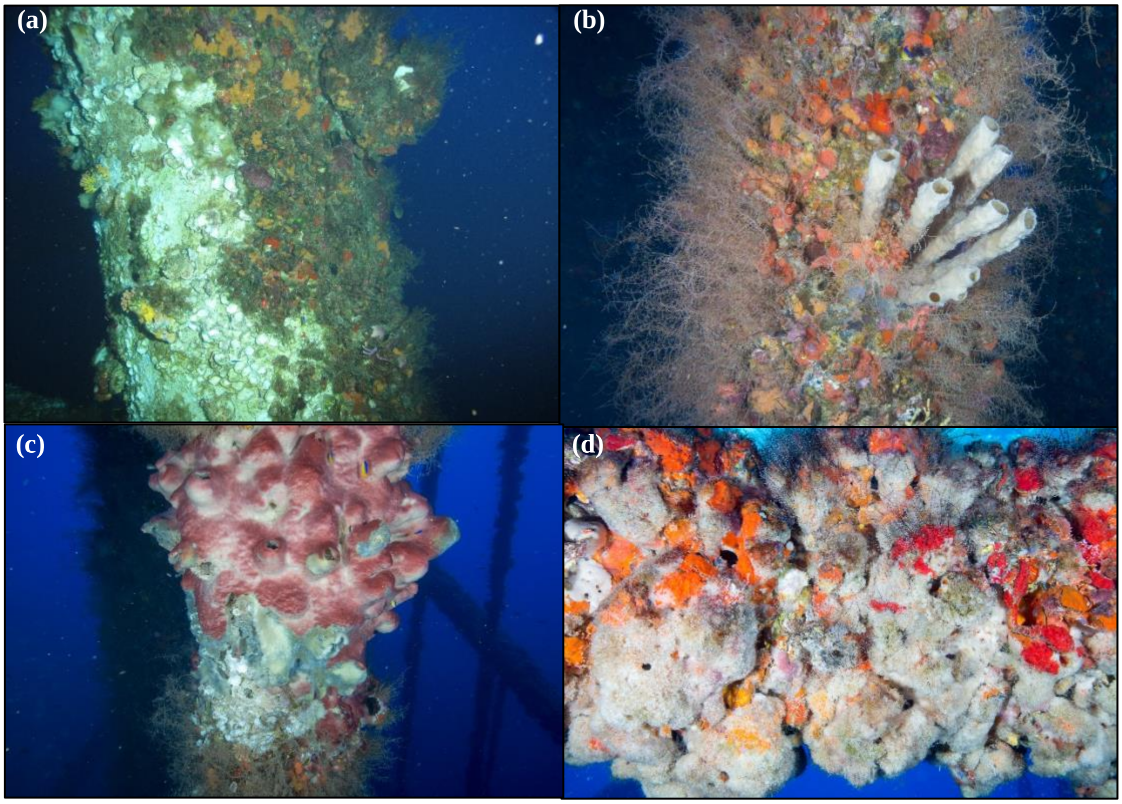


Figure 3.13. Images of dead and damaged sponges (a) from the opportunistic ROV vertical transect and (b, c, d) diver observations on HI-A-389-A after the 2016 localized mortality event at EFGB. Photos: (a) UNCW-UVP and (b, c, d) G.P. Schmahl/NOAA

Post-Removal Vertical Piling Benthic Results

After the top portion of the HI-A-389-A platform was removed in July 2018, all four vertical photo transect surveys were completed during the ROV post-removal cruise from the seafloor at L8 up to L3.

Mean percent cover varied among the benthic groups analyzed with CPCe throughout the various depths (Table 3.42). Sponge was the most abundant type of cover observed on L3 (27%), L4 (40%), and L5 (34%), encrusting sponge was most abundant on L6 and L7 (49% and 48%, respectively), and other sessile invertebrates was most abundant on L8 (59%) (Figure 3.14).

Table 3.42. Mean percent cover ± SE of benthic groups identified in CPCe post-removal analysis on depth delineated vertical pilings from L3 to L8: 1) fire coral, 2) stony coral, 3) hydroids, 4) sponges, 5) encrusting sponges, 6) macroalgae, 7) bivalves, 8) barnacles, 9) black corals 10) octocorals, 11) other motile organisms (including fish, urchins, etc.), 12) other sessile invertebrates, 13) bare substrate, and 14) marine debris. The components of these benthic groups are further broken down throughout this report section.

Level (L) (Depth m)	Fire coral	Stony coral	Hydroids	Sponge	Encrusting sponge	Macroalgae	Bivalves	Barnacles	Black corals	Octocorals	Other motile organisms	Other sessile invertebrates	Bare substrate	Marine debris
L3 (22.1 m to 37 m)	0.25 ± 0.25	5.68 ± 2.14	9.10 ± 5.45	27.38 ± 10.62	18.08 ± 2.42	23.44 ± 2.21	4.92 ± 3.72	0.00	0.00	0.00	0.51 ± 0.18	1.51 ± 0.90	9.12 ± 3.68	0.00
L4 (37.1 m to 52 m)	0.00	1.00 ± 0.59	6.58 ± 2.28	32.99 ± 7.11	25.00 ± 4.12	19.69 ± 3.51	7.92 ± 4.11	0.00	0.00	0.00	0.17 ± 0.17	1.04 ± 0.43	5.61 ± 1.67	0.00
L5 (52.1 m to 72 m)	0.00	0.54 ± 0.31	0.14 ± 0.14	34.18 ± 5.09	25.18 ± 3.61	22.98 ± 2.64	6.95 ± 3.44	0.00	2.31 ± 1.33	0.00	0.33 ± 0.33	0.64 ± 0.47	6.74 ± 1.56	0.00
L6 (72.1 m to 91 m)	0.00	0.83 ± 0.83	0.75 ± 0.48	9.60 ± 3.38	49.04 ± 7.52	24.09 ± 3.07	7.61 ± 4.23	0.00	1.34 ± 0.82	0.00	0.25 ± 0.25	0.15 ± 0.15	6.33 ± 0.94	0.00
L7 (91.1 m to 108 m)	0.00	4.67 ± 1.68	0.00	0.00	48.14 ± 8.27	7.99 ± 1.03	14.05 ± 1.93	0.00	0.00	0.00	0.18 ± 0.18	18.33 ± 8.73	6.64 ± 3.73	0.00
L8 (108.1 m to 125 m)	0.00	3.99 ± 3.99	0.00	0.00	9.50 ± 4.65	1.44 ± 0.63	11.95 ± 8.43	0.00	0.00	0.00	0.20 ± 0.20	59.04 ± 16.22	13.88 ± 6.16	0.00

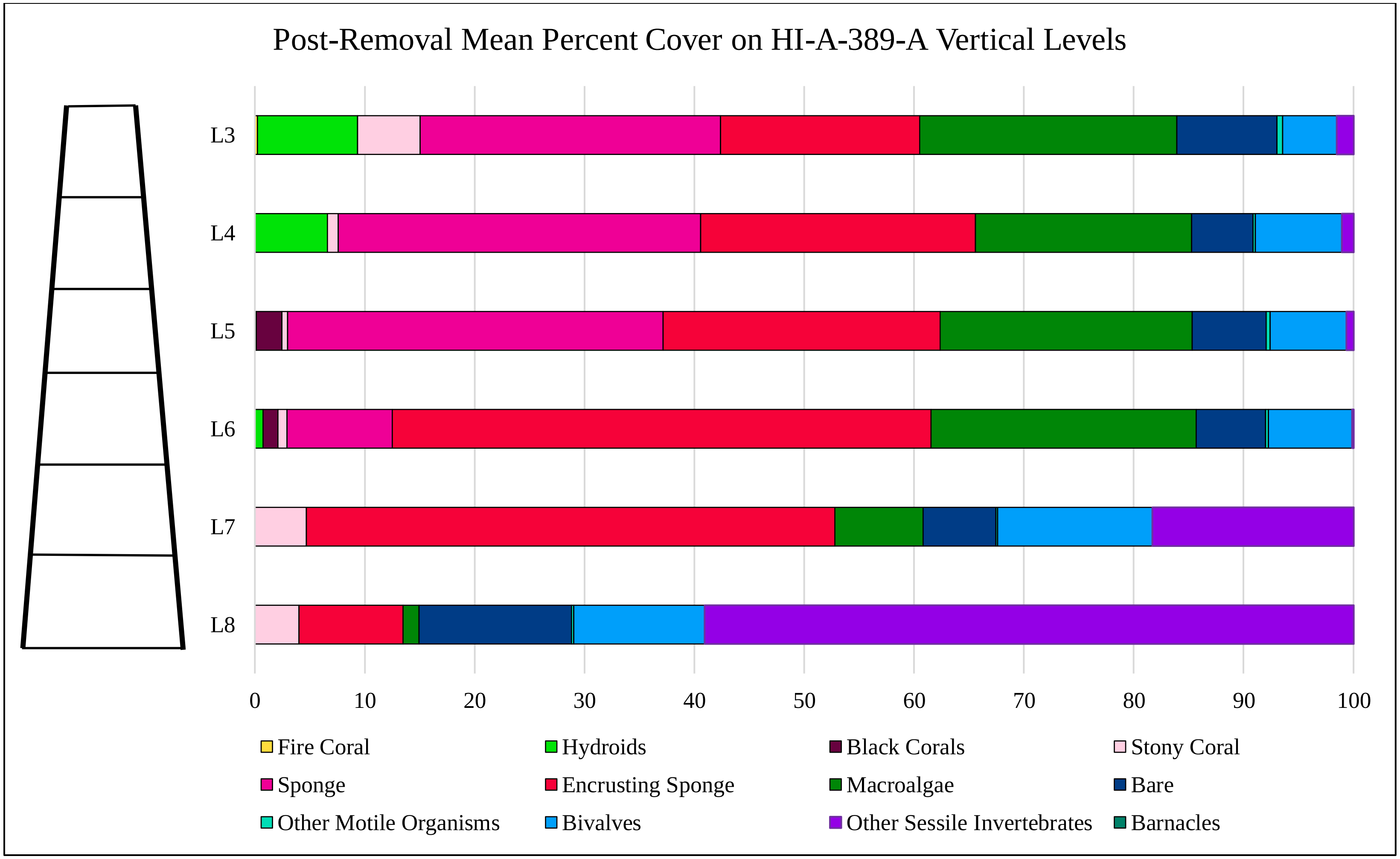


Figure 3.14. Percent composition of benthic cover groups identified in CPCe post-removal analysis across vertical levels (L3-L8). Outline of HI-A-389-A to the left of the stacked bar graph helps to visually represent the depth delineations of each level (between horizontal beams below the surface).

Among species interactions noted in CPCe, bivalve overgrowth was the most common type of interaction observed among all levels, and was most abundant on L7 and L8 (Table 3.43).

Table 3.43. Mean percent cover ± SE of noted interaction types for benthic organisms identified in CPCe on depth-delineated vertical pilings from L3 to L8.

Level (L) (Depth m)	Overgrown with bivalve	Overgrown with algae	Overgrown with hydroid	Silted	Bleached	Other disease or damage	Attached to debris
L3 (22.1 m to 37 m)	12.37 ± 4.22	9.22 ± 3.87	9.74 ± 5.06	0.00	0.63 ± 0.41	0.00	0.00
L4 (37.1 m to 52 m)	17.86 ± 6.51	10.41 ± 3.43	9.98 ± 2.79	0.63 ± 0.47	4.69 ± 1.56	0.00	0.00
L5 (52.1 m to 72 m)	28.13 ± 4.24	10.68 ± 3.03	0.43 ± 0.43	0.25 ± 0.25	4.53 ± 0.80	0.20 ± 0.20	0.00
L6 (72.1 m to 91 m)	30.32 ± 3.76	7.53 ± 2.83	1.05 ± 0.41	4.63 ± 3.91	4.51 ± 1.26	0.00	0.00
L7 (91.1 m to 108 m)	34.51 ± 4.54	6.02 ± 4.90	0.00	12.71 ± 4.59	0.00	0.00	0.00
L8 (108.1 m to 125 m)	34.55 ± 13.05	0.20 ± 0.20	0.00	20.01 ± 11.42	0.00	0.00	0.00

Millepora alcicornis was observed on L3 (0.25± 0.25%) and was only present on the northwest vertical piling (Figure 3.15).

Stony corals were found on L3 to L8, but were most abundant on L3 (Table 3.42 and 3.44). *Madracis decactis* and *Tubastraea* sp. were observed on L3 to L5, colonial cup coral was observed on L3, great star coral (*Montastraea cavernosa*) was observed on L4, and *Oculina* sp. was observed on L6 to L8. Stony corals were most abundant on the southeast piling (Figure 3.15).

Table 3.44. Mean percent cover ± SE of stony corals identified in CPCe post-removal analysis on depth-delineated vertical pilings from L3 to L8.

Level (Depth m)	***Madracis decactis***	***Tubastraea* sp.**	**Colonial cup coral**	***Montastraea cavernosa***	***Oculina* sp.**
L3 (22.1 m to 37 m)	4.14 ± 1.96	0.54 ± 0.38	0.00	0.00	0.00
L4 (37.1 m to 52 m)	0.51 ± 0.51	0.37 ± 0.22	0.00	0.12 ± 0.12	0.00
L5 (52.1 m to 72 m)	0.14 ± 0.14	0.25 ± 0.25	0.14 ± 0.14	0.00	0.00
L6 (72.1 m to 91 m)	0.00	0.00	0.00	0.00	0.83 ± 0.83
L7 (91.1 m to 108 m)	0.00	0.00	0.00	0.00	4.66 ± 1.68
L8 (108.1 m to 125 m)	0.00	0.00	0.00	0.00	3.99 ± 3.99

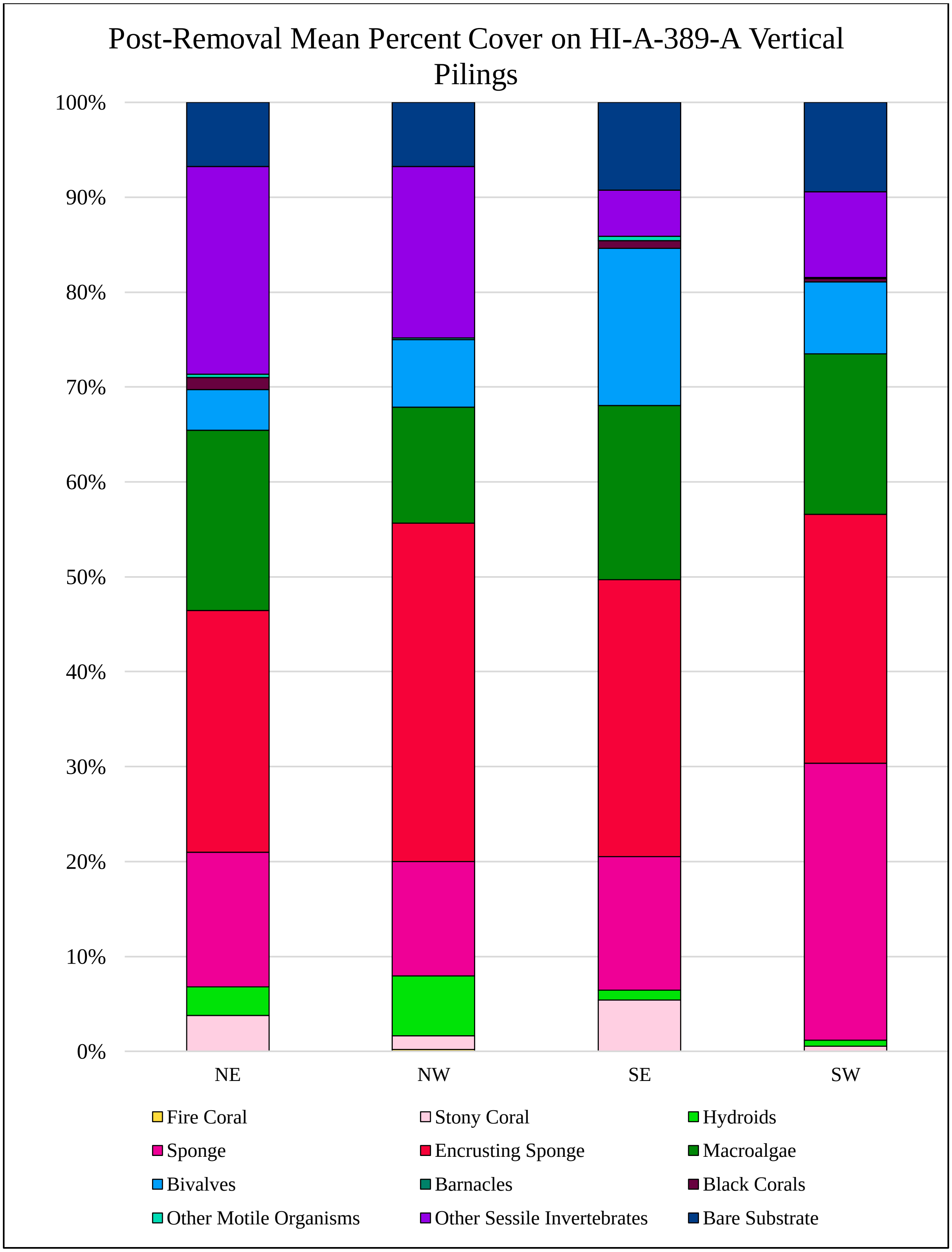


Figure 3.15. Percent composition of benthic cover groups on HI-A-389-A vertical pilings (northeast, northwest, southeast, and southwest) as identified in CPCe post-removal analysis.

Hydroids were found on levels L3 to L6, but were most abundant on L3 (Table 3.42). Hydroids were observed on all four vertical pilings, but were most abundant on the northwest piling (Figure 3.15).

Sponges were found on L3 to L6, but were most abundant on L5 (Table 3.42). The most common species of sponge observed in surveys was *Neofibularia nolitangere* (Table 3.45). Sponges were observed on all four vertical pilings, but were most abundant on the southwest piling (Figure 3.15).

Table 3.45. Mean percent cover ± SE of sponges identified in CPCe post-removal analysis on depth-delineated vertical pilings from L3 to L8.

Level (L) (Depth m)	***Callyspongia vaginalis***	***Dictyonella ruetzleri***	***Ircinia* sp.**	***Ircinia felix***	***Ircinia strobilina***	***Neofibularia nolitangere***	**Unidentified sponge**
L3 (22.1 m to 37 m)	0.57 ± 0.57	3.25 ± 0.97	4.10 ± 1.60	4.20 ± 1.64	2.16 ± 2.16	12.16 ± 12.16	0.34 ± 0.20
L4 (37.1 m to 52 m)	0.00	1.45 ± 0.76	6.04 ± 1.87	0.69 ± 0.34	0.42 ± 0.25	23.62 ± 8.16	0.63 ± 0.49
L5 (52.1 m to 72 m)	0.00	3.07 ± 0.77	6.54 ± 1.04	0.00	0.57 ± 0.57	22.96 ± 5.13	0.90 ± 0.42
L6 (72.1 m to 91 m)	0.00	0.00	3.88 ± 0.44	0.00	0.00	4.30 ± 2.49	1.42 ± 0.91
L7 (91.1 m to 108 m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L8 (108.1 m to 125 m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Encrusting sponges were found on L3 to L8, but were most abundant on L6 (Table 3.42). Encrusting sponges were observed on all four vertical pilings, but were most abundant on the northwest piling (Figure 3.15).

Macroalgae was found on L3 to L8, but was most abundant on L6 (Table 3.42). Macroalgae was not identified to the species level. Macroalgae was observed on all four vertical pilings, but was most abundant on the northeast piling (Figure 3.15).

Bivalves were found on L1 to L8, but were most abundant on L8 (Table 3.42). Unidentified bivalves were observed on all levels: L3 (4.92 ± 3.72%), L4 (7.92 ± 4.11%), L5 (6.95 ± 3.44%), L6 (7.36 ± 3.99%), L7 (14.05 ± 1.93%), and L8 (11.95 ± 8.43%). *Spondylus americanus* was also present on L6 (0.26 ± 0.26%). Bivalves were observed on all four vertical pilings, but were most abundant on the southeast piling (Figure 3.15).

Black corals were found on L5 and L6, but were most abundant on L5 (Table 3.42). The black corals observed in surveys were the black coral sea fan on L5 (2.31 ± 1.33%) and L6 (0.51 ± 0.51%) and *Tanacetipathes* sp. on L6 (0.83 ± 0.83%). *Tanacetipathes* sp. was observed on the northeast vertical piling and black coral sea fans were observed on the northeast, southeast, and southwest vertical pilings (Figure 3.15).

Other motile organisms were found from L3 to L8, but were most abundant on L3 (Table 3.42). Other motile organisms were observed on all four vertical pilings, but were most abundant on the southeast piling (Figure 3.15).

Other sessile invertebrates were found from L3 to L8, and were most abundant on L8 (Table 3.42). Zoanthids were the most common organism observed in this group (Table 3.46). Other sessile organisms were observed on all four vertical pilings, but were most abundant on the northeast piling (Figure 3.15).

Table 3.46. Mean percent cover ± SE of other sessile invertebrates identified in CPCe post-removal analysis on depth-delineated vertical pilings from L3 to L8.

Level (Depth m)	Bryozoan	Cnidaria	Tunicate	Zoanthid
L3 (22.1 m to 37 m)	0.14 ± 0.14	0.00	1.23 ± 0.98	0.14 ± 0.14
L4 (37.1 m to 52 m)	0.66 ± 0.28	0.00	0.38 ± 0.38	0.00
L5 (52.1 m to 72 m)	0.33 ± 0.33	0.00	0.31 ± 0.18	0.00
L6 (72.1 m to 91 m)	0.00	0.00	0.15 ± 0.15	0.00
L7 (91.1 m to 108 m)	0.26 ± 0.26	0.26 ± 0.26	0.00	17.82 ± 9.06
L8 (108.1 m to 125 m)	0.00	0.00	0.00	59.04 ± 16.22

Bare substrate was present on all levels, but was most prevalent on L8 (Table 3.42). Bare substrate was observed on all four vertical pilings, but was most abundant on the southwest piling (Figure 3.15).

No octocorals, barnacles, or marine debris were observed on the vertical pilings in post-removal surveys.

Hierarchical cluster analysis detected numerous significant clusters among the various vertical depth levels; however, the clusters overlapped greatly and did not produce clear groupings among the levels. PERMANOVA analysis comparing benthic groups by depth on vertical pilings revealed significant differences, suggesting that the benthic community of HI-A-389-A differed by depth in post-removal surveys. Significant differences also existed among the four pilings (Table 3.47).

Table 3.47. PERMANOVA results comparing benthic groups by depth and direction of vertical pilings in post-removal analysis. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Depth	1158	1	36.38	**0.001**
Direction	241	3	2.52	**0.002**
Res	3821	120		
Total	5220	124		

Pairwise tests for direction detected a significant difference between the northwest and southeast pilings and northeast and southeast pilings (Table 3.48). Mean percent cover of other sessile invertebrates was the primary contributor (16.11%) to the observed dissimilarity between the northwest and southeast pilings based on SIMPER analysis, and sponge percent cover was the primary contributor (15.68%) to the observed dissimilarity between the northeast and southeast pilings.

Table 3.48. PERMANOVA pairwise test results for significant differences of individual vertical pilings from post-removal surveys on HI-A-389-A. Bold text denotes significant value.

Groups	t	Unique perms	P (perm)
SW, SE	1.4057	998	0.075
SW, NE	1.3474	998	0.101
SW, NW	1.2695	998	0.135
SE, NE	2.0076	999	**0.004**
SE, NW	1.8646	998	**0.003**
NE, NW	1.3387	998	0.11

Comparison of Pre- and Post-Removal Vertical Piling Benthic Results

Pre-removal surveys were conducted on L1 to L8 in 2015 and 2017, and post-removal surveys were conducted on levels L3 to L8 in 2019 (Figure 3.9). Percent cover varied among the 14 groups used in the CPCe analysis throughout the various depths for pre- and post-removal photographic transects on the vertical pilings (Table 3.49). Percent cover of fire and stony coral, bivalves, and other sessile invertebrates increased on pilings after partial removal. Hydroid cover decreased at all depth levels observed (L3 to L6) between pre- and post-removal surveys. Percent cover of sponges and encrusting sponges followed similar patterns, decreasing on L3 and L6, but increasing on L4 and L5. No sponge cover was noted on L7 and L8, while encrusting sponge cover decreased on L7 and increased on L8 post-removal. There was a decrease in percent cover of barnacles on L8 between pre- and post-removal surveys. Macroalgae cover increased on L3 and L6, but decreased on average on L4, L5, L7, and L8. Black coral cover increased on L5, but decreased on L6. No octocorals were observed on vertical pilings during pre- or post-removal surveys. There was an increase in other motile organisms between pre- and post-removal surveys on most vertical pilings (L4 and L6 to L8), while bare substrate cover decreased on most levels (L4 to L7) (Figure 3.16).

Table 3.49. Mean percent cover and change for benthic groups identified in CPCe pre-removal and post-removal analysis on depth-delineated vertical pilings from L1 to L8: 1) fire coral, 2) stony coral, 3) hydroids, 4) sponges, 5) encrusting sponges, 6) macroalgae, 7) bivalves, 8) barnacles, 9) black corals 10) octocorals, 11) other motile organisms (including fish, urchins, etc.), 12) other sessile invertebrates (including anemones, tunicates, zoanthids, etc.)., 13) bare substrate, and 14) marine debris. No post-removal surveys were conducted on H8. Change in cover between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level	Fire coral	Stony coral	Hydroids	Sponge	Encrusting sponge	Macroalgae	Bivalves	Barnacles	Black Corals	Octocorals	Other motile organisms	Other sessile invertebrates	Bare substrate	Marine debris
Pre-Removal L1	18.63	0.00	6.25	10.26	24.50	19.27	12.02	0.00	0.00	0.00	0.84	0.00	8.22	0.00
Pre-Removal L2	0.00	0.00	27.96	13.93	29.77	21.52	2.73	0.00	0.00	0.00	0.81	0.00	3.27	0.00
Pre-Removal L3	0.00	0.30	19.73	28.69	30.11	15.72	0.62	0.00	0.00	0.00	0.64	0.00	4.20	0.00
Post-Removal L3	0.25	5.68	9.10	27.38	18.08	23.44	4.92	0.00	0.00	0.00	0.51	1.51	9.12	0.00
Change L3	*+ 0.25*	*+ 5.38*	*- 10.63*	*- 1.31*	*- 12.08*	*+ 7.72*	*+ 4.30*	*0.00*	*0.00*	*0.00*	*- 0.13*	*+ 1.51*	*+ 4.92*	*0.00*
Pre-Removal L4	0.00	0.00	13.01	32.82	21.64	22.70	0.74	0.00	0.00	0.00	0.00	0.00	9.09	0.00
Post-Removal L4	0.00	1.00	6.58	32.99	25.00	19.69	7.92	0.00	0.00	0.00	0.17	1.04	5.61	0.00
Change L4	*0.00*	*+1.0*	*- 6.43*	*- 0.17*	*+ 0.36*	*- 3.01*	*+ 7.18*	*0.00*	*0.00*	*0.00*	*+ 0.17*	*+ 1.04*	*- 4.29*	*0.00*
Pre-Removal L5	0.00	0.00	12.66	21.23	22.72	33.93	0.46	0.00	1.33	0.00	0.46	0.00	7.20	0.00
Post-Removal L5	0.00	0.54	0.14	34.18	25.18	22.98	6.95	0.00	2.31	0.00	0.33	0.64	6.74	0.00
Change L5	*0.00*	*+ 0.54*	*- 12.52*	*+ 12.95*	*- 2.48*	*- 10.95*	*+ 6.49*	*0.00*	*+ 0.98*	*0.00*	*- 0.13*	*+ 0.64*	*- 0.46*	*0.00*
Pre-Removal L6	0.00	1.30	5.22	3.72	57.31	19.49	0.42	0.00	4.67	0.00	0.00	0.00	7.86	0.00
Post-Removal L6	0.00	0.83	0.75	9.60	49.04	24.09	7.61	0.00	1.34	0.00	0.25	0.15	6.33	0.00
Change L6	*0.00*	*- 0.47*	*- 4.47*	*+ 6.40*	*- 8.27*	*+ 4.60*	*+ 7.19*	*0.00*	*- 3.33*	*0.00*	*+ 0.25*	*+ 0.15*	*- 1.53*	*0.00*
Pre-Removal L7	0.00	1.76	0.00	0.00	52.95	9.15	2.43	0.00	0.00	0.00	0.00	23.43	10.27	0.00
Post-Removal L7	0.00	4.67	0.00	0.00	48.14	7.99	14.05	0.00	0.00	0.00	0.18	18.33	6.64	0.00
Change L7	*0.00*	*- 2.91*	*0.00*	*0.00*	*- 4.81*	*- 1.16*	*+ 11.62*	*0.00*	*0.00*	*0.00*	*+ 0.18*	*- 5.10*	*- 3.63*	*0.00*
Pre-Removal L8	0.00	2.31	0.00	0.00	3.65	39.20	1.41	0.46	0.00	0.00	0.00	41.78	11.19	0.00
Post-Removal L8	0.00	3.99	0.00	0.00	9.50	1.44	11.95	0.00	0.00	0.00	0.20	59.04	13.88	0.00
Change L8	*0.00*	*+ 1.68*	*0.00*	*0.00*	*+ 5.85*	*- 37.80*	*+ 10.54*	*- 0.46*	*0.00*	*0.00*	*+ 0.20*	*+ 17.26*	*+ 2.69*	*0.00*

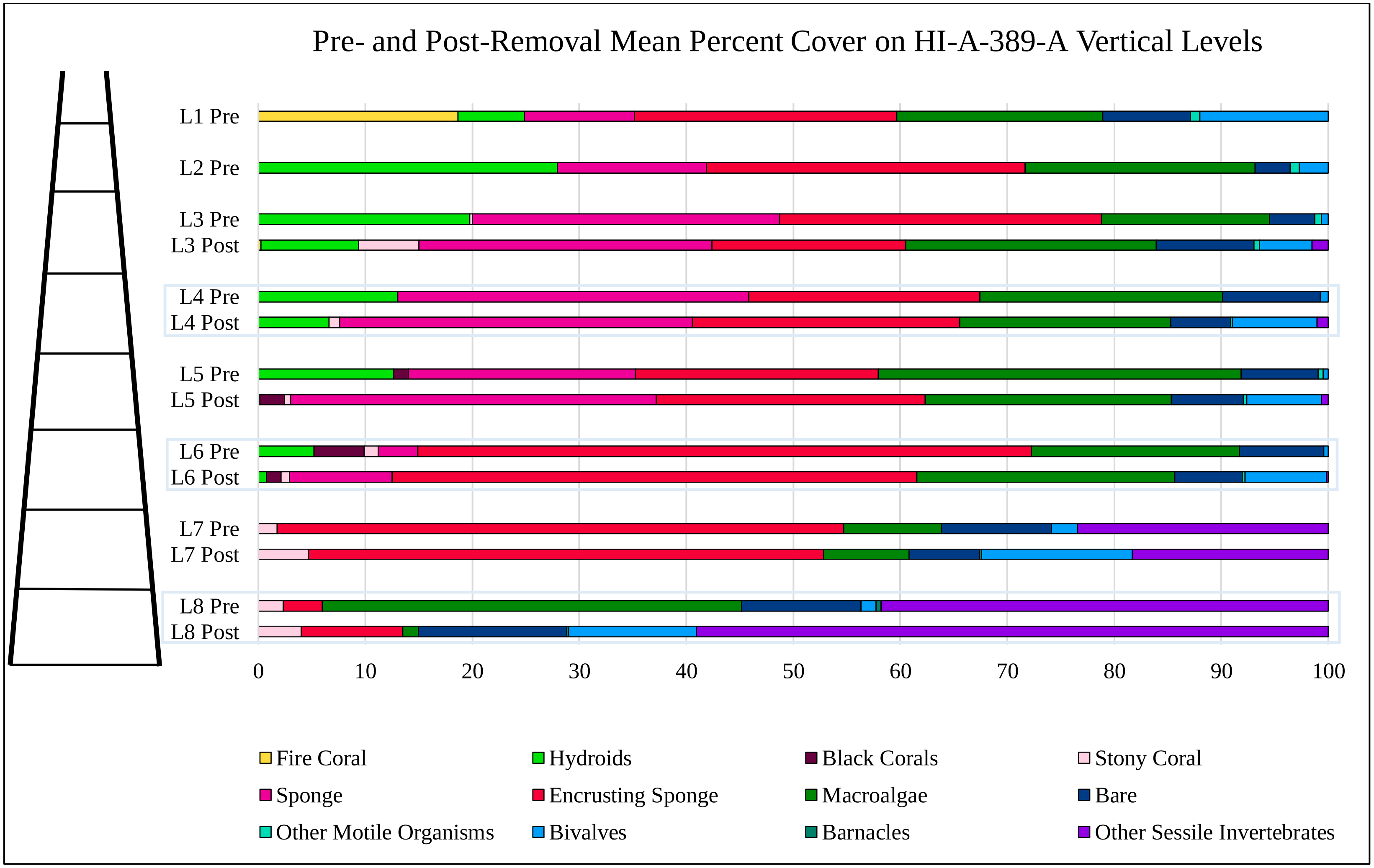


Figure 3.16. Percent composition of benthic cover groups on vertical levels (L1-L8) identified in CPCe pre- and post-removal analysis. Outline of HI-A-389-A to the left of the stacked bar graph helps to visually represent the depth delineations of the level between horizontal beams below the surface. The light blue rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Within the CPCe additional note category for species interactions, bivalve overgrowth decreased on most levels (L3, L4, L6, and L7), but increased on L5 and L8. Percent cover of organisms overgrown with algae and hydroids increased at all depth levels between pre- and post-removal surveys. Organisms covered with silt increased on all levels except L8. Cover of bleached sponges and/or corals and other disease or damage increased at all levels of the vertical pilings post-removal (Table 3.50).

Table 3.50. Pre-removal and post-removal mean and change in percent cover for noted interaction types identified in CPCe during benthic surveys of depth-delineated vertical pilings from L1 to L8. Change in percent cover between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level (L)	**Overgrown with bivalve**	**Overgrown with algae**	**Overgrown with hydroid**	**Silted**	**Bleached**	**Other disease or damage**	**Attached to debris**
Pre-Removal L1	25.50	0.00	0.00	0.00	0.00	0.00	0.00
Pre-Removal L2	17.69	0.00	0.00	0.00	0.00	0.00	0.00
Pre-Removal L3	14.15	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal L3	12.37	9.22	9.74	0.00	0.63	0.00	0.00
Change L3	*- 1.78*	*+ 9.22*	*+ 9.74*	*0.00*	*+ 0.63*	*0.00*	*0.00*
Pre-Removal L4	20.49	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal L4	17.86	10.41	9.98	0.63	4.69	0.00	0.00
Change L4	*- 2.63*	*+ 10.41*	*+ 9.98*	*+ 0.63*	*+ 4.69*	*0.00*	*0.00*
Pre-Removal L5	18.66	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal L5	28.13	10.68	0.43	0.25	4.53	0.20	0.00
Change L5	*+ 9.47*	*+ 10.68*	*+ 0.43*	*+ 0.25*	*+ 0.53*	*+ 0.20*	*0.00*
Pre-Removal L6	40.70	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal L6	30.32	7.53	1.05	4.63	4.51	0.00	0.00
Change L6	*- 10.38*	*+ 7.53*	*+ 1.05*	*+ 4.63*	*+ 4.51*	*0.00*	*0.00*
Pre-Removal L7	47.39	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal L7	34.51	6.02	0.00	12.71	0.00	0.00	0.00
Change L7	*- 12.88*	*+ 6.02*	*0.00*	*+ 12.71*	*0.00*	*0.00*	*0.00*
Pre-Removal L8	27.11	0.00	0.00	31.04	0.00	0.00	0.00
Post-Removal L8	34.55	0.20	0.00	20.01	0.00	0.00	0.00
Change L8	*+ 7.43*	*+ 0.20*	*0.00*	*- 11.03*	*0.00*	*0.00*	*0.00*

Mean percent cover of the most common species within the 14 groups used in the CPCe analysis throughout the various depth levels was further investigated to compare pre- and post-removal surveys.

Millepora alcicornis was observed on L1 (18.63 ± 14.22%) in pre-removal surveys and it was only present on the southwest vertical piling (Table 3.49 and Figure 3.17). *Millepora* *alcicornis* was observed on L3 (0.25 ± 0.25%) in post-removal surveys and it was only present on the northwest vertical piling (Table 3.49 and Figure 3.17).

Stony corals were found on L3 and L6 to L8, but were most abundant on L8 in pre-removal surveys (Table 3.49). Stony corals were found on L3 to L8 in post-removal surveys, but were most abundant on L3 (Table 3.49). *Madracis decactis* and *Oculina* sp. were the most common species in pre- and post-removal surveys (Table 3.51). In pre- and post-removal surveys, stony corals were observed on all vertical pilings (Figure 3.17).

Table 3.51. Mean and change in percent cover ± SE of stony corals identified in CPCe pre- and post-removal analyses on depth-delineated vertical pilings from L1 to L8. Calculated change between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level (L)	***Madracis decactis***	***Tubastraea* sp.**	**Colonial cup coral**	***Montastraea cavernosa***	***Oculina* sp.**
Pre-Removal L1	0.00	0.00	0.00	0.00	0.00
Pre-Removal L2	0.00	0.00	0.00	0.00	0.00
Pre-Removal L3	0.30 ± 0.30	0.00	0.00	0.00	0.00
Post-Removal L3	4.14 ± 1.96	0.54 ± 0.38	0.00	0.00	0.00
Change L3	*+ 3.84*	*+ 0.54*	*0.00*	*0.00*	*0.00*
Pre-Removal L4	0.00	0.00	0.00	0.00	0.00
Post-Removal L4	0.51 ± 0.51	0.37 ± 0.22	0.00	0.12 ± 0.12	0.00
Change L4	*+ 0.51*	*+ 0.37*	*0.00*	*+ 0.12*	*0.00*
Pre-Removal L5	0.00	0.00	0.00	0.00	0.00
Post-Removal L5	0.14 ± 0.14	0.25 ± 0.25	0.14 ± 0.14	0.00	0.00
Change L5	*+ 0.14*	*+ 0.25*	*+ 0.14*	*0.00*	*0.00*
Pre-Removal L6	0.00	0.00	0.00	0.00	1.30 ± 0.66
Post-Removal L6	0.00	0.00	0.00	0.00	0.83 ± 0.83
Change L6	*0.00*	*0.00*	*0.00*	*0.00*	*- 0.47*
Pre-Removal L7	0.00	0.00	0.00	0.00	1.76 ± 0.83
Post-Removal L7	0.00	0.00	0.00	0.00	4.66 ± 1.68
Change L7	*0.00*	*0.00*	*0.00*	*0.00*	*+ 2.90*
Pre-Removal L8	0.00	0.00	0.00	0.00	2.31 ± 2.09
Post-Removal L8	0.00	0.00	0.00	0.00	3.99 ± 3.99
Change L8	*0.00*	*0.00*	*0.00*	*0.00*	*+ 1.68*

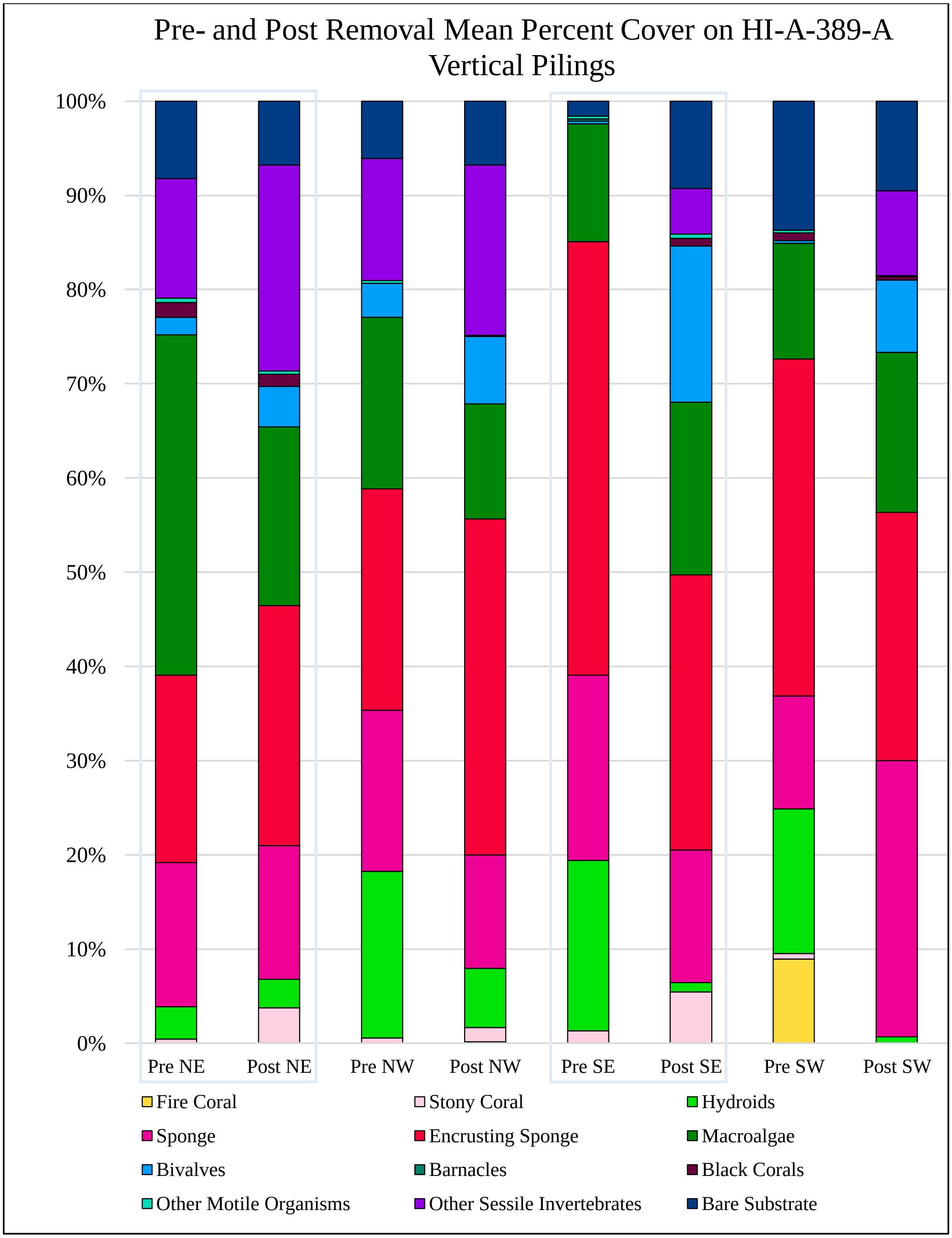


Figure 3.17. Percent composition of benthic cover groups on HI-A-389-A vertical pilings (northeast, northwest, southeast, and southwest) as identified in CPCe pre- and post-removal analysis. Light blue columns aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Hydroids were found on levels L1 to L6, but were most abundant on L2 in pre-removal surveys and L3 in post-removal surveys (Table 3.49). Hydroids were observed on all four vertical pilings, and in all instances decreased from pre-removal surveys to post-removal surveys (Figure 3.17).

Sponges were found on L1 to L6, but were most abundant on L4 in pre-removal surveys and L5 in post-removal surveys (Table 3.49). *Ircinia strobilina*, *Neofibularia nolitangere*, and unidentified sponges were the most common type of sponge in pre- and post-removal surveys (Table 3.52). Sponges were observed on all four vertical pilings, and decreased in mean percent cover from pre- to post-removal surveys on all pilings except for the southwest piling (Figure 3.17).

Table 3.52. Mean percent cover ± SE of sponge species identified in CPCe pre- and post-removal analyses on depth-delineated vertical pilings from L1 to L8. Change in cover between pre- and post-removal surveys for each depth level is in italics. Grey rows aid in visually differentiating even and odd levels with coupled pre- and post-removal survey results.

Level (L)	***Dictyonella ruetzleri***	***Geodia gibberosa***	***Ircinia* sp.**	***Ircinia strobilina***	***Neofibularia nolitangere***	***Aiolochroia crassa***	***Suberites* sp.**	**Unidentified sponge**
Pre-Removal L1	0.00	0.00	0.00	0.00	0.79 ± 0.79	0.00	0.84 ± 0.84	7.84 ± 3.99
Pre-Removal L2	0.00	0.42 ± 0.42	0.44 ± 0.44	0.44 ± 0.44	2.00 ± 1.67	0.40 ± 0.40	5.25 ± 3.93	4.32 ± 1.88
Pre-Removal L3	0.00	1.02 ± 1.02	0.34 ± 0.34	0.89 ± 0.89	13.93 ± 7.70	1.24 ± 0.71	0.32 ± 0.32	3.19 ± 1.30
Post-Removal L3	3.25 ± 0.97	4.10 ± 1.60	0.00	4.20 ± 1.64	2.16 ± 2.16	12.16 ± 12.16	0.00	0.34 ± 0.20
Change L3	*+ 3.25*	*+ 3.50*	*- 0.34*	*+ 3.31*	*+ 11.77*	*+ 10.92*	*- 0.32*	*- 2.85*
Pre-Removal L4	0.00	0.00	0.00	1.06 ± 0.75	25.88 ± 11.29	1.75 ± 0.97	0.00	0.00
Post-Removal L4	1.45 ± 0.76	6.04 ± 1.87	0.00	0.69 ± 0.34	0.42 ± 0.25	23.62 ± 8.16	0.00	0.63 ± 0.49
Change L4	*+ 1.45*	*+ 6.04*	*0.00*	*- 0.86*	*- 25.46*	*+ 21.87*	*0.00*	*+ 0.63*
Pre-Removal L5	0.00	0.00	1.33 ± 1.33	0.00	13.40 ± 6.40	2.51 ± 1.73	0.00	1.91 ± 1.47
Post-Removal L5	3.07 ± 0.77	6.54 ± 1.04	0.00	0.00	0.57 ± 0.57	22.96 ± 5.13	0.00	0.90 ± 0.42
Change L5	*+ 3.07*	*+ 6.54*	*- 1.33*	*0.00*	*- 12.83*	*+ 20.45*	*0.00*	*-1.01*
Pre-Removal L6	0.00	0.00	0.00	0.00	1.60 ± 1.60	0.83 ± 0.83	0.00	1.29 ± 0.92
Post-Removal L6	0.00	3.88 ± 0.44	0.00	0.00	0.00	4.30 ± 2.49	0.00	1.42 ± 0.91
Change L6	*0.00*	*+ 3.88*	*0.00*	*0.00*	*-1.60*	*+ 3.47*	*0.00*	*+ 0.13*
Pre-Removal L7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Level (L)	***Dictyonella ruetzleri***	***Geodia gibberosa***	***Ircinia* sp.**	***Ircinia strobilina***	***Neofibularia nolitangere***	***Aiolochroia crassa***	***Suberites* sp.**	**Unidentified sponge**
Post-Removal L7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change L7	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Pre-Removal L8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post-Removal L8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change L8	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

Encrusting sponges were found on L1 to L8, but were most abundant on L6 in both pre- and post-removal surveys (Table 3.49). Mean percent cover decreased on L3, L6, and L7, but increased on L4 and L8 from pre- to post-removal surveys. Encrusting sponges were observed on all four vertical pilings in both pre- and post-removal surveys (Figure 3.17).

Macroalgae was found on L1 to L8, but was most abundant on L8 in pre-removal surveys and L6 in post-removal surveys (Table 3.49). Mean percent cover increased on L3 and L6, but decreased on L4, L5, L7, and L8 from pre- to post-removal surveys. Macroalgae was observed on all four vertical pilings; percent cover decreased on the north pilings but increased on the south pilings (Figure 3.17).

Bivalves were found on L1 to L8, but were most abundant on L8 in pre- and post-removal surveys (Table 3.49). Unidentified bivalves were the most common type of bivalve observed on all levels. Bivalve cover increased from pre- to post-removal surveys and bivalves were observed on all four vertical pilings (Figure 3.17).

Barnacles were observed on L8 (Table 3.49) and were only present on the southeast vertical piling in pre-removal surveys (Figure 3.17). No barnacles were observed in post-removal surveys.

Black corals were found on L5 and L6, but were most abundant on L6 in pre-removal surveys and L5 in post-removal surveys (Table 3.49). Black coral mean percent cover increased on L5 but decreased on L6 from pre- to post-removal surveys. Black coral sea fans were the most common type of black coral in both pre- and post-removal surveys. Black corals were observed on all vertical pilings except the northwest piling in pre- and post-removal surveys (Figure 3.17)

Other motile organisms were found on L1 to L3 and L5, but were most abundant on L1, in pre-removal surveys (Table 3.49). In post-removal surveys, other motile organisms were found from L3 to L8, but were most abundant on L3 (Table 3.49). Mean percent cover on L3 and L5 decreased from pre- to post-removal surveys, but increased on all over levels. Other motile organisms were observed on all four vertical pilings in both pre- and post-removal surveys (Figure 3.17).

Other sessile invertebrates were found on L7 and L8, and were most abundant on L8 in pre-removal surveys (zoanthids were the only sessile invertebrate observed) (Table 3.49). In post-removal surveys, other sessile invertebrates were found from L3 to L8, and were most abundant on L8 (Table 3.49). Zoanthids were the most common type of other sessile invertebrate observed in post-removal surveys. Other sessile organisms were observed on all four vertical pilings, and increased in percent cover on all pilings from pre- to post-removal surveys (Figure 3.17).

Bare substrate was present on all levels, but was most prevalent on L8 in pre- and post-removal surveys (Table 3.49). Bare substrate mean percent cover increased on L3 and L8, but decreased on all other levels from pre- to post-removal surveys. Bare substrate was observed on all four vertical pilings (Figure 3.17).

No octocorals or marine debris were observed on the vertical pilings in pre- or post-removal surveys.

PERMANOVA analysis indicated significant differences among benthic groups on vertical pilings between pre-removal and post-removal surveys, suggesting that the benthic community of HI-A-389-A changed after the top of the platform was removed (Table 3.53). SIMPER analysis identified that the greatest contributors to the overall observed dissimilarity between pre- and post-removal surveys were sponge (17%) and encrusting sponge (16%) cover on the vertical pilings.

Table 3.53. PERMANOVA results comparing mean percent cover of benthic groups from pre- and post-removal surveys of vertical pilings. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Survey	246	1	5.59	**0.001**
Res	8094	184		
Total	8340	185		

Pairwise tests between depth and pre- and post-removal surveys detected significant differences in the benthic community on L3, L5, and L8 (Table 3.54).

Table 3.54. PERMANOVA pairwise test results for significant differences of pre- and post-removal surveys from L3 to L8 at HI-A-389-A. Bold text denotes significant value.

Groups	t	Unique perms	P (perm)
L3 - Pre, Post	1.6429	999	**0.022**
L4 - Pre, Post	1.4063	999	0.083
L5 - Pre, Post	1.8304	998	**0.008**
L6 - Pre, Post	1.2969	997	0.119

Groups	t	Unique perms	P (perm)
L7 - Pre, Post	1.0915	999	0.281
L8 - Pre, Post	2.2234	996	**0.008**

Direction of the pilings (northeast, northwest, southeast, and southwest) also had an effect on the benthic community from pre- and post-removal surveys of HI-A-389-A, suggesting that the individual pilings displayed different benthic communities in pre- and post-removal surveys (Table 3.55). Because the interaction between the pre- and post-removal surveys and the piling direction was significant, pairwise analyses were conducted for the pilings individually (Table 3.56).

Table 3.55. PERMANOVA results comparing pre- and post-removal surveys and the four vertical piling directions. Bold text denotes significant value.

Source	Sum of Squares	df	Pseudo-F	P (perm)
Survey	120	1	2.75	**0.017**
Piling Direction (NE, NW, SE, SW)	239	1	5.47	**0.001**
Res	7981	183		
Total	8340	185		

Pairwise tests between pre-removal and post-removal surveys and piling direction indicated that there was a significant change in the benthic community on the southeast vertical piling after the top deck of the platform was removed, however all other pilings did not change significantly (Table 3.56).

Table 3.56. PERMANOVA pairwise test results for comparisons of the benthic community before and after platform removal for each of the vertical pilings on HI-A-389-A. Bold text denotes significant value.

Groups	t	Unique perms	P (perm)
NE - Pre, Post	1.0985	999	0.291
NW - Pre, Post	1.3233	997	0.116
SE - Pre, Post	2.7165	998	**0.001**
Top - Pre, Post	1.5098	998	0.054

Repetitive Photostations

Repetitive Photostation Analysis and Results

The results from the descriptive comparisons of repetitive photostations pre- and post-removal are presented in Table 3.57. Unfortunately, due to weather logistics, diving limitations, and time constraints, not all repetitive photostations were photographed in 2019 during the post-removal cruise. Repetitive stations experienced a decrease in hydroid cover on both H2 and H3. In many instances, the repetitive stations gained colonies of sponges such as *Dictyonella ruetzleri*, *Ircinia felix*, and *Geodia gibberosa*. Overall, only one species of scleractinian coral, the invasive *Tubastraea* sp., was noted in the stations. One antipatharian, *Plumapathes* sp., was recorded at station 3 in 2017 and 2019.

Table 3.57. Results from the descriptive comparisons of repetitive photostations on HI-A-389-A.

Station ID	Level	Qualitative descriptions of the comparative changes from pre- to post-removal
1	H3	Loss of hydroids and *Ircinia* sp. colony
3	H3	Minimal changes - retained *Plumapathes* sp., *Ircinia felix*, and various sponge spp.; potential loss of *Callyspongia vaginalis*
4	H3	Loss of hydroids and *Callyspongia vaginalis*; increase in algae cover
6	H3	Gained colonies of *Dictyonella ruetzleri, Ircinia felix,* and *Tubastraea* sp.; loss of hydroids
7	H3	Growth of *Aplysina cauliformis* and *Ircinia felix* colonies; gained colonies of *Dictyonella ruetzleri;* loss of hydroids
10	H3	Retained *Neofibularia nolitangere;* gained *Tubastraea* sp.
11	H3	Loss of *Tubastraea* sp. and hydroids; retained *Ircinia felix* and *Neofibularia nolitangere* colonies
12	H2	Loss of all organisms on N and W sides of pipe
13	H2	Gained colonies of *Geodia gibberosa*, *Scopalina ruetzleri*, and *Dictyonella ruetzleri;* gained tunicates; loss of bryozoan colonies, turf algae, hydroids, and *Ircinia felix* colony; growth of *Geodia gibberosa* colony
15	H2	Reduction of bryozoan colony; growth of *Ircinia strobilina* colony; loss of hydroids; gained *Dictyonella ruetzleri* colonies; increase in algae cover
16	H2	Gained *Dictyonella ruetzleri* colonies and tunicates; growth of *Ircinia felix* colony; loss of hydroids; increase in algae cover
17	H2	Growth of *Geodia gibberosa* and bryozoan colonies; loss of hydroids; increase in algae and crustose coralline algae cover
19	H2	Growth of *Geodia gibberosa* colonies; gained bryozoan colonies; loss of hydroids, *Ircinia felix* colony, and *Dictyonella ruetzleri* colonies; increased in algae and crustose coralline algae cover
20	H2	Retained *Ircinia felix, Geodia gibberosa,* and *Ircinia strobilina* colonies; gained tunicates; loss of hydroids

Figure 3.18 shows an example from repetitive photostation #13 on H2 in 2017 and 2019. The loss of hydroids, turf algae, and some *Ircinia felix* colonies was apparent from 2017 to 2019. Less noticeable is the loss of a bryozoan colony to the left of the T-frame. In addition, a *Geodia gibberosa* colony to the left of the T-frame grew over time. Tunicates, as well as additional colonies of the sponges *Scopalina ruetzleri* and *Dictyonella ruetzleri*, were gained between 2017 and 2019.

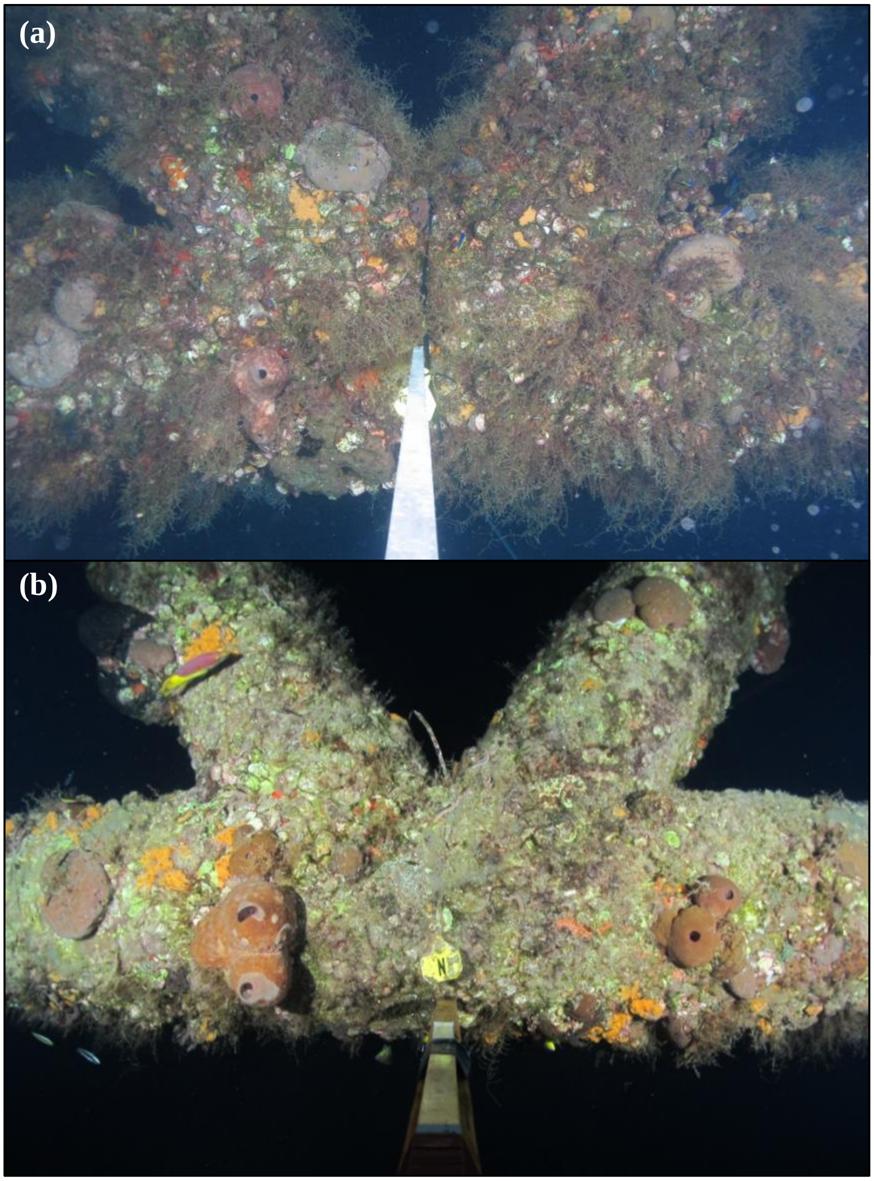


Figure 3.18. Comparison of station 13 on level 2 (H2) of HI-A-389-A in (a) 2017 and (b) 2019. Photographs were viewed simultaneously, on side by side screens, to assess changes in the benthic community over time. Qualitative descriptions of these changes are documented in Table 3.57. Photo: NOAA

Figure 3.19 shows repetitive photostation #3 on H3 in 2017 and 2019. *Plumapathes* sp., *Ircinia felix*, and *Aplysina cauliformis* colonies were retained from 2017 to 2019. The unknown purple, rope sponge grew over time and the number of tunicates increased. There may have been a loss of *Callyspongia vaginalis*, but it is also possible this apparent loss was an artifact of the different camera angles between the photographs taken in 2017 and 2019.

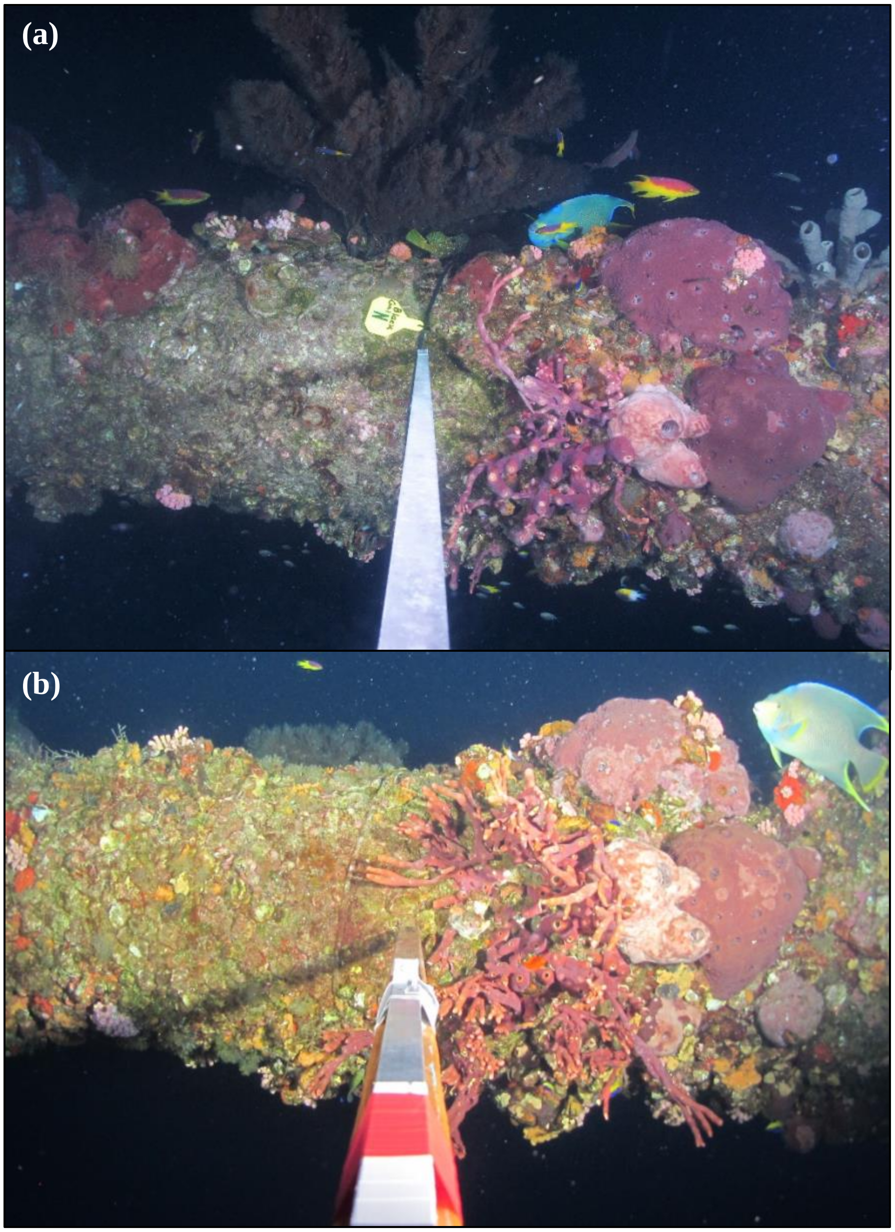


Figure 3.19. Comparison of station 3 on H3 of HI-A-389-A from (a) 2017 to (b) 2019. Photographs were viewed simultaneously, on side by side screens, to determine the changes in the benthic community over time. Qualitative descriptions of these changes are documented in Table 3.57. Photo: NOAA

Seafloor Surveys

Pre-Removal Seafloor Surveys Benthic Results

At the base of HI-A-389-A, four repetitive photographic transects were completed on the seafloor and two were completed along the gas pipeline during the ROV pre-removal cruise. All seafloor and pipeline images consisted of mud bottom with no significant epifauna (Figure 3.20). Benthic percent cover was not calculated for random or repetitive transects for the seafloor or pipeline.

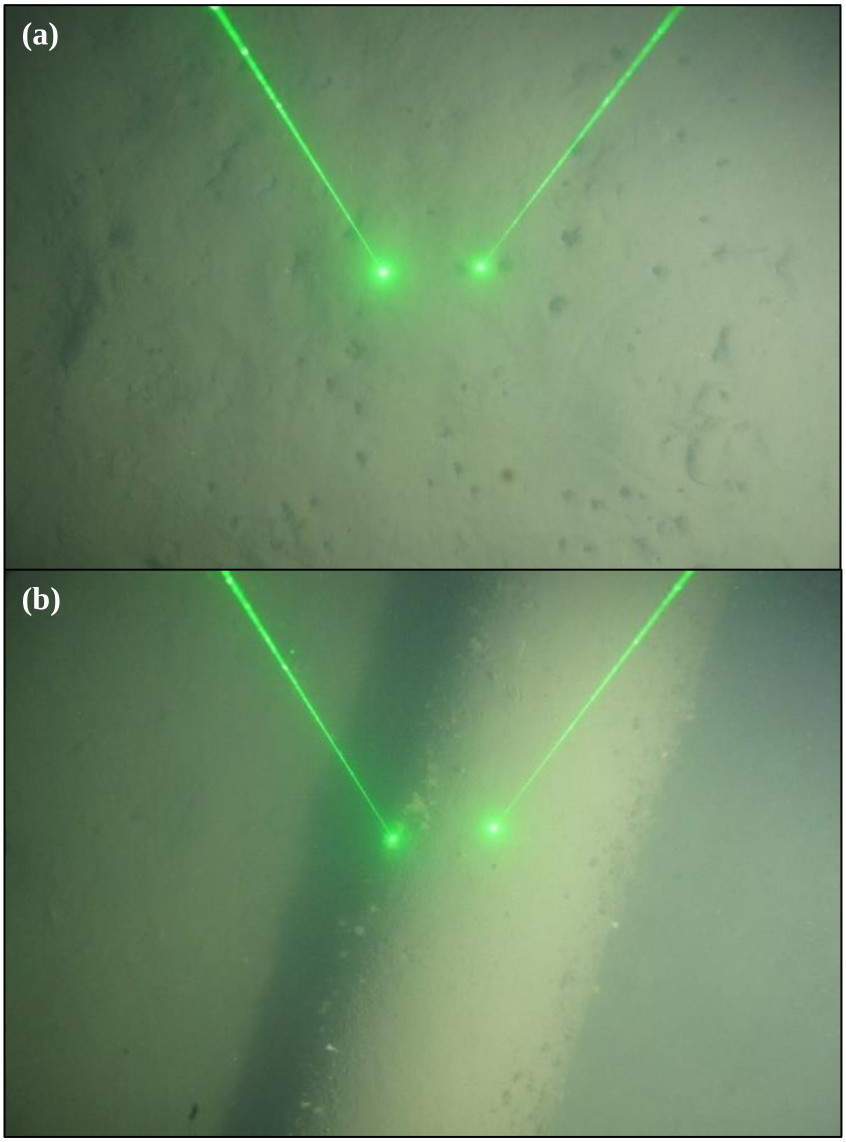


Figure 3.20. Images of mud bottom along (a) seafloor and (b) gas pipeline from pre-removal surveys. Photo: NOAA/UNCW-UVP

Although no significant epifauna was observed in seafloor pre-removal surveys, various types of marine debris were detected, including cord, rope, metal cans, and metal grating (Figure 3.21).

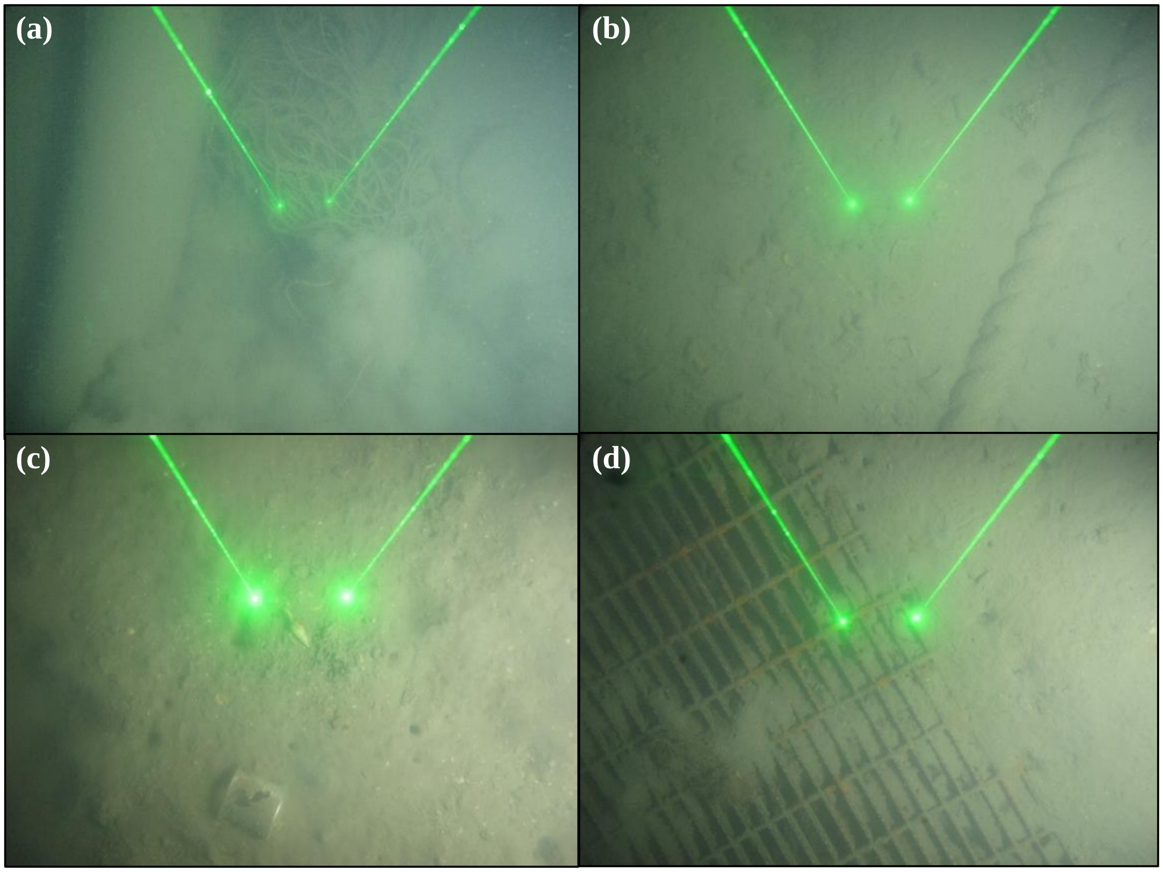


Figure 3.21. Marine debris including (a) cord, (b) rope, (c) metal can, and (d) metal grating observed in seafloor photographic transect pre-removal surveys. Photo: NOAA/UNCW-UVP

Post-Removal Seafloor Surveys Benthic Results

At the base of HI-A-389-A, only one repetitive photographic transect was completed on the seafloor due to poor visibility during the ROV post-removal cruise. Post-removal benthic percent cover from seafloor random photographic transects and seafloor and gas pipeline repetitive photographic transects was not calculated because all images consisted of a mud bottom with no significant epifauna. Figure 3.21 highlights the mud bottom observed in all photographs and the gas pipeline on the seafloor.

Although no significant epifauna was observed in seafloor post-removal surveys (Figure 3.22), marine debris was detected, including cord and braided rope near the pipeline on the mud bottom (Figure 3.23).

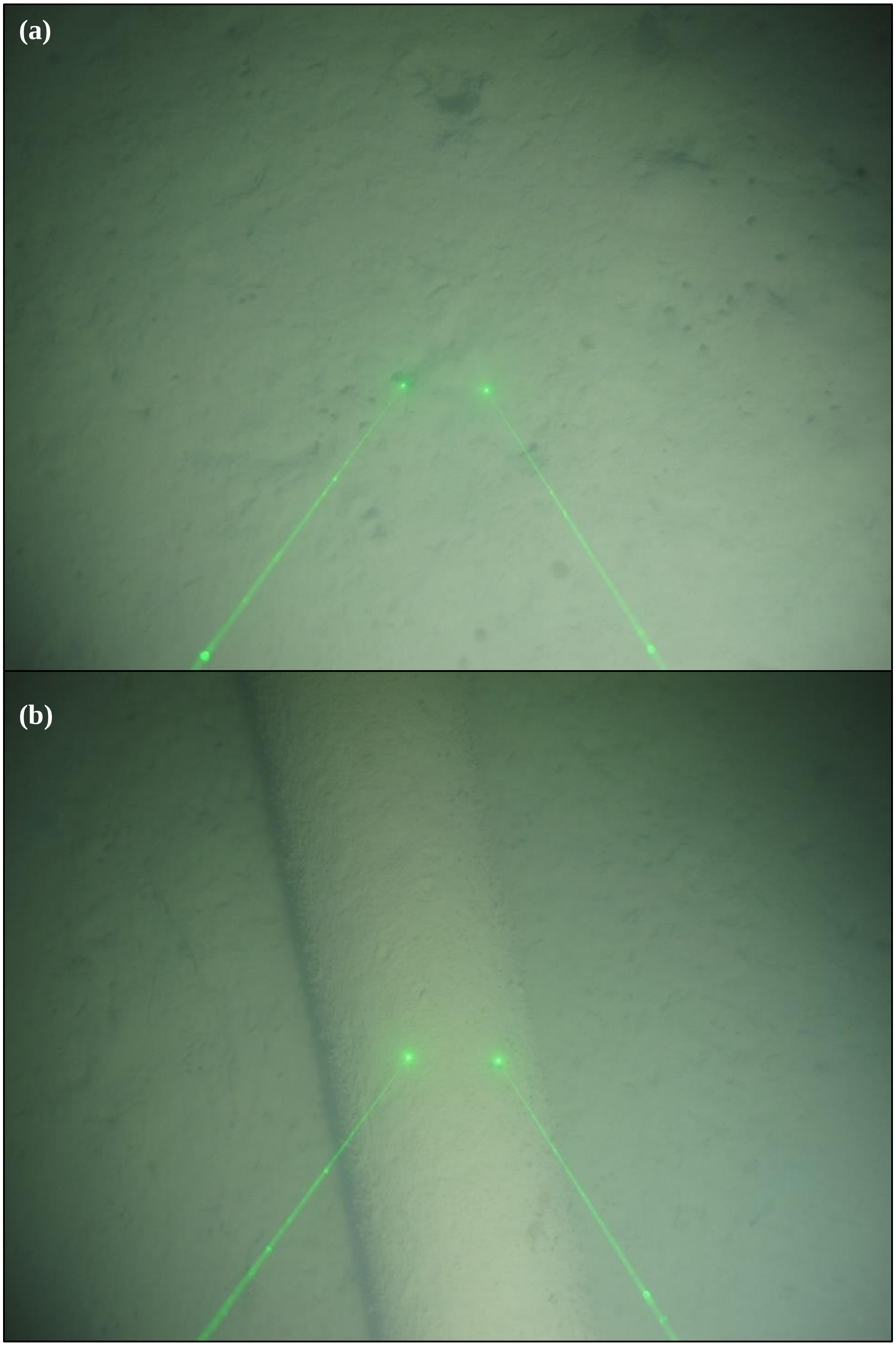


Figure 3.22. Images of mud bottom along (a) seafloor and (b) gas pipeline photographic transect post-removal surveys. Photo: UNCW-UVP

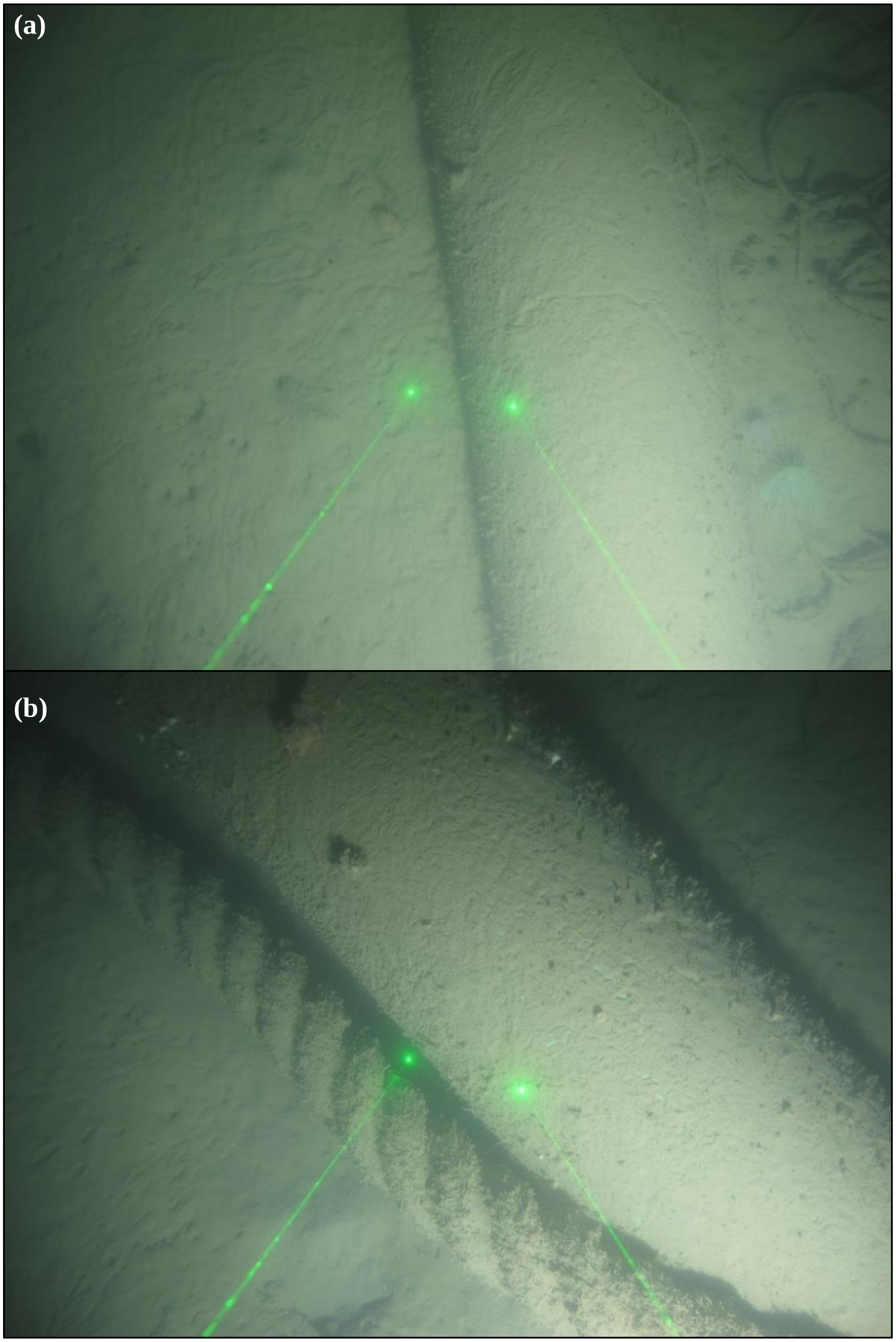


Figure 3.23. Marine debris including (a) cord and (b) rope observed in seafloor photographic transect post-removal surveys. Photo: UNCW-UVP

Comparison of Pre- and Post-Removal Seafloor Surveys Benthic Results

Pre- and post-removal benthic percent cover from seafloor random photographic transects and seafloor and gas pipeline repetitive photographic transect was not calculated because all images consisted of a mud bottom with no significant epifauna. Qualitative observations from ROV surveys did not change from pre-removal to post-removal surveys. Conspicuous marine debris that was observed on the seafloor in pre- and post-removal surveys was located and removed on two separate occasions by the leaseholder, W&T Offshore, Inc., according to the site clearance agreement after the removal of the top portion of the structure.

Benthic Community Comparison and Discussion

Pre-Removal Benthic Community

The pre-removal benthic community did not vary based on direction of the horizontal beams of the platform (north, south, east, and west). Even though location of the beams was not a significant factor, orientation (B, I, O, T) did affect the composition of colonized benthic organisms. The PERMANOVA pairwise test suggested that the top side of the structure was significantly different from the bottom, inside, and outside in H1 diver surveys and different from the bottom and inside in H2 diver surveys. Settlement upon the top of the horizontal beams rather than on the sides or bottom is likely due to a preference of the larvae.

For vertical pilings, the benthic community also differed significantly by depth. While direction did not significantly contribute to differences among benthic communities on horizontal beams of HI-A-389-A, direction of vertical pilings (NE, NW, SE, SW) was a factor in dissimilarities among those benthic communities. This suggests that vertical pilings may be more influenced by ocean currents, differences in light availability, space for settlement, or other factors.

Due to the layered nature of the benthic community on the pilings, bivalve populations are likely underrepresented in the horizontal and vertical survey data. This was captured by interaction notes included in CPCe analysis and displayed in Table 3.3 and 3.38. Bivalves were frequently overgrown with layers of other encrusting/fouling organisms. Furthermore, other organisms were commonly overgrown with bivalves.

There were few native coral species observed on the structure. The most abundant coral species in this study was *Tubastraea* sp. This invasive species typically inhabits structure pilings and other artificial reefs, but is uncommon on healthy reefs in the Atlantic and Caribbean (Fenner and Banks 2004; Precht et al. 2014; Sammarco and Strychar 2016; Kolian et al. 2017). The benthic development on platforms is conducive to settlement and growth of *Tubastraea* sp., which typically tends to be the most prominent scleratinian species on artificial reef structures (Sammarco et al. 2004; Kolian et al. 2017). Azooxanthellate corals are not constrained or limited to shallow water like most corals, as they are not limited primarily by light penetration. However, *Tubastraea* sp. was not observed on or below H5 at 72 m depth. The factor limiting depth for this species is not yet known, but may be attributable to settlement preferences or larval dispersal (Kolian et al. 2017).

While the horizontal beams and vertical pilings were colonized by similar sponge, encrusting sponge, and macroalgae organisms, a difference was the lack of stony corals on vertical pilings. While *Tubastraea* sp. was the most abundant coral species on horizontal beams, no *Tubastraea* sp. were observed on vertical pilings, possibly due to the orientation of the substrate or some other factor.

Bare substrate was highest near the seafloor at H8, where silted percent cover was highest. Lower levels of the platform were less diverse and it is possible the persistent silt and limited light in the nepheloid layer generates a less than favorable environment for benthic organisms to colonize. However, zoanthids were common on horizontal beams on lower levels where silt was not observed (H6, H7). This may suggest that zoanthids can colonize or outcompete other organisms at these depths on the platform. The seafloor consisted of mud bottom habitat with no significant epifuana and various types of marine debris, including cord, rope, metal cans, and metal grating.

Post-Removal Benthic Community

Benthic groups exhibited significant differences in horizontal levels by depth: sponges were the major contributor to dissimilarities between the cluster of H2 through H5 and all other clusters; bivalves were the major contributor to dissimilarities between the cluster of H6 and H7 and all other clusters. Level H8 was not surveyed due to poor visibility. Direction of the horizontal pilings on the platform (E, W, N, S) did not significantly contribute to the differences in mean cover post-removal. Biofouler zonation, in which benthic fouling organisms exhibit depth preferences, is a characteristic feature of offshore platforms (Venugopalan and Wagh 1990). In post-removal surveys of the platform, all of the horizontal beams showed a mixed community of stony corals, hydroids, sponges, macroalgae, and bivalves (Table 3.15). There were common changes noted in the benthic community with depth, such as the decrease in percent cover of hydroids with increasing depth, the increasing percent cover of bivalves with increasing depth, and the increasing percent cover of octocorals with increasing depth. Bryozoans and zoanthids were the most common organisms observed on the deeper levels (H7), which is consistent with other research (Venugopalan and Wagh 1990).

Although the direction of horizontal pilings did not contribute to the differences in the benthic community, orientation (B, I, O, T) was a factor in the composition of colonized benthic organisms on H2. The PERMANOVA pairwise test suggested significant differences existed among all orientations on H2, potentially resulting from the removal of the upper portion of the structure and exposing organisms on H2 to stresses from the removal process and additional light with the shade structure of the platform removed.

There were no significant differences in the benthic community among the beam orientations on H3 in the post-removal surveys.

For vertical pilings, the benthic community also differed significantly by depth. While direction was not a significant contributor to differences among benthic communities on HI-A-389-A horizontal beams, direction (NE, NW, SE, SW) of vertical pilings did contribute to dissimilarities in those benthic communities. Pairwise tests detected that the southeast piling was significantly different from the northeast and northwest pilings. The primary contributor to the differences between the northeast and southeast pilings was sponges, while other sessile invertebrates contributed to the differences between the northwest and southeast pilings. Collectively, these data suggest that the benthic community changes with depth, and in some instances directionality, on the platform; however, the drivers of these differences (e.g. biophysical parameters, resource availability, and interspecific relationships) require further investigation.

These analyses aimed to capture the percent cover of the benthic community on the HI-A-389-A platform after the upper 22 m was removed; however, due to the nature of analyzing data from photographs, caveats exist when interpreting the results. The community that colonizes the platform pilings is often characterized by layers of overgrowth, in which organisms overlap during colonization, which may lead to an underrepresentation of taxa that typically occupy the bottom layers. For example, bivalves are captured in the horizontal and vertical survey data as “bivalves” and “bivalves overgrown with”. As a group, bivalves were identified as the singular organism bivalve with no overgrowth, comprising <27% (Table 3.15) and <15% (Table 3.42) cover on horizontal and vertical pilings, respectively. In contrast, the grouping “bivalve overgrown with” was identified as the overgrowing taxon (e.g. algae, encrusting sponge, tunicate) and then noted to have a bivalve beneath the growth. Bivalves overgrown with other species represented 46% (Table 3.16) and 34% (Table 3.43) cover on horizontal and vertical pilings, respectively. H7 and L7 had the greatest cover of bivalves without overgrowth, whereas H6 and L8 had the highest percent cover of bivalves overgrown with other organisms. This difference in categorization could affect the interpretation of the benthic community structure of the platform; however, regardless of categorization, bivalves consistently comprised the greatest percent cover at depths below 91 m.

There were few native coral species observed on the structure, and the most abundant coral species on horizontal beams was *Tubastraea* sp. This invasive species, potentially limited by light penetration, was not observed on or below H6. While the horizontal beams and vertical pilings were colonized by similar sponge, encrusting sponge, and macroalgae organisms, a difference was the limited amount of stony corals found on vertical pilings. *Tubastraea* sp. was the most abundant coral species on the horizontal beams, but was less abundant on the vertical pilings than *Madracis decactis*. Settlement and survival of *Madracis decactis* and *Tubastraea* sp. are affected by low salinities, increased sedimentation, and increased nutrients (Sammarco et al. 2012). It is unclear why *Madracis decactis* is more abundant than *Tubastraea* sp. on the vertical pilings in post-removal surveys; however, after *Tubastraea sp*., *Madracis decatis* is the most prominent hermatypic coral found on platforms in the region (Sammarco et al. 2012). This may be an artifact of the methodology used to survey vertical transects, in that the entire piling is not captured during the survey, which may underrepresent the total percent cover of *Tubastraea* sp. on the vertical structure.

Bare substrate was highest near the seafloor, on H7 (Table 3.15) and L8 (Table 3.42), where silted percent cover was highest (Table 3.16 and Table 3.43). The deeper levels of the platform had lower total percent cover of stony corals, hydroids, macroalgae, encrusting sponges, and sponges than the shallower horizontal beams; however, there was a greater coverage of other sessile invertebrates, other motile organisms, and bivalves at these deeper levels. This difference in species distribution may be attributable to the nepheloid layer found at the deeper levels, below 110 m. The nepheloid layer may generate nutrients (i.e. bacteria and plankton) (Cartes and Sarda 1993) that are favorable to filter and suspension feeders (e.g. bryozoans, tunicates), and carnivores that feed on plankton (e.g. anemones, zoanthids). Alternatively, the high sedimentation and low light at deeper depths are not conducive for other organisms such as stony corals and sponges (Sammarco et al. 2012; Bell et al. 2015), which may explain the low abundances of these organisms on H7. Vertical pilings showed a similar trend in that percent cover of stony corals, sponges, encrusting sponges, and hydroids decreased at the deeper levels, while percent cover of other sessile invertebrates, other motile organisms, and bivalves increased.

Seafloor surveys consisted of mud bottom habitat with no significant epifauna and two marine debris items, including a cord and braided rope.

Pre- and Post-Removal Benthic Community

Benthic groups on horizontal levels differed significantly between pre- and post-removal surveys. The loss of hydroids from the structure was the main contributor to differences.

On average, stony and fire coral cover increased post-removal on the upper two horizontal beams (H2 and H3) and on all levels of the vertical pilings of the platform, while stony coral cover generally decreased on the deeper levels of the horizontal beams (H4, H5, and H7). Overall, mean percent cover of *Tubastraea* sp. decreased on the horizontal beams of the platform and increased on the vertical pilings. In contrast, mean percent cover of *Madracis decactis* and *Oculina* sp. increased on horizontal beams and vertical pilings. Additionally, *Siderastraea radians* mean percent cover increased on horizontal beams and *Montastraea cavernosa* mean percent cover increased on vertical pilings.

The increase in stony coral cover cannot directly be attributed to the removal of upper structure of the platform given the relatively short study period and the ecology, settlement regime, and growth rates of stony corals (e.g. Weber and White 1977);

however, it may be related to the random nature of the transects and natural variability. Continued study and analysis could discern whether the survey methods resulted in the observed increase in stony coral cover on the shallower levels of the platform.

Tubastraea sp. was the only stony coral species observed in repetitive photostations and the most common scleractinian coral recorded on surveys of horizontal beams, while *Madracis decactis* and *Oculina* sp. were the most common stony coral species recorded on the vertical piling surveys. *Tubastraea* sp. is an invasive species that is native to the Indo-Pacific, but has become the most abundant stony coral in the northern Gulf of Mexico on artificial substrate; hundreds of thousands of colonies can be found on a single platform (Sammarco et al. 2012). *Tubastraea* sp. was first documented on HI-A-389-A in 1991 by Dr. Steve Gittings and Carl Beaver (Fenner 2001). Hickerson and Schmahl (2005) reported a thriving population on the platform.

It is well known that substantial coral communities can be supported on oil and gas platforms, though it is not well understood what impact removing a portion of the structure can have on these communities. Sammarco et al. (2014) found significantly higher densities of *Tubastraea* sp. and *Madracis decactis* on a toppled platform, compared to a standing production platform. Results from the present study could not be directly compared to Sammarco (2014), as coral densities were not evaluated; however, similar observations were made during both studies. In 2014, relative coral abundances on a standing platform exhibited a trimodal distribution, with corals peaking at 30, 40, and 75 m depth (Sammarco et al. 2014). Congruently, percent coral cover at HI-A-389-A showed a trimodal distribution, peaking at 37, 52, and 91 m depth. Coral colonies, primarily Oculinidae, were observed to 108 m depth on HI-A-389-A post-removal. *Oculina* sp. observed in 2014 extended to 95 m on a standing platform (Sammarco et al. 2014).

Tubastraea sp. grow well in disturbed habitats (Byers 2002; Sheehy and Vik 2010), which may explain the increase in cover on vertical pilings after the top of the platform was removed. *Madracis decactis* requires light for colony survival and growth (Sammarco et al. 2014), which may explain the increase in percent cover on the horizontal beams and vertical pilings following the partial platform removal. With the loss of the shade structure, the remaining upper levels of the platform were exposed to more light, which could provide a more suitable environment for the growth of *Madracis decactis*. Previous work suggests light may not be as important to the distribution of Oculinidae (Sammarco et al. 2014); however, after the removal of the upper deck, the distribution of *Oculina* sp. extended into shallower depths (37 m), which may suggest that light availability did play a role at HI-A-389-A for this coral.

The first comprehensive characterization of sponges on HI-A-389-A took place in 1993 and 1994, but was limited to the upper 37 m (Adams 1996), equating to H3 and above in this study. Similar to Adams (1996), sponges were present through the depth ranges, with some species exhibiting distinct depth preference. Mean percent cover of sponges followed similar trends (Adams 1996) on the upper levels of the horizontal beams (H2 and H3) and vertical pilings (L3 and L4). Post-removal, an overall decrease in mean percent sponge cover was observed from H2 to a depth of 50 m (2 meters above the H4), while an increase was observed on the lower horizontal beams (H4 through H7) and L6 on the vertical pilings. Sponges are generally less abundant in high light environments and tend to be more restricted to shaded microhabitats (Cárdenas et al. 2012). The removal of the upper shade structure may have influenced the sponge community on the remaining upper levels of the platform. Sponge mortality was observed on the upper portion of the platform in August and September 2016; however, there is insufficient data to directly correlate this observation with the localized mortality event at EFGB in 2016 (Johnston et al. 2019). Although additional data are required to fully assess potential impacts of the 2016 mortality event, it is possible that this event may be a confounding factor in our assessment of the effects of the HI-A-389-A shade structure removal on the sponge community.

Sponge distribution and abundance have been found to have weak relationships with environmental variables; rather, these population characteristics have a greater correlation with habitat preferences, which can be patchy in nature (Zea 2001). A species-specific and colony-centric analysis would provide information needed to determine whether the change in the sponge community was due to growth and/or regression of single colonies, or because of an increase/decrease in overall abundance and distribution of sponge colonies. Additionally, it would reveal if any species interactions or competition were present after the partial platform removal, and shed light on the ability of sponges to resist this level of disturbance.

Sponges that were identified to species level showed interesting trends, such as the significant decrease in *Neofibularia nolitangere* cover on L4 through L6 of the vertical pilings, and the significant increase in *Aiolochroia crassa* cover on the same levels. *Dictyonella ruetzleri* and *Geodia gibberosa* both increased on L3 through L5 post-removal. It is difficult to compare species-specific changes in sponge cover on the horizontal beams and vertical pilings, because the communities varied greatly, which may reflect specific adaptations to environmental parameters and/or habitat preferences. No *Callyspongia vaginalis* or *Ircinia felix* were recorded on the vertical pilings pre- or post-removal, but were observed on the horizontal beams during both surveys. Though no *Geodia gibberosa, Aiolochroia crassa*, or S*uberites* sp. were observed on horizontal beams pre- or post-removal, they were recorded on the vertical pilings pre- and post-removal. Sponges tend to be more abundant on vertical surfaces than horizontal ones, which indicates that the orientation of the substrate is a major factor in patchiness of sponge distribution (Maldonado and Young 1996). This holds true for HI-A-389-A, as a greater diversity of sponge species was found on the vertical pilings than the horizontal beams. Sponge abundance does not typically have a linear relationship with depth, but often shows a bimodal distribution, with peaks at 100 m and 230 m (Maldonado and Young 1996); however, this was not the case for HI-A-389-A. Mean percent cover of sponges peaked at 37 m on horizontal beams and between 37 m and 52 m on vertical pilings.

Sponge and algae abundance have been found to be negatively correlated (as algal cover increases, sponge cover decreases) (Cárdenas et al. 2012). This relationship was observed for macroalgae and sponge cover on the upper three levels of the horizontal beams (H2 through H4) and L3 of the vertical pilings post-removal; however, it did not hold true for the deeper levels of the structure. It was expected that this relationship would be evident on the horizontal beams, as this part of the structure is characterized by higher light availability than the vertical pilings. The increase in both sponge and macroalgae cover on the lower levels of the horizontal beams (H5 through H7) lacks a clear explanation; light is limited at lower levels and is thus not believed to be a factor in driving community structure.

Encrusting sponge cover on horizontal beams increased on all levels except H5 and H7, where it decreased. Surveys from the vertical pilings indicated a decrease in encrusting sponge cover on L6 and L7, and an increase in cover on L4. These results suggest that there was an overall loss in the mean percent cover of encrusting sponges from 72 m to 108 m below the surface on the platform post-removal. Because encrusting sponges were not identified to species level, it is difficult to discern if there were any species-specific competitive interactions, damage, or regeneration after the top of the structure was removed. Some species of encrusting sponge exhibit enhanced chemical and physical defenses in shaded, animal-dominated habitats as compared to well-illuminated habitats, dominated by algae (Turon et al. 2002). Mortality in encrusting sponges is significantly higher in well-illumnated habitats (e.g. Turon et al. 2002), and thus the increase in light availability due to the removal of the upper portion of the platform may have resulted in increased mortality. This may be particularly true at deeper depths (72 to 108 m) that were previously exposed to very low light.

In contrast, mean percent cover of encrusting sponges increased on the upper three horizontal beams (H2, H3, H4) post-removal. Encrusting sponges tend to be more abundant in shaded areas (Turon et al. 2002); it is possible that encrusting sponge cover increased on the bottom of beams H2 through H4, which may explain the increase in overall percent cover post-removal. A comparison of encrusting sponge cover among beam orientations was outside the scope of the present study, however more detailed analyses could shed light on this possible explanation.

Percent cover of macroalgae and organisms overgrown with algae increased on all levels after the top portion of the platform was removed. Concurrently, hydroid cover decreased on all levels of horizontal beams and vertical pilings, while organisms overgrown with hydroids increased for each level. This increase in organisms overgrown with hydroids likely still reflects a net loss of hydroids, as the organisms beneath the hydroids became visible in the post-removal surveys (due to the layered nature of the fouling community) as the overall density of overgrowing hydroids was lost. The changes in mean percent cover of macroalgae and hydroids were inversely related on horizontal beams and vertical pilings: as hydroid cover decreased, macroalgae cover increased (Figure 3.24). The decrease in hydroid cover may be attributable to factors related to light exposure, water movement, and food availability.

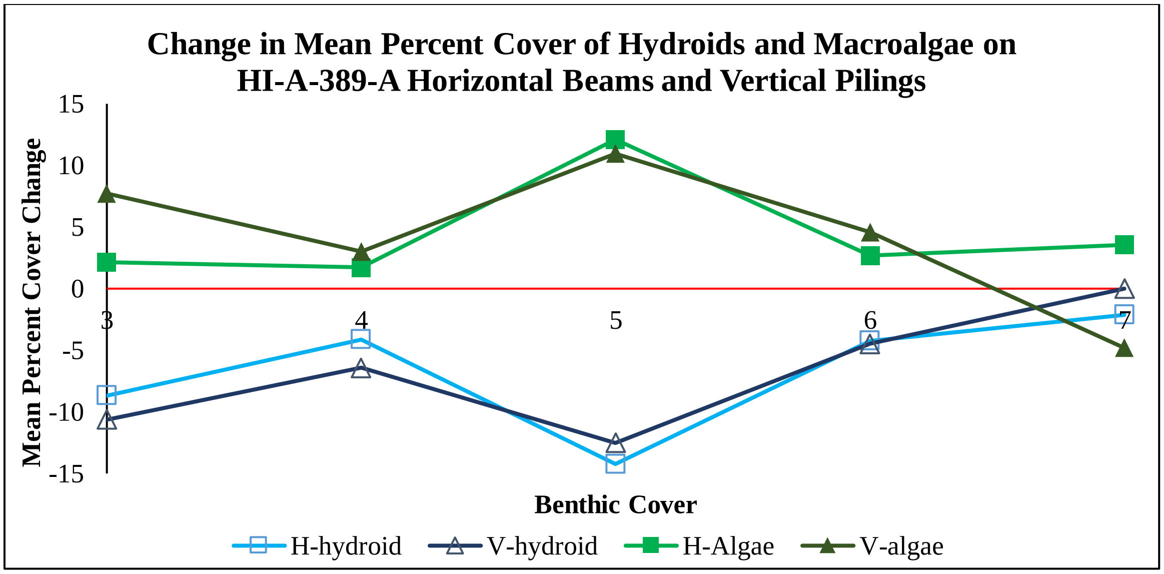


Figure 3.24. Comparison of change in hydroid and macroalgae mean percent cover on horizontal beams (H) and vertical pilings (V) following platform removal. The changes in percent cover are inversely related, such that when hydroid cover decreased, macroalgae cover increased.

Exposure to light may be an important factor in determining the distribution of hydroids and macroalgae. Many species of hydroids are sensitive to ultraviolet light, whereby exposure can result in colony degeneration or the prevention of colony growth (Gili and Hughes 1995). Additionally, larvae of some hydroid species selectively settle at low light sites. In general, most hydroids are less abundant in well-lit environments, where competition with algae for the substratum is greatest (Calder and Cairns 2009). It is not known whether this is an effect of direct competition or an evolved avoidance behavior of hydroids (Gili and Hughes 1995); however, the general assumption is that as hydroid cover declines, more substrate becomes available and is colonized by macroalgae. The present study supports this assumption and also suggests that macroalgae are more adept than hydroids at colonizing the platform under stressful conditions. The analyses needed to confirm these inferences are outside the scope of the present study, but may be an area for future study.

Hydroid size is correlated inversely with water movement, such that smaller specimens are found in areas where water movement is more intense, while larger hydroids are found in areas with calm water (Puce et al. 2002; Gili and Hughes 1995). The removal of the upper levels of the platform may have exposed hydroids to stronger water movement or altered fish feeding patterns, resulting in reduced hydroid size. Additionally, water movement can impact the feeding behavior of hydroids; a morpho-functional modification in feeding structure can occur in association with an increase in water turbulence, whereby the hydroid acquires the ability to efficiently suspension feed (Puce et al. 2002). However, hydroids are predominantly carnivorous and primarily feed on zooplankton (Gili and Hughes 1995). A change in food capture rate, brought on by a reduction in food availability and/or high velocity water movement, can impact the growth of hydroids and affect colony morphology, such that when food is scarce, a colony may undergo regression (Gili and Hughes 1995). It is possible that the removal of the upper structure resulted in a reduction of food commonly consumed by hydroids (Claisse et al. 2015), as well as an increase in water movement that transported zooplankton past hydroids too quickly for effective consumption (Puce et al. 2002).

Percent cover of bivalves and bivalves that were over grown with other biota decreased on the upper two horizontal beams (H2 and H3), while cover increased on the deeper beams (H4 through H6). Mean percent cover of bivalves on vertical pilings increased on all levels post-removal. In general, offshore coastal platforms may not harbor high bivalve cover at shallower depths, but deeper portions of the platform may harbor larger numbers of oysters and other bivalves (Gallaway and Lewbel 1982). This trend was true for HI-A-389-A; bivalve percent cover remained low on the upper portions of the platform, but increased with water depth on vertical pilings and horizontal beams, where bivalves contributed significantly to the percent cover on the structure between 91 and 125 m. It should be noted that overall percent cover of bivalves may be higher than the value reported in the “bivalves” category alone, as bivalves were also captured in CPCe interaction notes as “bivalve overgrowth” due to the layered nature of the fouling community.

At least four species of oysters are common on platforms in the Gulf of Mexico (Gallaway and Lewbel 1982), though species-level identification was not possible for this study due to the overgrowth of other organisms and clustered nature of bivalves. Because of this, it is difficult to determine what led to changes in the bivalve community post-removal, as this is often species-specific in terms of response to environmental parameters and physical disturbance. It is probable that the physical removal of the upper portion of the platform had some effect that led to the decrease in percent cover of bivalves on the upper two levels of the horizontal beams. Additionally, as bivalves are filter feeders, an increase in sedimentation during the removal of the upper deck may have had an impact on these shallower communities.

Barnacles were absent from horizontal beams and vertical pilings post-removal, declining by 0.02% and 0.06% from pre-removal surveys on H2 and H3, respectively, and by 0.46% on L8. This loss of barnacle cover may be an artifact of methodology, in that CPCe analyzes mean percent cover rather than total colony counts. Barnacles may not have been represented in the post-removal analysis because a point did not land on one in CPCe, or they may have in fact disappeared post-removal, as that they already exhibited low mean percent cover on the platform in 2015 and 2017.

Barnacles are very successful colonizers on exposed structures, and their distributions are primarily driven by species-specific range or depth restrictions (Gallaway and Lewbel 1982). Typically, barnacles are found in greater densities in shallow water and decrease rapidly with increasing water depth. The two most common species of barnacles observed in the northern Gulf of Mexico are restricted to the upper 9.1 m on platform pilings (Gallaway and Lewbel 1982), which may explain why percent cover was so low in general on HI-A-389-A. In the context of offshore biota, barnacles are relatively unimportant on offshore oil and gas platforms located in deep water (Gallaway and Lewbel 1982). Species-level observations were not made during this analysis, which also limits our ability to determine why barnacles were absent from post-removal surveys.

There was a decrease in percent cover of black coral on HI-A-389-A post-removal on horizontal beams H3 and H5 through H7, as well as the vertical piling L6. A 0.98% increase in percent cover of black coral was observed on L5 post-removal. In general, black coral cover was relatively low at the platform, accounting for a cumulative 7.26% and 3.65% of all horizontal beams and vertical pilings, respectively. In general, black corals have a patchy distribution and occur in low abundances (Boland and Sammarco 2005), therefore the low percent cover observed in this study is likely representative for this taxon. It is unclear whether this decrease represents an actual decline in percent cover of the black coral, or if it is an artifact of the data analysis method. Colony-centric data would help clarify the impacts that the removal of the upper structure may have had on these colonies.

Mean percent cover of octocorals increased on H2, but decreased on H6 and H7 of the horizontal beams post-removal. No octocorals were observed on the vertical pilings during pre- or post-removal surveys. The density of octocoral on offshore oil and gas platforms has been found to decrease with increasing water depth (Kolian et al. 2017), which is consistent with the trend in percent cover of octocorals on horizontal beams in the present study. Mean cover of octocorals decreased from 91 to 108 m water depth in pre- and post-removal surveys, though the overall cover was low (2.35% and 0.43% on H6 and H7, respectively). This decrease in cover could be a result of disturbance from the removal of the upper portion of the platform, or it may be an artifact of the methodology, in that CPCe does not capture total colony counts. As the percent cover of octocorals was low on HI-A-389-A prior to removal of the upper 20 m, it is difficult to deduce the level of impact this disturbance may have had on these organisms.

The percent cover of other motile organisms increased on the upper levels of horizontal beams (H2 through H4), and increased on most vertical pilings. The sessile members of the epifaunal community on offshore platforms provide shelter and food to a diverse assemblage of small and large motile invertebrates. The most common motile invertebrates are often associated with hydroids, sponges, and other mat organisms (Gallaway and Lewbel 1982), which were widely distributed on HI-A-389-A, and likely contribute to the distribution of the motile organisms on the structure.

Trends in other sessile invertebrate cover were similar to those of other motile organisms; cover of other sessile invertebrates increased on the upper horizontal beams (H2 through H4) and on vertical pilings post-removal. Percent cover of sessile invertebrates was highest below 91 m water depth, with the greatest percent cover on H6 and H7, as well as L7 and L8. Sessile invertebrates that were included in this group were anemones, bryozoans, tubeworms, tunicates, and zoanthids. Zoanthids contributed to the greatest overall decrease in percent cover of other sessile invertebrates post-removal, decreasing by nearly 30% on H6 and H7. The other four organisms included in this category, including bryozoans, had low percent cover pre- and post-removal on horizontal beams, which suggests these organisms do not significantly contribute to the biotic composition of HI-A-389-A. Bryozoans are common on offshore platforms in the northern Gulf of Mexico, but often exhibit a patchy distribution. They are also subject to considerable dieback in warmer months (Gallaway and Lewbel 1982); this may be reflected in the data collected during pre- and post-removal surveys, which were collected during June, July, and September. Species-level observations were not made for the other sessile invertebrates group, reducing the ability to make general assumptions about the patterns exhibited post-removal.

Mean percent cover of bare substrate increased on all horizontal levels post-removal, but generally decreased on most levels of the vertical pilings (L4 to L7).

In general, there was an increase in the percent cover of bleached organisms, which included corals and sponges, following removal of the top portion of the structure. Reasons for coral bleaching are well known in the scientific community; however, sponges are also vulnerable to environmental stressors, and often exhibit signs of bleaching in response to stress (Whalan 2018). Specific changes in water quality parameters were not measured during or immediately after the removal of the structure, which reduces our ability to explain this observation. The physical removal of the upper shade structure of the platform represents a significant disturbance to the benthic community, though additional data would be needed to determine the most critical factors that contributed to the responses observed.

Additionally, percent cover of diseased or damaged organisms increased post-removal on horizontal beams H3 through H5, and on all levels of the vertical pilings. As this observation is generalized, no specific inferences can be made as to why these changes may have occurred. While sponges and other invertebrates were observed to bleach and die in the same timefame as the EFGB localized mortality event in 2016, it is unlikely that this mortality event would cause the bleaching and mortality observed during post-removal surveys. It is more likely that these impacts resulted from the removal of the upper shade structure.

Repetitive stations afforded the opportunity to observe changes in the benthic community structure following the partial removal of the upper 20 m of the platform. It was evident from the comparison of photographs taken in 2017 and 2019 that a wide range of changes occurred, such as the loss or regression of some sponge and cnidarian species, as well as growth of sponge colonies and tunicates. However, similar to previously described surveys, an overall loss of hydroids was observed at each station. Again, this may be explained by changes in currents, access to food, and light exposure.

Faunal zonation and organism colonization is often controlled by hydrographic conditions such as water temperature, salinity, light availability, gas concentrations, current, dissolved oxygen, etc., which have a strong correlative relationship with depth (Gallaway and Lewbel 1992; Cartes and Sarda 1993). Shifts in the benthic community of HI-A-389-A may be associated with these biophysical parameters, but more data is needed to characterize this relationship.

Considerable scientific debate has centered on the role oil and gas platforms play in the ecosystem of the Gulf of Mexico, and whether the communities on these structures are similar to natural coral reefs. Based on surveys conducted by FGBNMS scientists in 2012 on HI-A-389-A from a depth of 40 m to the surface (Embesi et al. 2013) and the results of this study, the benthic community did not resemble the nearby coral reef at EFGB, even at comparable depths. Very few native coral colonies were observed on the platform, contrasting with EFGB benthic cover, which is comprised of living hermatypic corals (over 50% coral cover) in depths less than 40 m (Johnston et al. 2016, 2018). Benthic cover at HI-A-389-A from 20 m to 40 m was comprised of mostly sponges, encrusting bivalves, macroalgae, and hydroids (Embesi et al. 2013), which are rarely observed on the nearby natural reef at these depths (Figure 3.25).

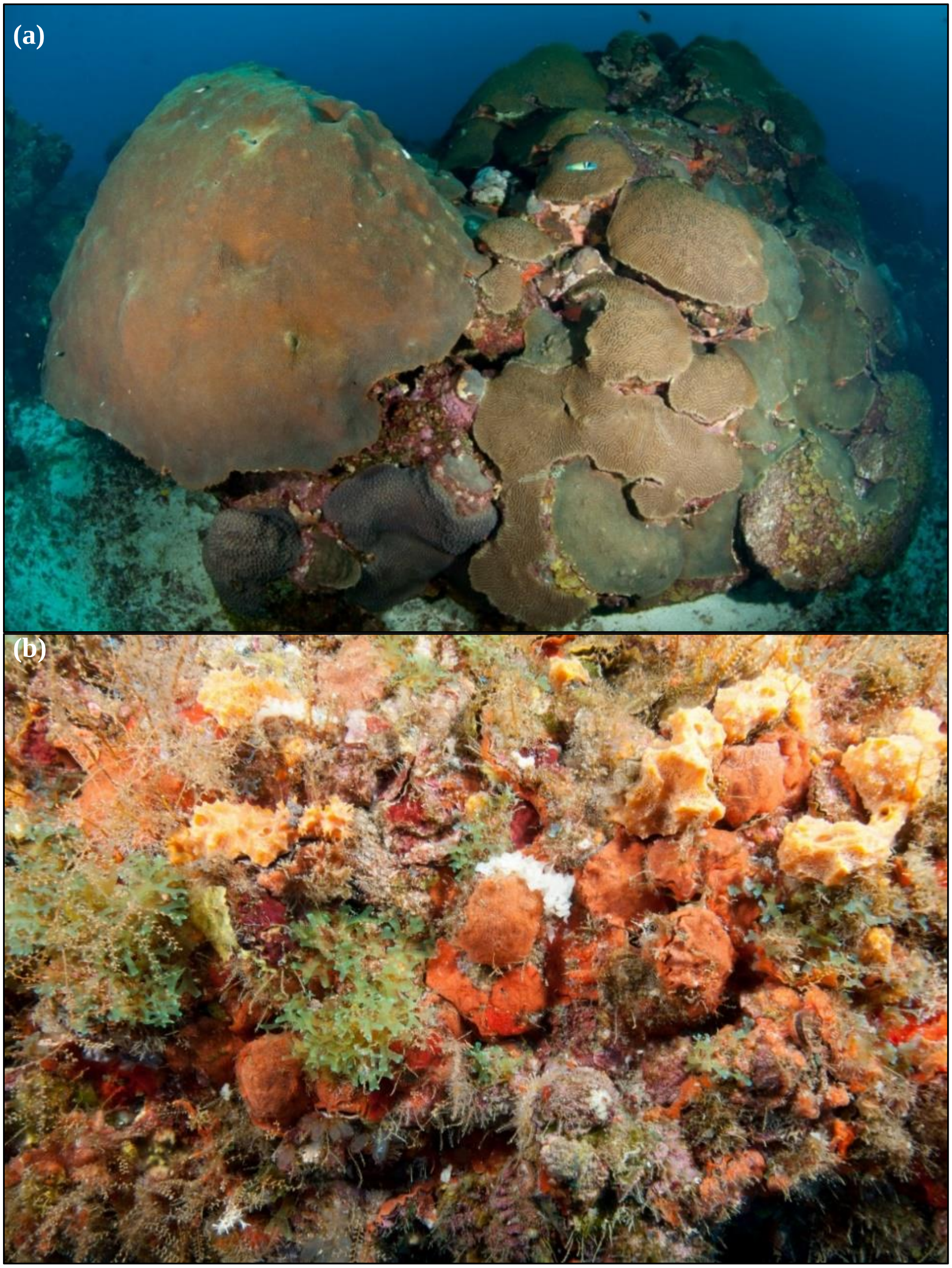


Figure 3.25. Typical benthic community at (a) EFGB, dominated by boulder star and brain corals, and at (b) HI-A-389-A, dominated by sponges, macroalgae, bivalves, and hydroids. HI-A-389-A is located 1.6 km southeast from the EFGB coral reef cap. Photos: G.P. Schmahl/NOAA

Chapter 4: Fish Surveys

Horse-eye jack swim through HI-A-389-A while a NOAA diver conducts a post-removal roving fish survey.
Photo: Kelly O’Connell/CPC

Fish Surveys

Pre-Removal Fish Abundance Results

Table 4.1 summarizes completed surveys conducted on scuba and ROV. Poor visibility and strong currents did not allow for the completion of ROV surveys on H8. Each scuba survey was significantly more diverse than each ROV survey, and scuba and ROV surveys were therefore analyzed separately ($p<0.001$, $F=28.176$).

Table 4.1. Completed pre-removal fish surveys conducted using scuba and ROV at HI-A-389-A.

Horizontal Level and Depth (m)	SCUBA Roving	SCUBA Belt	ROV Roving
H1 (9 m)	7	4	10
H2 (22 m)	13	5	8
H3 (37 m)	13	2	8
H4 (52 m)	-	-	7
H5 (72 m)	-	-	6
H6 (91 m)	-	-	7
H7 (108 m)	-	-	5
H8 (125 m)	-	-	-
Seafloor (125m)	-	-	4

Prior to removal, a total of 85 species (or groups) and 30 families were observed throughout the platform on ROV surveys. Table 4.2 provides a comprehensive species list from ROV pre-removal surveys along with DI and %SF values.

Table 4.2. Pre-removal ROV fish species list, along with trophic guild, density index (DI), sighting frequency (%SF), and minimum and maximum depth (m) sighted. H= herbivore, I = invertivore, PL = planktivore, and P = piscivore.

Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Bicolor damselfish	*Stegastes partitus*	Pomacentridae	H	3.03	60.00	9	108
Cocoa damselfish	*Stegastes variabilis*	Pomacentridae	H	2.96	45.45	9	108
Stegastes spp.	*Stegastes* spp.	Pomacentridae	H	3.50	32.73	9	108
Chub (Bermuda/yellow)	*Kyphosus saltatrix/incisor*	Kyphosidae	H	2.76	30.91	9	108
Blue tang	*Acanthurus coeruleus*	Acanthuridae	H	2.00	29.09	9	108
Redlip blenny	*Ophioblennius macclurei*	Blenniidae	H	2.00	14.55	9	108
Cherubfish	*Centropyge argi*	Pomacanthidae	H	2.00	12.73	37	72
Yellowtail damselfish	*Microspathodon chrysurus*	Pomacentridae	H	1.56	16.36	9	108
Dusky damselfish	*Stegastes adustus*	Pomacentridae	H	1.44	16.36	9	91
Redband parrotfish	*Sparisoma aurofrenatum*	Labridae	H	1.50	14.55	9	91
Greenblotch parrotfish	*Sparisoma atomarium*	Labridae	H	1.50	3.64	37	52
Longfin damselfish	*Stegastes diencaeus*	Pomacentridae	H	2.00	1.82	22	22
Flameback angelfish	*Centropyge aurantonotus*	Pomacentridae	H	1.00	1.82	52	52
Queen parrotfish	*Scarus vetula*	Labridae	H	1.00	1.82	37	37
Bluehead	*Thalassoma bifasciatum*	Labridae	I	3.81	58.18	9	108
Spanish hogfish	*Bodianus rufus*	Labridae	I	2.83	54.55	9	108
Brown chromis	*Chromis multilineata*	Pomacentridae	I	3.23	40.00	9	91
Rock hind	*Epinephelus adscensionis*	Epinephelidae	I	2.03	63.64	9	108
Yellowtail reeffish	*Chromis enchrysura*	Pomacentridae	I	2.81	38.18	22	91
Sharpnose puffer	*Canthigaster rostrata*	Tetraodontidae	I	1.67	60.00	9	108
Beaugregory	*Stegastes leucostictus*	Pomacentridae	I	2.60	36.36	9	108
Blue angelfish	*Holacanthus bermudensis*	Pomacanthidae	I	1.88	47.27	9	108
Seaweed blenny	*Parablennius marmoreus*	Blenniidae	I	1.76	45.45	9	108
Reef butterflyfish	*Chaetodon sedentarius*	Chaetodontidae	I	1.80	27.27	22	91

Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Spotfin hogfish	*Bodianus pulchellus*	Labridae	I	1.86	25.45	22	91
Sergeant major	*Abudefduf saxatilis*	Pomacentridae	I	3.14	12.73	9	108
Threespot damselfish	*Stegastes planifrons*	Pomacentridae	I	1.38	29.09	9	91
Rock beauty	*Holacanthus tricolor*	Pomacanthidae	I	1.58	21.82	9	52
Queen angelfish	*Holacanthus ciliaris*	Pomacanthidae	I	1.42	21.82	9	52
Redspotted hawkfish	*Amblycirrhitus pinos*	Cirrhitidae	I	1.33	21.82	9	91
Townsend angelfish	*Holacanthus townsendi*	Pomacanthidae	I	1.88	14.55	22	37
Orangespotted filefish	*Cantherhines pullus*	Monacanthidae	I	1.40	18.18	9	108
French angelfish	*Pomacanthus paru*	Pomacanthidae	I	1.83	10.91	22	52
Squirrelfish	*Holocentrus adscensionis*	Holocentridae	I	1.43	12.73	22	91
Saddle bass	*Serranus notospilus*	Serranidae	I	1.40	9.09	108	125
Angelfish spp.	*Pomacanthidae*	Pomacanthidae	I	2.00	5.45	9	37
Whitespotted filefish	*Cantherhines macrocerus*	Monacanthidae	I	1.50	7.27	22	52
Gray triggerfish	*Balistes capriscus*	Balistidae	I	1.25	7.27	9	91
Red hogfish	*Decodon puellari*	Labridae	I	1.25	7.27	125	125
Scrawled filefish	*Aluterus scriptus*	Monacanthidae	I	1.33	5.45	9	37
Gray snapper	*Lutjanus griseus*	Lutjanidae	I	1.50	3.64	22	37
Hunchback scorpionfish	*Scorpaena dispar*	Scorpaenidae	I	1.50	3.64	108	125
Slantbrow batfish	*Ogcocephalus declivirostris*	Ogcocephalidae	I	1.00	5.45	108	125
Spinycheek soldierfish	*Corniger spinosus*	Holocentridae	I	1.50	3.64	91	108
Bandtail puffer	*Sphoeroides spengleri*	Tetraodontidae	I	1.00	3.64	37	125
Bandtail searobin	*Prionotus ophryas*	Triglidae	I	1.00	3.64	125	125
Cubbyu	*Pareques umbrosus*	Sciaenidae	I	1.00	3.64	91	108
Dwarf goatfish	*Upeneus parvus*	Mullidae	I	2.00	1.82	108	108
Goldface toby	*Canthigaster jamestyleri*	Tetraodontidae	I	2.00	1.82	52	52
Neon goby	*Elacatinus oceanops*	Gobiidae	I	1.00	3.64	22	52

Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Yellowedge grouper	*Hyporthodus flavolimbatus*	Epinephelidae	I	1.00	3.64	91	108
Tilefish spp.	*Caulolatilus* spp.	Malacanthidae	I	1.00	1.82	125	125
Balloonfish	*Diodon holocanthus*	Diodontidae	I	1.00	1.82	9	9
Goldentail moray	*Gymnothorax miliaris*	Muraenidae	I	1.00	1.82	9	9
Longsnout butterflyfish	*Prognathodes aculeatus*	Chaetodontidae	I	1.00	1.82	52	52
Mexican flounder	*Cyclopsetta chittendeni*	Bothidae	I	1.00	1.82	125	125
Red hind	*Epinephelus guttatus*	Epinephelidae	I	1.00	1.82	22	22
Horse-eye jack	*Caranx latus*	Carangidae	P	2.67	38.18	9	91
Bar jack	*Caranx ruber*	Carangidae	P	1.81	47.27	9	108
Scamp	*Mycteroperca phenax*	Epinephelidae	P	1.70	36.36	37	108
Greater amberjack	*Seriola dumerili*	Carangidae	P	1.88	30.91	22	125
Red snapper	*Lutjanus campechanus*	Lutjanidae	P	2.25	21.82	52	125
Almaco jack	*Seriola rivoliana*	Carangidae	P	1.86	25.45	37	108
Black jack	*Caranx lugubris*	Carangidae	P	2.18	20.00	22	52
Blue runner	*Caranx crysos*	Carangidae	P	2.67	16.36	9	91
Graysby	*Cephalopholis cruentata*	Epinephelidae	P	1.50	18.18	9	91
Lionfish	*Pterois volitans/miles*	Scorpaenidae	P	1.56	16.36	37	91
Great barracuda	*Sphyraena barracuda*	Sphyraenidae	P	1.20	18.18	9	91
Crevalle jack	*Caranx hippos*	Carangidae	P	1.50	10.91	9	108
Yellowmouth grouper	*Mycteroperca interstitialis*	Epinephelidae	P	1.50	10.91	9	52
Grouper spp.	*Epinephelidae* spp.	Epinephelidae	P	2.50	3.64	91	108
Shark spp.	*Carcharhinus* spp.	Carcharhinidae	P	1.00	5.45	37	52
Queen snapper	*Etelis oculatus*	Lutjanidae	P	1.00	1.82	125	125
Rainbow runner	*Elagatis bipinnulata*	Carangidae	P	1.00	1.82	9	9
Snowy grouper	*Hyporthodus niveatus*	Epinephelinae	P	1.00	1.82	91	91
Vermilion snapper	*Rhomboplites aurorubens*	Lutjanidae	P	1.00	1.82	91	91

Common Names	**Latin Name**	**Family**	**Primary Trophic Guild**	**DI**	**%SF**	**Min Depth (m)**	**Max Depth (m)**
Wenchman	*Pristipomoides aquilonaris*	Lutjanidae	P	1.00	1.82	108	108
Atlantic creolefish	*Paranthias furcifer*	Epinephelidae	PL	3.39	56.36	9	108
Threadnose bass	*Choranthias tenuis*	Serranidae	PL	3.33	32.73	52	108
Sunshinefish	*Chromis insolata*	Pomacentridae	PL	2.19	38.18	9	72
Purple reeffish	*Chromis scotti*	Pomacentridae	PL	2.00	14.55	9	52
Blue chromis	*Chromis cyanea*	Pomacentridae	PL	2.67	10.91	9	52
Roughtongue bass	*Pronotogrammus martinicensis*	Serranidae	PL	1.86	12.73	52	91
Creole wrasse	*Clepticus parrae*	Labridae	PL	2.20	9.09	9	37
Twospot cardinalfish	*Apogon pseudomaculatus*	Apogonidae	PL	1.00	1.82	52	52
Unknown	Unknown	Unknown		1.00	3.64	125	125

Density index was summed over trophic guilds. At every level, invertivores were the most prevalent species, accounting for 42-52% of the total DI. Herbivores were most prevalent on H7 and H1, comprising 30% and 27% of the total DI, respectively (Figure 4.1). Herbivore DI decreased from H1 through H5, but increased again on H6 and H7 due to the high density index of bicolor damselfish (*Stegastes partitus*) and Bermuda/yellow chub (*Kyphosus saltatrix/incisor*).

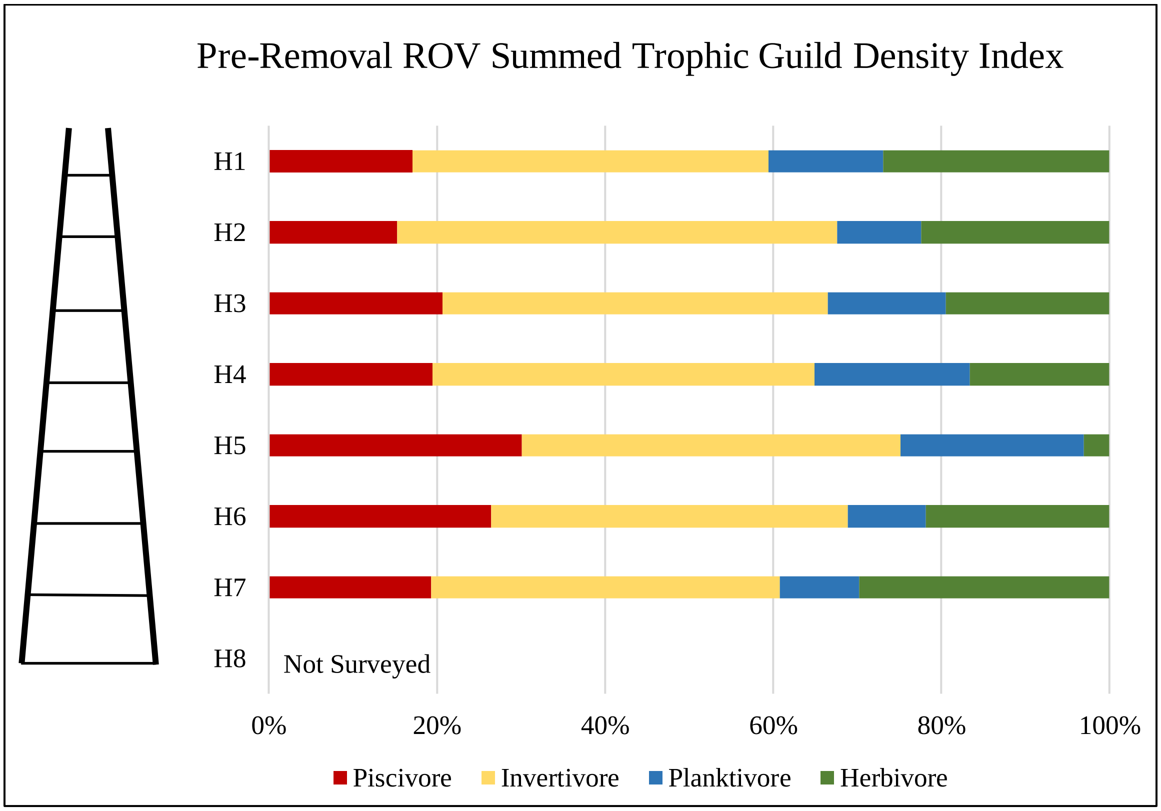


Figure 4.1. Pre-removal ROV summed trophic guild density index on horizontal levels (H1-H8). Outline of HI-A-389-A to the left of the bar graph helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m).

Based on DI*%SF data, five clusters were found between platform levels. Level H1 was unique, levels H2 and H3 were similar, levels H4 and H5 were similar, levels H6 and H7 were similar, and the seafloor was unique. Grouped by these clusters, the 20 most important species in the whole dataset are presented in Figure 4.2.

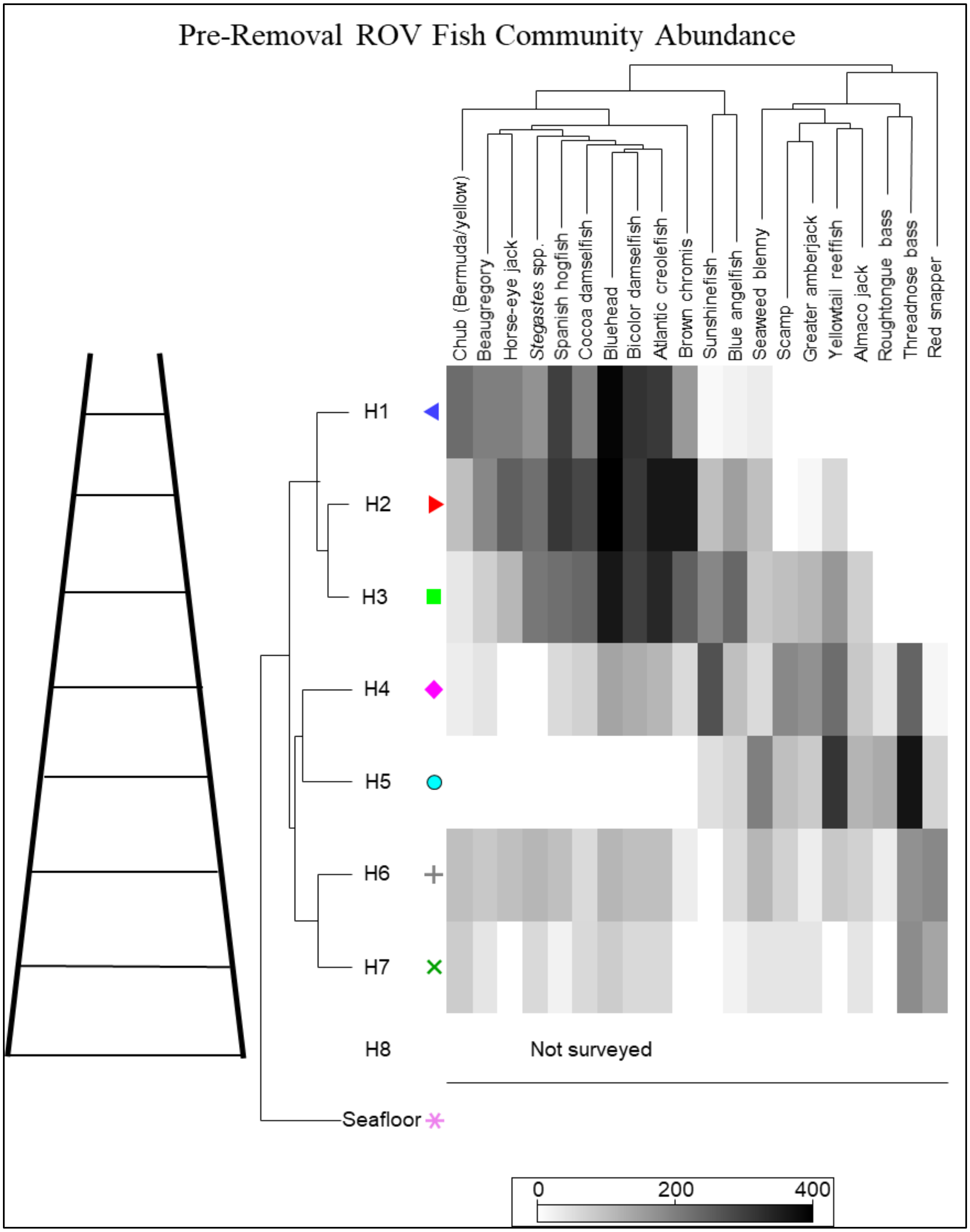


Figure 4.2. Pre-removal ROV fish community abundance and sighting frequency shade plot based on the 20 most important species for the entire dataset. Shade represents DI*%SF value. Outline of HI-A-389-A to the left of the shade plot helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m).

Fish communities observed during scuba roving diver surveys were significantly more diverse on a survey by survey basis than those observed during ROV surveys. Scuba surveys were only conducted on the upper three levels of the platform (H1-H3). A total of 58 species (or groups) and 20 families were found in these surveys, nine of which were unique to scuba surveys (Table 4.3).

Table 4.3. Pre-removal scuba diver survey fish species list with unique species in bold, along with trophic guild, density index (DI), sighting frequency (%SF), and minimum and maximum depth (m) sighted. H= herbivore, I = invertivore, PL = planktivore, and P = piscivore.

Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Cocoa damselfish	*Stegastes variabilis*	Pomacentridae	H	3.72	96.97	9	37
Chub (Bermuda/yellow)	*Kyphosus saltatrix/incisor*	Kyphosidae	H	3.04	72.73	9	37
Bicolor damselfish	*Stegastes partitus*	Pomacentridae	H	2.92	75.76	9	37
Dusky damselfish	*Stegastes adustus*	Pomacentridae	H	2.18	51.52	9	37
Blue tang	*Acanthurus coeruleus*	Acanthuridae	H	1.69	39.39	9	37
Yellowtail damselfish	*Microspathodon chrysurus*	Pomacentridae	H	1.75	24.24	9	22
Redlip blenny	*Ophioblennius macclurei*	Blenniidae	H	1.27	33.33	9	22
Greenblotch parrotfish	*Sparisoma atomarium*	Labridae	H	1.5	18.18	22	37
Longfin damselfish	*Stegastes diencaeus*	Pomacentridae	H	1.33	9.09	9	22
Redband parrotfish	*Sparisoma aurofrenatum*	Labridae	H	1	9.09	22	37
Striped parrotfish	***Scarus iseri***	**Labridae**	**H**	**1**	**3.03**	**37**	**37**
Bluehead	*Thalassoma bifasciatum*	Labridae	I	3.44	96.97	9	37
Spanish hogfish	*Bodianus rufus*	Labridae	I	3	87.88	9	37
Brown chromis	*Chromis multilineata*	Pomacentridae	I	3.55	60.61	9	37
Threespot damselfish	*Stegastes planifrons*	Pomacentridae	I	2.71	51.52	9	37
Rock hind	*Epinephelus adscensionis*	Epinephelidae	I	1.63	72.73	9	37
Queen angelfish	*Holacanthus ciliaris*	Pomacanthidae	I	1.88	51.52	9	37
Blue angelfish	*Holacanthus bermudensis*	Pomacanthidae	I	1.93	42.42	9	37
Sergeant major	*Abudefduf saxatilis*	Pomacentridae	I	2.17	36.36	9	9
Seaweed blenny	*Parablennius marmoreus*	Blenniidae	I	2.56	27.27	9	9

Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Sharpnose puffer	*Canthigaster rostrata*	Tetraodontidae	I	1.57	42.42	9	37
Rock beauty	*Holacanthus tricolor*	Pomacanthidae	I	1.4	30.3	9	37
Beaugregory	*Stegastes leucostictus*	Pomacentridae	I	3.67	9.09	9	22
Orangespotted filefish	*Cantherhines pullus*	Monacanthidae	I	1.1	30.3	9	22
Whitespotted filefish	*Cantherhines macrocerus*	Monacanthidae	I	1.33	18.18	9	37
Spotfin hogfish	*Bodianus pulchellus*	Labridae	I	1.75	12.12	22	37
Squirrelfish	*Holocentrus adscensionis*	Holocentridae	I	1.2	15.15	22	37
French angelfish	*Pomacanthus paru*	Pomacanthidae	I	1.33	9.09	37	37
Redspotted hawkfish	*Amblycirrhitus pinos*	Cirrhitidae	I	1	9.09	22	22
Ocean triggerfish	***Canthidermis sufflamen***	**Balistidae**	**I**	**1**	**9.09**	**9**	**22**
Gray triggerfish	*Balistes capriscus*	Balistidae	I	1	6.06	22	22
Scrawled filefish	*Aluterus scriptus*	Monacanthidae	I	1	6.06	9	9
Townsend angelfish	*Holacanthus townsendi*	Pomacanthidae	I	2	3.03	37	37
Goldentail moray	*Gymnothorax miliaris*	Muraenidae	I	1	3.03	9	9
Permit	***Trachinotus falcatus***	**Carangidae**	**I**	**1**	**3.03**	**37**	**37**
Horse-eye jack	*Caranx latus*	Carangidae	P	2.23	78.79	9	37
Great barracuda	*Sphyraena barracuda*	Sphyraenidae	P	2.2	60.61	9	22
Bar jack	*Caranx ruber*	Carangidae	P	2.22	54.55	9	37
Black jack	*Caranx lugubris*	Carangidae	P	1.73	45.45	22	37
Crevalle jack	*Caranx hippos*	Carangidae	P	2.2	30.3	9	37
Greater amberjack	*Seriola dumerili*	Carangidae	P	2.2	30.3	22	37
Silky shark	***Carcharhinus falciformis***	**Carcharhinidae**	**P**	**1.58**	**36.36**	**9**	**37**
Blue runner	*Caranx crysos*	Carangidae	P	2.6	15.15	22	37
Graysby	*Cephalopholis cruentata*	Epinephelidae	P	1.57	21.21	9	37
Lionfish	*Pterois volitans/miles*	Scorpaenidae	P	1.33	18.18	22	37
Little tunny	***Euthynnus alletteratus***	**Scombridae**	**P**	**4**	**6.06**	**37**	**52**
Rainbow runner	*Elagatis bipinnulata*	Carangidae	P	2.5	6.06	22	22

Common Names	**Latin Name**	**Family**	**Primary Trophic Guild**	**DI**	**%SF**	**Min Depth (m)**	**Max Depth (m)**
Red snapper	*Lutjanus campechanus*	Lutjanidae	P	1	9.09	37	37
Shark spp.	*Carcharhinus* spp.	Carcharhinidae	P	1	9.09	9	37
Dusky shark	***Carcharhinus obscurus***	**Carcharhinidae**	**P**	**1.5**	**6.06**	**9**	**37**
Caribbean reef shark	***Carcharhinus perezii***	**Carcharhinidae**	**P**	**1**	**6.06**	**9**	**9**
Scamp	*Mycteroperca phenax*	Epinephelidae	P	1	3.03	37	37
Yellowmouth grouper	*Mycteroperca interstitialis*	Epinephelidae	P	1	3.03	37	37
Atlantic trumpetfish	***Aulostomus maculatus***	**Aulostomidae**	**P**	**1**	**3.03**	**22**	**22**
Spotted moray	***Gymnothorax moringa***	**Muraenidae**	**P**	**1**	**3.03**	**22**	**22**
Atlantic creolefish	*Paranthias furcifer*	Epinephelidae	PL	3.47	90.91	9	37
Creole wrasse	*Clepticus parrae*	Labridae	PL	2.67	18.18	9	37
Blue chromis	*Chromis cyanea*	Pomacentridae	PL	3	3.03	37	37

Density index was summed over trophic guilds. At every level, invertivores were the most prevalent guild, accounting for 37-45% of the total DI. The highest incidence of piscivores was on H2, comprising 32% of the total DI, the highest incidence of planktivores was on H3, comprising 13% of the total DI, and the highest incidence of herbivores was on H1, comprising 24% of the total DI (Figure 4.3).

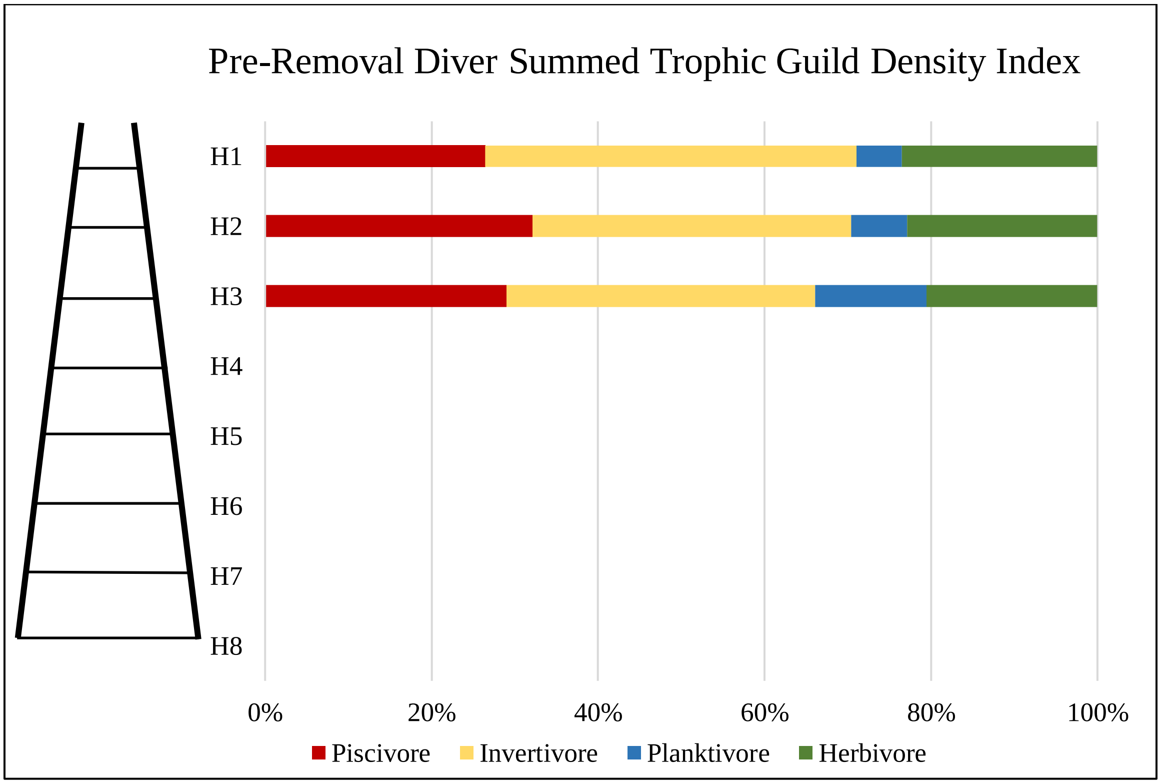


Figure 4.3. Summed trophic guild density index on horizontal levels (H1-H3) from pre-removal diver surveys. Outline of HI-A-389-A to the left of the bar graph helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m).

Based on DI*%SF data, two clusters were found between platform levels. Level H1 was unique and levels H2 and H3 were similar. Grouped by these clusters, the 20 most important species are presented in Figure 4.4.

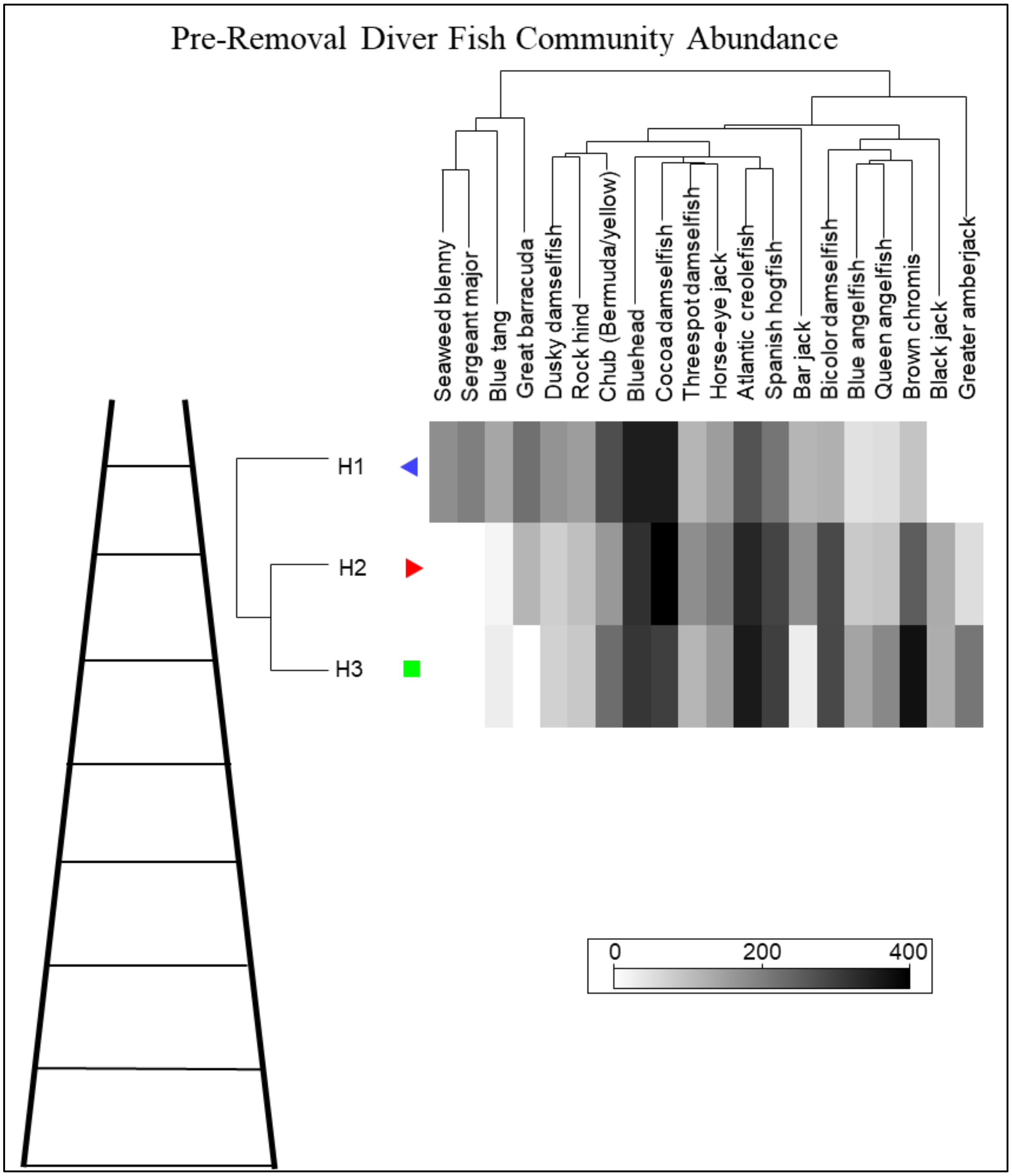


Figure 4.4. Pre-removal diver fish community abundance and sighting frequency shade plot based on the 20 most important species for the entire dataset. Shade represents DI*%SF value. Outline of HI-A-389-A to the left of the shade plot helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m).

Belt transects were conducted by divers on the upper three levels of the platform (H1-H3). Density and biomass were calculated for a total of 36 species and groups and 15 families. Four species were only recorded in belt transects and not observed in other surveys. All species and their density and biomass are presented in Table 4.4.

Table 4.4. Pre-removal belt transect fish species list along with trophic guild, density, biomass, and minimum and maximum depth (m) sighted. H= herbivore, I = invertivore, PL = planktivore, and P = piscivore. Values are presented ± SE. Species in bold were only observed in belt transects.

Common Names	Latin Name	Family	Primary Trophic Guild	Density (/100m2)	Biomass (g/100m2)	Min Depth (m)	Max Depth (m)
Cocoa damselfish	*Stegastes variabilis*	Pomacentridae	H	474.55 ± 36.18	715.31 ± 56.72	9	37
Bicolor damselfish	*Stegastes partitus*	Pomacentridae	H	50.91 ± 3.92	104.81 ± 12.63	9	37
Dusky damselfish	*Stegastes adustus*	Pomacentridae	H	18.18 ± 2.09	51.14 ± 9.21	9	37
Chub (Bermuda/yellow)	*Kyphosus saltatrix/incisor*	Kyphosidae	H	11.64 ± 2.72	3153.12 ± 688.73	9	37
Longfin damselfish	*Stegastes diencaeus*	Pomacentridae	H	4.36 ± 0.64	62.53 ± 8.06	9	22
Blue tang	*Acanthurus coeruleus*	Acanthuridae	H	2.55 ± 0.34	557.14 ± 80.14	9	37
Redlip blenny	*Ophioblennius macclurei*	Blenniidae	H	2.18 ± 0.55	3.26 ± 0.67	9	9
Redband parrotfish	*Sparisoma aurofrenatum*	Labridae	H	1.45 ± 0.34	0.47 ± 0.11	22	37
Yellowtail damselfish	*Microspathodon chrysurus*	Pomacentridae	H	1.45 ± 0.25	4.76 ± 1.29	9	9
Stoplight parrotfish	***Sparisoma viride***	**Labridae**	**H**	**0.36 ± 0.11**	**0.19 ± 0.06**	22	22
Bluehead	*Thalassoma bifasciatum*	Labridae	I	169.45 ± 17.42	201.80 ± 22.14	9	37
Brown chromis	*Chromis multilineata*	Pomacentridae	I	77.09 ± 16.75	17.25 ± 3.63	9	37
Spanish hogfish	*Bodianus rufus*	Labridae	I	34.91 ± 3.80	1883.33 ± 212.78	9	37
Sergeant major	*Abudefduf saxatilis*	Pomacentridae	I	31.64 ± 9.18	112.90 ± 24.15	9	9
Seaweed blenny	*Parablennius marmoreus*	Blenniidae	I	10.18 ± 1.34	20.42 ± 3.82	9	22
Threespot damselfish	*Stegastes planifrons*	Pomacentridae	I	6.18 ± 0.68	24.06 ± 3.08	9	37
Rock hind	*Epinephelus adscensionis*	Epinephelidae	I	4.36 ± 0.41	1465.24 ± 263.71	9	37
Sharpnose puffer	*Canthigaster rostrata*	Tetraodontidae	I	3.27 ± 0.65	3.39 ± 0.77	9	37
Queen angelfish	*Holacanthus ciliaris*	Pomacanthidae	I	2.55 ± 0.37	1001.93 ± 173.58	9	22
Blue angelfish	*Holacanthus bermudensis*	Pomacanthidae	I	1.09 ± 0.24	732.94 ± 153.19	22	37
Orangespotted filefish	*Cantherhines pullus*	Monacanthidae	I	1.09 ± 0.24	46.79 ± 11.53	22	22
Tessellated blenny	***Hypsoblennius invemar***	**Labrisomidae**	**I**	**1.09 ± 0.24**	**2.32 ± 0.68**	9	9
Redspotted hawkfish	*Amblycirrhitus pinos*	Cirrhitidae	I	0.73 ± 0.22	1.89 ± 0.57	9	9
Rock beauty	*Holacanthus tricolor*	Pomacanthidae	I	0.73 ± 0.22	202.39 ± 61.02	22	22

Common Names	Latin Name	Family	Primary Trophic Guild	Density (/100m2)	Biomass (g/100m2)	Min Depth (m)	Max Depth (m)
Clown wrasse	***Halichoeres maculipinna***	**Labridae**	**I**	**0.36 ± 0.11**	**1.74 ± 0.52**	9	9
Spotfin hogfish	*Bodianus pulchellus*	Labridae	I	0.36 ± 0.11	0.09 ± 0.03	37	37
Graysby	*Cephalopholis cruentata*	Epinephelidae	P	2.18 ± 0.25	389.44 ± 50.85	9	37
Black jack	*Caranx lugubris*	Carangidae	P	1.45 ± 0.34	6345.70 ± 1466.52	22	22
Bar jack	*Caranx ruber*	Carangidae	P	0.36 ± 0.11	33.75 ± 10.18	9	9
Great barracuda	*Sphyraena barracuda*	Sphyraenidae	P	0.36 ± 0.11	494.84 ± 149.20	9	9
Red lionfish	*Pterois volitans*	Scorpaenidae	P	0.36 ± 0.11	49.60 ± 14.95	37	37
Scamp	*Mycteroperca phenax*	Epinephelidae	P	0.36 ± 0.11	1059.66 ± 319.50	22	22
Atlantic creolefish	*Paranthias furcifer*	Epinephelidae	PL	25.45 ± 3.46	2981.75 ± 439.77	9	37
Creole wrasse	*Clepticus parrae*	Labridae	PL	12.73 ± 3.84	2.79 ± 0.84	37	37
Sunshinefish	*Chromis insolata*	Pomacentridae	PL	3.27 ± 0.99	0.75 ± 0.23	37	37
Blenny spp.	***Emblemariopsis* spp.**	**Chaenopsidae**	**PL**	**0.36 ± 0.11**	**0.04 ± 0.01**	9	9

Density and biomass were summed over trophic guilds. On levels H1 and H3, invertivores were the most abundant guild, accounting for 52-58% of the total density. Piscivores were least abundant on every level. Planktivores were most abundant on H3, comprising 13% of the total density, and herbivores were most abundant on H2, comprising 72% of the total density. On levels H1 and H3, invertivores comprised the greatest biomass, accounting for 48-56% of total biomass. Piscivores had the greatest biomass on H2, comprising 44% of total biomass, planktivores had the second greatest biomass on H2, comprising 16% of total biomass, and herbivores had the greatest biomass on H3, comprising 31% of total biomass (Figure 4.5).

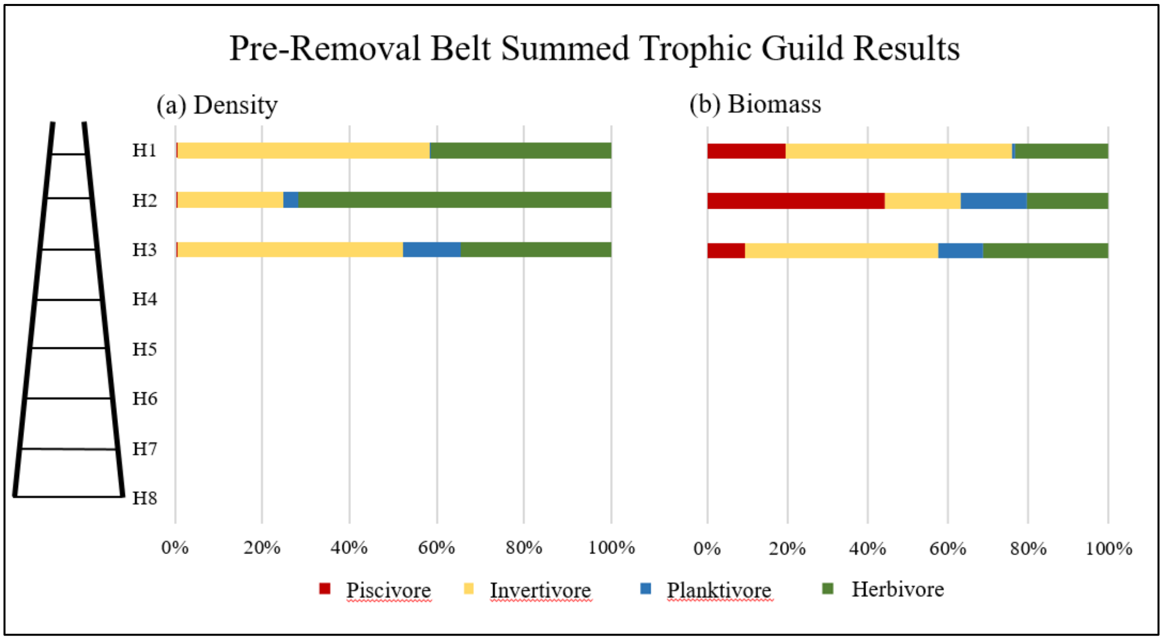


Figure 4.5. Summed trophic guild results (H1-H3) from pre-removal belt transect surveys. (a) Density and (b) biomass. Outline of HI-A-389-A to the left of the bar graph helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m).

Density and biomass *w* values were close to zero and similar between levels, indicating that accumulated biomass was evenly distributed between large and small species (Table 4.5).

Table 4.5. Mean *w* values. Values are presented ± SE for each level.

Level	***w***
H1	0.06 ± 0.04
H2	-0.01 ± 0.04
H3	0.01 ± 0.04

Size frequency of herbivores was similar between levels and indicated this guild was primarily comprised of small individuals. Invertivores appeared to decrease in size with increased depth, with more <5 cm individuals on level H3 than H1, but was generally predominanted by small individuals. Similarly, planktivores were primarily small individuals, with the exception of H2 where larger individuals were observed. Piscivore size frequency was variable between levels, with no apparent pattern, but was generally comprised of larger individuals than all other trophic guilds (Figure 4.6).

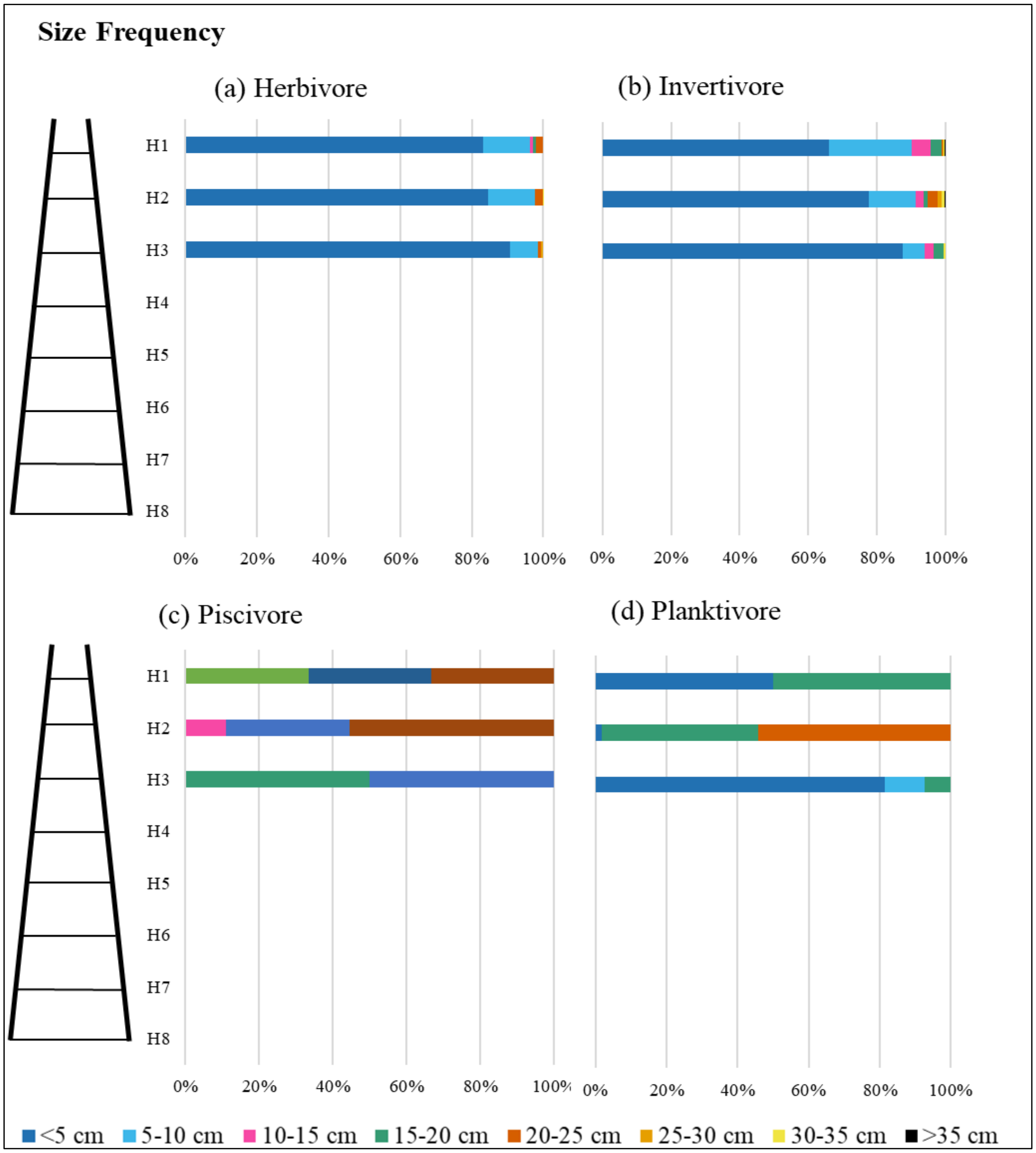


Figure 4.6. Size frequency trophic guild results (H1-H3) from pre-removal belt transects, (a) Herbivores, (b) invertivores, (c) piscivores, and (d) planktivores. Outline of HI-A-389-A to the left of the bar graph visually represents the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m).

Post-Removal Fish Abundance Results

Table 4.6 summarizes completed surveys conducted using scuba and ROV. Poor visibility and strong currents did not allow for the completion of ROV surveys on H8. As found in pre-removal surveys, fish communities observed during scuba surveys were significantly more diverse than those observed during ROV surveys and were analyzed separately. Scuba surveys were completed mid-water at 9 m post-removal to provide a comparative dataset for the pre-removal H1 depth.

Table 4.6. Completed post-removal fish surveys conducted with scuba and ROV on depth-delineated horizontal beams from H1 to H7. No surveys were conducted on H8 or the seafloor.

Horizontal Level and Depth (m)	SCUBA Roving	SCUBA Belt	ROV Roving
H1 - Removed (9 m, mid-water)	4	-	-
H2 (22 m)	8	2	3
H3 (37 m)	6	2	3
H4 (52 m)	-	-	3
H5 (72 m)	-	-	3
H6 (91 m)	-	-	3
H7 (108 m)	-	-	3
H8 (125 m)	-	-	-
Seafloor (125m)	-	-	-

In post-removal ROV surveys, a total of 60 species, 23 families, and one ‘unknown fish’ group were observed throughout the platform on ROV surveys. Table 4.7 provides a comprehensive post-removal species list along with DI and %SF values.

Table 4.7. Post-removal ROV fish species list, along with trophic guild, density index (DI), sighting frequency (%SF), and minimum and maximum depth (m) sighted. H= herbivore, I = invertivore, PL = planktivore, and P = piscivore.

Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Cocoa damselfish	*Stegastes variabilis*	Pomacentridae	H	2.60	55.56	22	72
Bicolor damselfish	*Stegastes partitus*	Pomacentridae	H	2.33	50.00	22	72
Chub (Bermuda/yellow)	*Kyphosus saltatrix/incisor*	Kyphosidae	H	2.83	33.33	22	72
Cherubfish	*Centropyge argi*	Pomacanthidae	H	1.75	44.44	37	91
Blue tang	*Acanthurus coeruleus*	Acanthuridae	H	1.40	27.78	22	72
Parrotfish spp.	*Scarus spp./Sparisoma* spp.	Labridae	H	1.00	16.67	22	72
Dusky damselfish	*Stegastes adustus*	Pomacentridae	H	1.00	5.56	22	22
Yellowtail damselfish	*Microspathodon chrysurus*	Pomacentridae	H	1.00	5.56	72	72
Spotfin hogfish	*Bodianus pulchellus*	Labridae	I	2.75	66.67	22	72
Spanish hogfish	*Bodianus rufus*	Labridae	I	2.82	61.11	22	72
Blue angelfish	*Holacanthus bermudensis*	Pomacanthidae	I	1.87	83.33	22	91
Bluehead	*Thalassoma bifasciatum*	Labridae	I	2.75	44.44	22	52
Rock beauty	*Holacanthus tricolor*	Pomacanthidae	I	1.73	61.11	22	72
Sharpnose puffer	*Canthigaster rostrata*	Tetraodontidae	I	1.70	55.56	37	91
Reef butterflyfish	*Chaetodon sedentarius*	Chaetodontidae	I	2.29	38.89	37	72
Brown chromis	*Chromis multilineata*	Pomacentridae	I	2.40	27.78	52	72
Rock hind	*Epinephelus adscensionis*	Epinephelidae	I	1.71	38.89	22	52
Yellowtail reeffish	*Chromis enchrysura*	Pomacentridae	I	2.67	16.67	72	72
French angelfish	*Pomacanthus paru*	Pomacanthidae	I	1.50	22.22	37	72
Queen angelfish	*Holacanthus ciliaris*	Pomacanthidae	I	1.50	22.22	22	52
Sergeant major	*Abudefduf saxatilis*	Pomacentridae	I	1.50	22.22	22	37
Threespot damselfish	*Stegastes planifrons*	Pomacentridae	I	1.50	22.22	37	72
Seaweed blenny	*Parablennius marmoreus*	Blenniidae	I	1.00	16.67	37	91

Common Names	**Latin Name**	**Family**	**Primary Trophic Guild**	**DI**	**%SF**	**Min Depth (m)**	**Max Depth (m)**
Cardinalfish spp.	*Apogon* spp.	Apogonidae	I	1.00	16.67	72	91
Redspotted hawkfish	*Amblycirrhitus pinos*	Cirrhitidae	I	1.00	11.11	72	72
Townsend angelfish	*Holacanthus townsendi*	Pomacanthidae	I	2.00	5.56	37	37
Whitespotted filefish	*Cantherhines macrocerus*	Monacanthidae	I	1.00	11.11	22	52
Goldentail moray	*Gymnothorax miliaris*	Muraenidae	I	1.00	5.56	72	72
Smooth trunkfish	*Lactophrys triqueter*	Ostraciidae	I	1.00	5.56	52	52
Butterflyfish spp.	*Chaetodontidae*	Chaetodontidae	I	1.00	5.56	108	108
Hamlet spp.	*Hypoplectrus* spp.	Serranidae	I	1.00	5.56	72	72
Soapfish spp.	*Rypticus* spp.	Serranidae	I	1.00	5.56	52	52
Squirrelfish spp.	*Holocentridae*	Holocentridae	I	1.00	5.56	72	72
Wrasse or parrotfish spp.	*Labridae*	Labridae	I	1.00	5.56	72	72
Graysby	*Cephalopholis cruentata*	Epinephelidae	P	2.00	55.56	22	72
Greater amberjack	*Seriola dumerili*	Carangidae	P	2.13	44.44	52	108
Bar jack	*Caranx ruber*	Carangidae	P	2.40	27.78	22	72
Red snapper	*Lutjanus campechanus*	Lutjanidae	P	1.67	33.33	52	108
Scamp	*Mycteroperca phenax*	Epinephelidae	P	1.33	33.33	52	91
Grouper spp.	*Epinephelidae*	Epinephelidae	P	1.25	22.22	37	108
Black jack	*Caranx lugubris*	Carangidae	P	1.67	16.67	37	52
Red lionfish	*Pterois volitans*	Scorpaenidae	P	1.00	22.22	37	108
Great barracuda	*Sphyraena barracuda*	Sphyraenidae	P	1.33	16.67	22	37
Horse-eye jack	*Caranx latus*	Carangidae	P	1.33	16.67	37	72
Yellowmouth grouper	*Mycteroperca interstitialis*	Epinephelidae	P	1.50	11.11	72	91
Shark spp.	*Carcharhinus* spp.	Carcharhinidae	P	1.00	11.11	37	52
Almaco jack	*Seriola rivoliana*	Carangidae	P	1.00	5.56	91	91
Silky shark	*Carcharhinus falciformis*	Carcharhinidae	P	1.00	5.56	52	52

Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Jack spp.	*Caranx* spp.	Carangidae	P	1.00	5.56	91	91
Atlantic creolefish	*Paranthias furcifer*	Epinephelidae	PL	3.55	61.11	22	72
Roughtongue bass	*Pronotogrammus martinicensis*	Serranidae	PL	3.44	50.00	72	108
Regal demoiselle	*Neopomacentrus cyanomos*	Neopomacentrus	PL	1.83	33.33	22	72
Sunshinefish	*Chromis insolata*	Pomacentridae	PL	1.80	27.78	37	72
Threadnose bass	*Choranthias tenuis*	Serranidae	PL	1.80	27.78	72	91
Blenny spp.	*Emblemariopsis* spp.	Chaenopsidae	PL	1.50	11.11	72	108
Chromis spp.	*Chromis* spp.	Pomacentridae	PL	3.00	5.56	37	37
Damselfish spp.	*Stegastes* spp.	Pomacentridae	PL	3.00	5.56	37	37
Blue chromis	*Chromis cyanea*	Pomacentridae	PL	2.00	5.56	22	22
Purple reeffish	*Chromis scotti*	Pomacentridae	PL	2.00	5.56	72	72
Creole wrasse	*Clepticus parrae*	Labridae	PL	1.00	5.56	52	52
Unknown	Unknown	Unknown	-	1.00	11.11	72	72

Density index was summed over trophic guilds. Invertivores were the most prevalent guild on levels H2-H5, accounting for 38-49% of the total DI, and piscivores were the most prevalent guild on levels H6-H7, accounting for 46-47% of the total DI. Planktivores were most prevalent on H7, comprising 42% of the DI, and herbivores were most prevalent on H2, comprising 31% of the total DI (Figure 4.7).

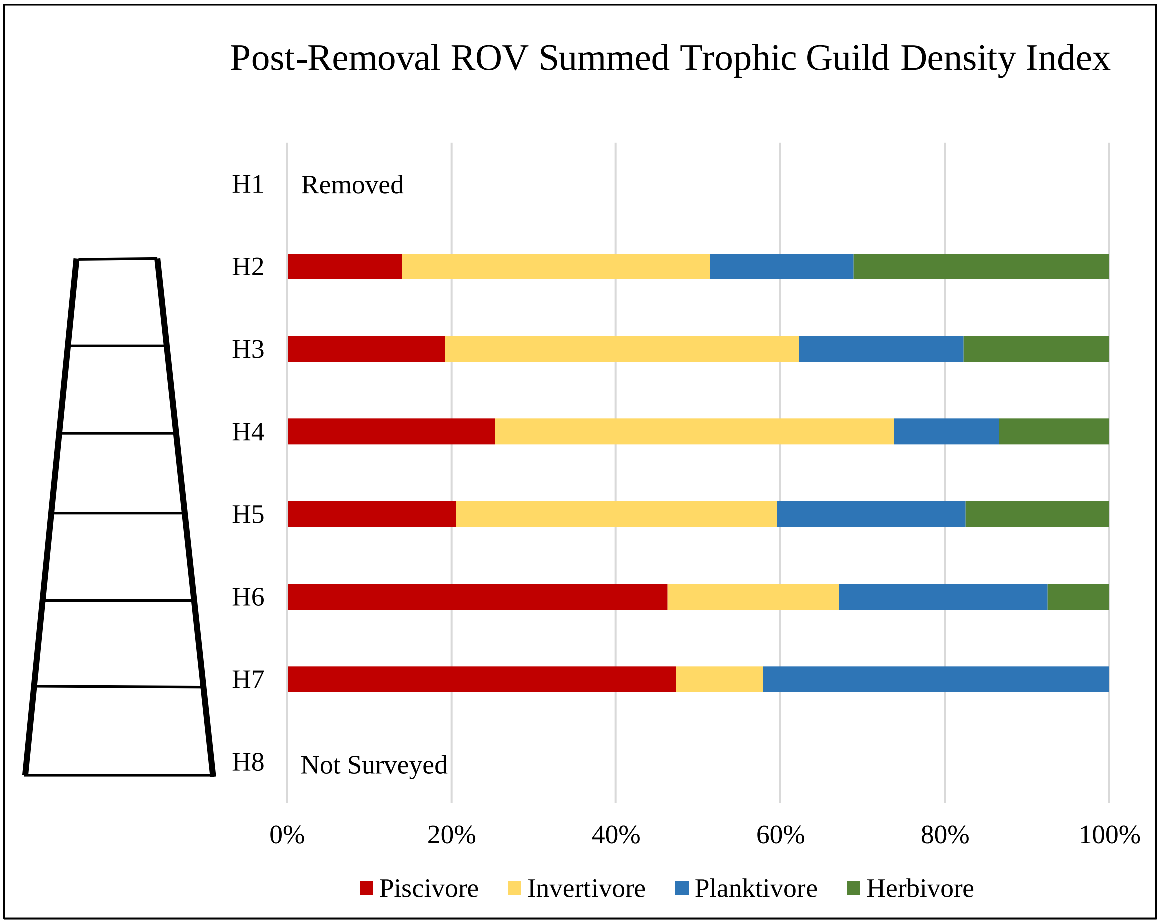


Figure 4.7. Summed trophic guild density index on horizontal levels (H2-H7) from post-removal ROV surveys. Outline of HI-A-389-A to the left of the bar graph helps to visually represent the depth delineations of the horizontal beams below the surface: H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m). No surveys were conducted on H8.

Based on DI*%SF data, four clusters were found among platform levels. Levels H2 and H3 were similar, level H4 was unique, levels H5 and H6 were similar, and level H7 was unique. No seafloor surveys were completed. Grouped by these clusters, the 20 most important species are presented in Figure 4.8.

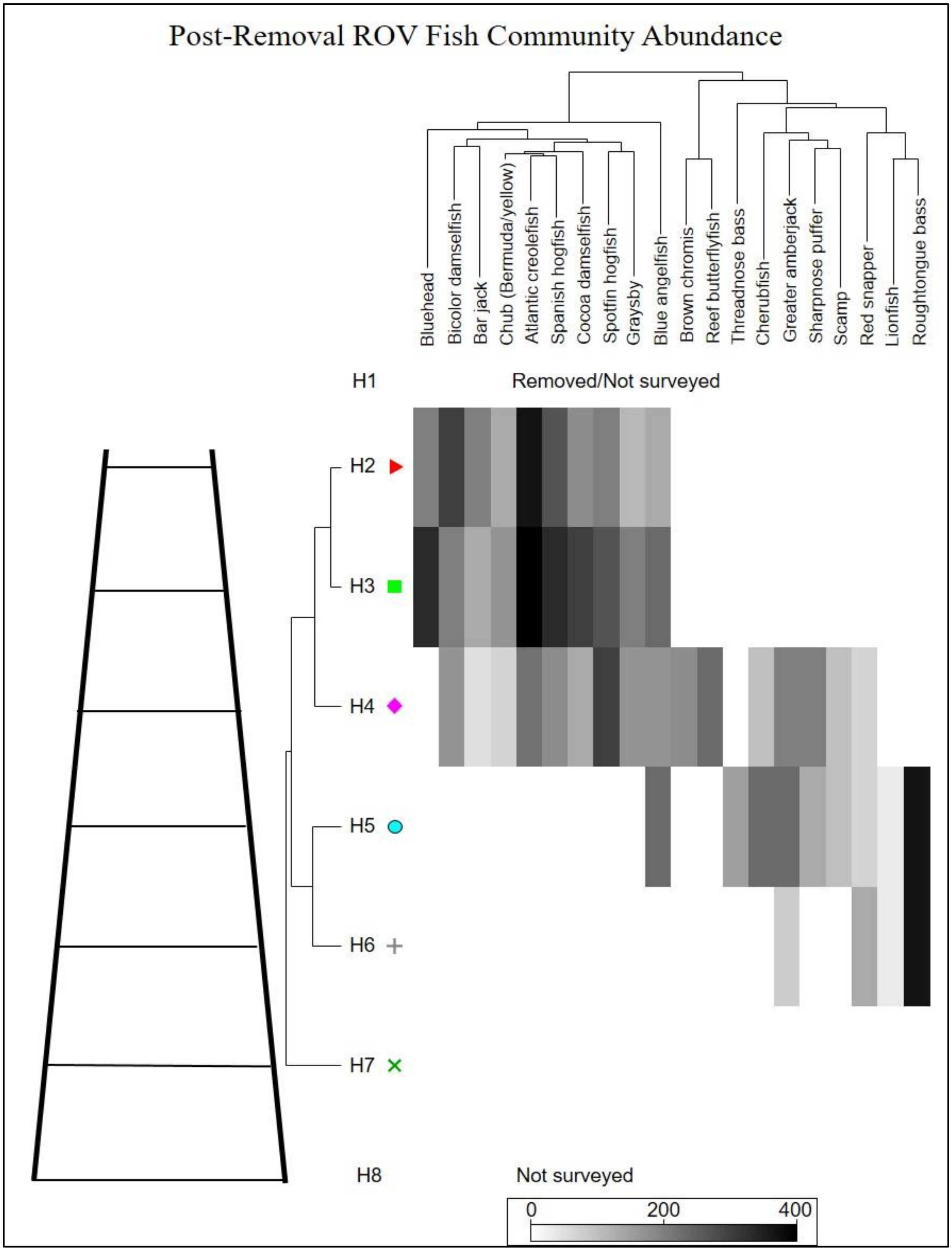


Figure 4.8. Post-removal fish abundance and sighting frequency from ROV surveys. Shade plot based on the 20 most important species for the entire dataset. Shade represents DI*%SF value. Outline of HI-A-389-A to the left of the shade plot helps to visually represent the depth delineations of the horizontal beams below the surface: H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m). No surveys were conducted on H8.

Roving diver surveys found significantly more diverse fish communities on a survey-by-survey basis than ROV surveys and were only conducted on the upper three levels of the platform (H1-H3, where mid-water surveys at 9 m were completed at the same depth as H1 pre-removal). A total of 56 species and groups and 19 families were found during diver surveys. Of these species, 17 were not recorded in ROV surveys (Table 4.8)

Table 4.8. Post-removal diver survey additional fish species list, along with trophic guild, density index (DI), sighting frequency (%SF), and minimum and maximum depth (m) sighted. H= herbivore, I = invertivore, PL = planktivore, and P = piscivore. Species in bold were unique to diver surveys.

Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Cocoa damselfish	*Stegastes variabilis*	Pomacentridae	H	3.50	66.67	22	37
Bicolor damselfish	*Stegastes partitus*	Pomacentridae	H	3.18	61.11	22	37
Chub (Bermuda/yellow)	*Kyphosus saltatrix/incisor*	Kyphosidae	H	2.80	55.56	22	37
Dusky damselfish	*Stegastes adustus*	Pomacentridae	H	2.38	44.44	22	37
Blue tang	*Acanthurus coeruleus*	Acanthuridae	H	1.78	50.00	22	37
Redband parrotfish	***Sparisoma aurofrenatum***	**Labridae**	**H**	**1.38**	**44.44**	**22**	**37**
Longfin damselfish	***Stegastes diencaeus***	**Pomacentridae**	**H**	**1.75**	**22.22**	**22**	**37**
Yellowtail damselfish	*Microspathodon chrysurus*	Pomacentridae	H	2.00	5.56	22	22
Ocean surgeonfish	***Acanthurus tractus***	**Acanthuridae**	**H**	**1.00**	**5.56**	**22**	**22**
Bluehead	*Thalassoma bifasciatum*	Labridae	I	3.58	66.67	22	37
Spanish hogfish	*Bodianus rufus*	Labridae	I	3.27	61.11	22	37
Brown chromis	*Chromis multilineata*	Pomacentridae	I	3.25	44.44	22	37
Queen angelfish	*Holacanthus ciliaris*	Pomacanthidae	I	2.00	61.11	22	37
Rock hind	*Epinephelus adscensionis*	Epinephelidae	I	1.50	66.67	22	37
Rock beauty	*Holacanthus tricolor*	Pomacanthidae	I	1.67	50.00	22	37
Sergeant major	*Abudefduf saxatilis*	Pomacentridae	I	2.17	33.33	22	22
Sharpnose puffer	*Canthigaster rostrata*	Tetraodontidae	I	1.38	44.44	22	37
Blue angelfish	*Holacanthus bermudensis*	Pomacanthidae	I	1.43	38.89	22	37
Townsend angelfish	*Holacanthus townsendi*	Pomacanthidae	I	1.33	33.33	22	37

Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Orangespotted filefish	***Cantherhines pullus***	**Monacanthidae**	**I**	**1.17**	**33.33**	**22**	**37**
Gray snapper	***Lutjanus griseus***	**Lutjanidae**	**I**	**2.00**	**16.67**	**37**	**37**
Whitespotted filefish	*Cantherhines macrocerus*	Monacanthidae	I	1.00	27.78	22	37
Squirrelfish	***Holocentrus adscensionis***	**Holocentridae**	**I**	**2.00**	**11.11**	**37**	**37**
Beaugregory	***Stegastes leucostictus***	**Pomacentridae**	**I**	**1.50**	**11.11**	**22**	**22**
Goldentail moray	*Gymnothorax miliaris*	Muraenidae	I	1.00	11.11	22	37
Scrawled filefish	***Aluterus scriptus***	**Monacanthidae**	**I**	**1.00**	**11.11**	**22**	**22**
Seaweed blenny	*Parablennius marmoreus*	Blenniidae	I	2.00	5.56	22	22
Dusky squirrelfish	***Sargocentron vexillarium***	**Holocentridae**	**I**	**2.00**	**5.56**	**37**	**37**
Smooth trunkfish	*Lactophrys triqueter*	Ostraciidae	I	2.00	5.56	22	22
Red hind	***Epinephelus guttatus***	**Epinephelidae**	**I**	**1.00**	**5.56**	**22**	**22**
Spotfin hogfish	*Bodianus pulchellus*	Labridae	I	1.00	5.56	37	37
Threespot damselfish	*Stegastes planifrons*	Pomacentridae	I	1.00	5.56	37	37
Gray angelfish	***Pomacanthus arcuatus***	**Pomacanthidae**	**I**	**1.00**	**5.56**	**37**	**37**
Horse-eye jack	*Caranx latus*	Carangidae	P	2.33	83.33	9	37
Bar jack	*Caranx ruber*	Carangidae	P	1.85	72.22	9	37
Graysby	*Cephalopholis cruentata*	Epinephelidae	P	2.00	61.11	22	37
Blue runner	***Caranx crysos***	**Carangidae**	**P**	**2.80**	**27.78**	**22**	**37**
Great barracuda	*Sphyraena barracuda*	Sphyraenidae	P	1.00	66.67	9	37
Black jack	*Caranx lugubris*	Carangidae	P	2.25	22.22	22	37
Greater amberjack	*Seriola dumerili*	Carangidae	P	2.00	22.22	37	37
Crevalle jack	***Caranx hippos***	**Carangidae**	**P**	**2.33**	**16.67**	**9**	**37**
Lionfish	*Pterois volitans/miles*	Scorpaenidae	P	1.00	22.22	22	37
Rainbow runner	***Elagatis bipinnulata***	**Carangidae**	**P**	**2.00**	**11.11**	**9**	**22**
Scalloped hammerhead	***Sphyrna lewini***	**Sphyrnidae**	**P**	**3.00**	**5.56**	**37**	**37**
Yellowmouth grouper	*Mycteroperca interstitialis*	Epinephelidae	P	2.00	5.56	22	22

Common Names	**Latin Name**	**Family**	**Primary Trophic Guild**	**DI**	**%SF**	**Min Depth (m)**	**Max Depth (m)**
Shark spp.	*Carcharhinus* spp.	Carcharhinidae	P	2.00	5.56	37	52
Silky shark	*Carcharhinus falciformis*	Carcharhinidae	P	2.00	5.56	37	37
Yellow jack	***Caranx bartholomaei***	**Carangidae**	**P**	**2.00**	**5.56**	**37**	**37**
Grouper spp.	Epinephelidae	Epinephelidae	P	1.00	5.56	9	37
Scamp	*Mycteroperca phenax*	Epinephelidae	P	1.00	5.56	37	37
Caribbean reef shark	***Carcharhinus perezii***	**Carcharhinidae**	**P**	**1.00**	**5.56**	**37**	**37**
Atlantic creolefish	*Paranthias furcifer*	Epinephelidae	PL	3.45	61.11	22	37
Regal demoiselle	*Neopomacentrus cyanomos*	Neopomacentrus	PL	2.86	38.89	22	37
Creole wrasse	*Clepticus parrae*	Labridae	PL	2.75	22.22	37	37
Blue chromis	*Chromis cyanea*	Pomacentridae	PL	3.00	5.56	37	37
Purple reeffish	*Chromis scotti*	Pomacentridae	PL	3.00	5.56	22	22

Density index was summed across trophic guilds. At both H2 and H3, invertivores were the most prevalent species, accounting for 35-39% of the total DI. Piscivores were the only trophic guild observed mid-water at 9 m, the same depth as H1 pre-removal, representing 100% of the total DI on that level. Planktivores were similar between H2 and H3, comprising 12% of the total DI on both levels, and herbivores were most prevalent on H2, comprising 24% of the total DI (Figure 4.9).

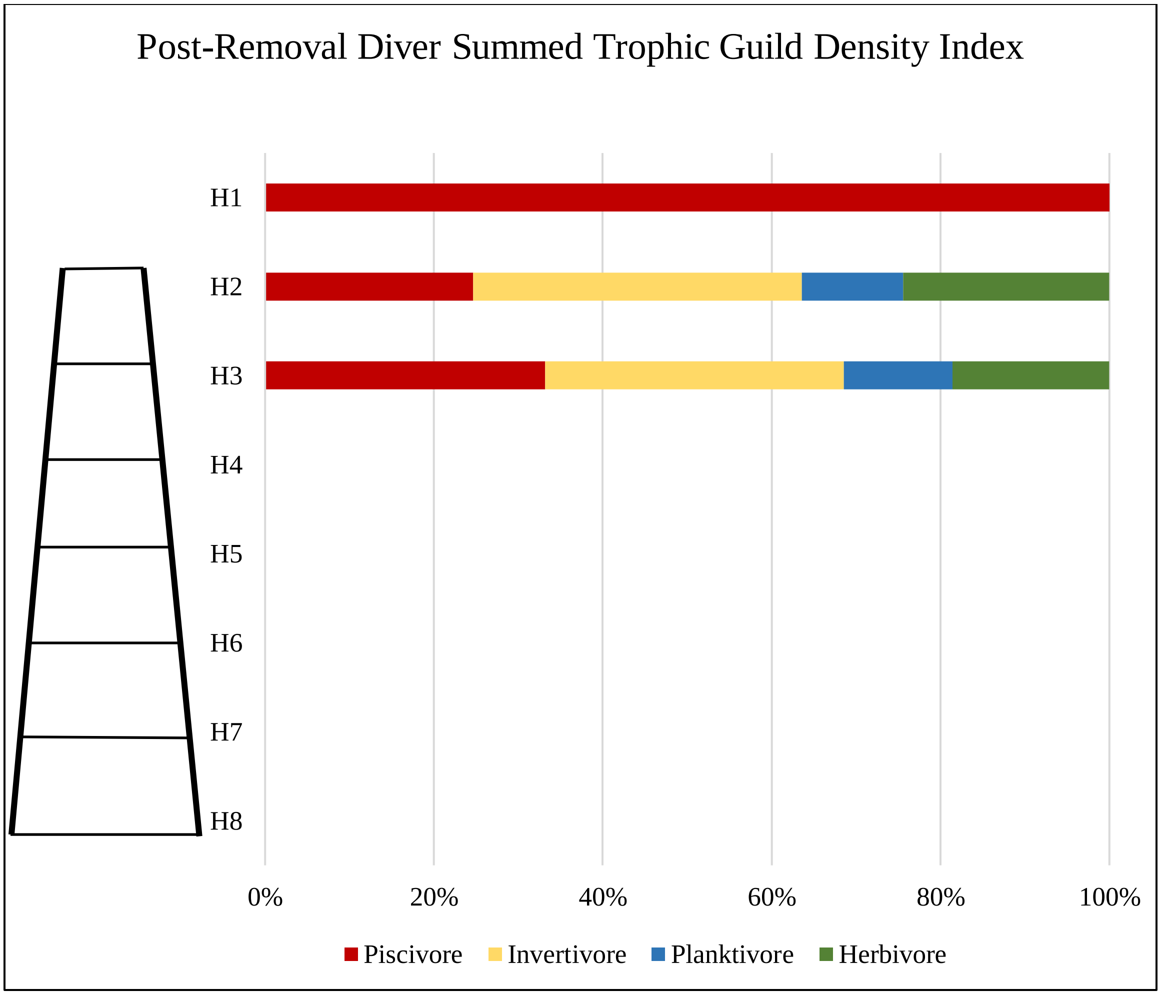


Figure 4.9. Post-removal diver summed trophic guild density index on horizontal levels (H1-H3). Post-removal surveys for H1 were completed by divers mid-water at 9m. Outline of HI-A-389-A to the left of the bar graph helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m). No surveys were conducted on H8.

Based on DI*%SF data, two clusters were found among platform levels. The water column at H1 was unique and levels H2 and H3 were similar. Grouped by these clusters, the 20 most important species were presented in Figure 4.10.

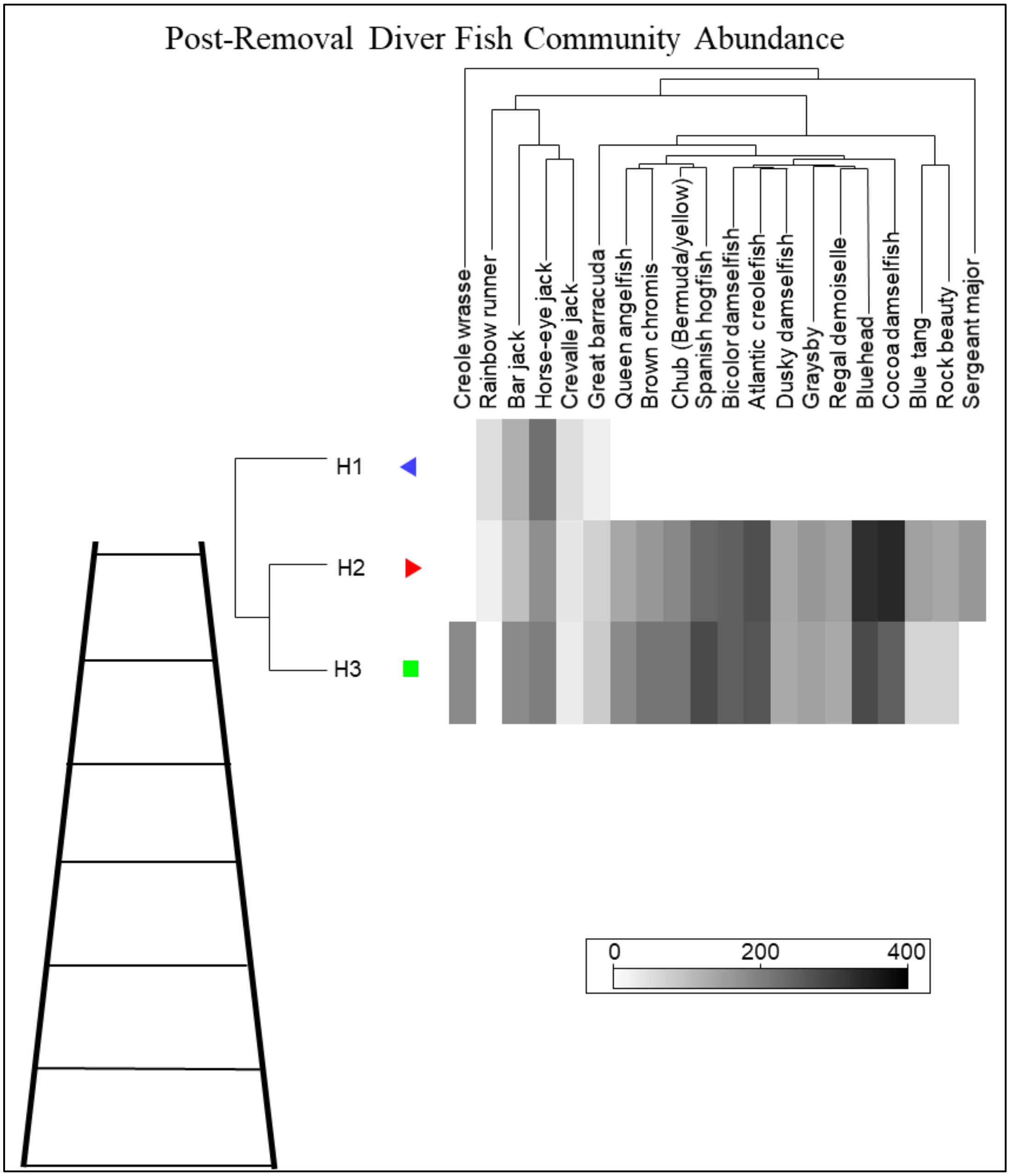


Figure 4.10. Post-removal fish abundance and sighting frequency from diver surveys. Shade plot based on the 20 most important species for the entire dataset. Shade represents DI*%SF value. Post-removal surveys for H1 were completed by divers mid-water at 9m. Outline of HI-A-389-A to the left of the shade plot helps to visually represent the depth delineations of the horizontal beams below the surface: H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m).

Belt transects were conducted by divers on the remaining upper two levels of the platform (H2-H3). Density and biomass were calculated for a total of 25 species and groups and nine families. All species recorded in belt transects were recorded in roving diver and ROV surveys (Table 4.9).

Table 4.9. Post-removal belt transect fish species list, along with trophic guild, density, biomass, and minimum and maximum depth (m) sighted. H= herbivore, I = invertivore, PL = planktivore, and P = piscivore. Values are presented ± standard error.

Common Name	Latin Name	Family	Primary Trophic Guild	Density (#/100m^2)	Biomass (g/100m^2)	Min Depth (m)	Max Depth (m)
Cocoa damselfish	*Stegastes variabilis*	Pomacentridae	H	96.00 ± 9.52	257.72 ± 79.70	22	37
Bicolor damselfish	*Stegastes partitus*	Pomacentridae	H	55.00 ± 9.36	78.59 ± 23.20	22	37
Dusky damselfish	*Stegastes adustus*	Pomacentridae	H	13.00 ± 3.59	121.42 ± 29.08	22	37
Chub (Bermuda/yellow)	*Kyphosus saltatrix/incisor*	Kyphosidae	H	7.00 ± 2.06	593.78 ± 221.65	22	37
Blue tang	*Acanthurus coeruleus*	Acanthuridae	H	6.00 ± 2.38	1611.73 ± 766.67	22	22
Redband parrotfish	*Sparisoma aurofrenatum*	Labridae	H	4.00 ± 2.00	97.85 ± 48.93	22	22
Longfin damselfish	*Stegastes diencaeus*	Pomacentridae	H	3.00 ± 0.96	35.96 ± 11.48	22	22
Bluehead	*Thalassoma bifasciatum*	Labridae	I	198.00 ± 46.11	591.88 ± 224.26	22	37
Spanish hogfish	*Bodianus rufus*	Labridae	I	78.00 ± 8.19	1617.66 ± 164.84	22	37
Brown chromis	*Chromis multilineata*	Pomacentridae	I	31.00 ± 15.50	128.20 ± 64.10	37	37
Rock hind	*Epinephelus adscensionis*	Epinephelidae	I	11.00 ± 2.63	627.54 ± 143.82	22	37
Sergeant major	*Abudefduf saxatilis*	Pomacentridae	I	10.00 ± 3.32	533.07 ± 187.71	22	22
Queen angelfish	*Holacanthus ciliaris*	Pomacanthidae	I	4.00 ± 1.41	1223.72 ± 525.33	22	37
Rock beauty	*Holacanthus tricolor*	Pomacanthidae	I	3.00 ± 0.50	269.57 ± 63.23	22	37
Blue angelfish	*Holacanthus bermudensis*	Pomacanthidae	I	1.00 ± 0.50	128.04 ± 64.02	22	22
Orangespotted filefish	*Cantherhines pullus*	Monacanthidae	I	1.00 ± 0.50	44.24 ± 22.12	37	37
Sharpnose puffer	*Canthigaster rostrata*	Tetraodontidae	I	1.00 ± 0.50	0.29 ± 0.14	37	37

Common Name	Latin Name	Family	Primary Trophic Guild	Density (#/100m^2)	Biomass (g/100m^2)	Min Depth (m)	Max Depth (m)
Townsend angelfish	*Holacanthus townsendi*	Pomacanthidae	I	1.00 ± 0.50	1448.93 ± 724.46	37	37
Whitespotted filefish	*Cantherhines macrocerus*	Monacanthidae	I	1.00 ± 0.50	575.43 ± 287.71	37	37
Horse-eye jack	*Caranx latus*	Carangidae	P	25.00 ± 12.50	158525.99 ± 79263.00	37	37
Graysby	*Cephalopholis cruentata*	Epinephelidae	P	4.00 ± 0.82	93.24 ± 15.80	22	37
Greater amberjack	*Seriola dumerili*	Carangidae	P	2.00 ± 1.00	20000.56 ± 10000.28	37	37
Atlantic creolefish	*Paranthias furcifer*	Epinephelidae	PL	119.00 ± 16.13	16007.30 ± 3350.54	22	37
Regal demoiselle	*Neopomacentrus cyanomos*	Pomacentridae	PL	38.00 ± 11.70	31.69 ± 12.48	22	37
Purple reeffish	*Chromis scotti*	Pomacentridae	PL	8.00 ± 4.00	63.14 ± 31.57	37	37

Due to the limited number of belt transects (two on each level), no additional results are presented.

Comparison of Pre- and Post-Removal Fish Abundance Results

In ROV surveys, 38 unique species or groups were observed in pre-removal surveys that were not observed in post-removal surveys. Likewise, 13 unique species or groups were documented in post-removal surveys not observed in pre-removal surveys. These unique species are reported in Table 4.10.

Table 4.10. Species observed in only pre- or post-removal roving ROV surveys, along with trophic guild, density index (DI), sighting frequency (%SF), and minimum and maximum depth (m) sighted. H= herbivore, I = invertivore, PL = planktivore, and P = piscivore.

Status	Common Name	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Pre-	Redlip blenny	*Ophioblennius macclurei*	Blenniidae	H	2.00	14.55	9	108
	Redband parrotfish	*Sparisoma aurofrenatum*	Labridae	H	1.50	14.55	9	91
	Greenblotch parrotfish	*Sparisoma atomarium*	Labridae	H	1.50	3.64	37	52
	Longfin damselfish	*Stegastes diencaeus*	Pomacentridae	H	2.00	1.82	22	22
	Cherubfish	*Centropyge argi*	Pomacentridae	H	1.00	1.82	37	72
	Queen parrotfish	*Scarus vetula*	Labridae	H	1.00	1.82	37	37
	Beaugregory	*Stegastes leucostictus*	Pomacentridae	I	2.60	36.36	9	108
	Orangespotted filefish	*Cantherhines pullus*	Monacanthidae	I	1.40	18.18	9	108
	Squirrelfish	*Holocentrus adscensionis*	Holocentridae	I	1.43	12.73	22	91
	Saddle bass	*Serranus notospilus*	Serranidae	I	1.40	9.09	108	125
	Angelfish spp.	Pomacanthidae	Pomacanthidae	I	2.00	5.45	9	37
	Gray triggerfish	*Balistes capriscus*	Balistidae	I	1.25	7.27	9	91
	Red hogfish	*Decodon puellari*	Labridae	I	1.25	7.27	125	125
	Scrawled filefish	*Aluterus scriptus*	Monacanthidae	I	1.33	5.45	9	37
	Gray snapper	*Lutjanus griseus*	Lutjanidae	I	1.50	3.64	22	37
	Hunchback scorpionfish	*Scorpaena dispar*	Scorpaenidae	I	1.50	3.64	108	125

Status	Common Name	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Pre-	Slantbrow batfish	*Ogcocephalus declivirostris*	Ogcocephalidae	I	1.00	5.45	108	125
	Spinycheek soldierfish	*Corniger spinosus*	Holocentridae	I	1.50	3.64	91	108
	Bandtail puffer	*Sphoeroides spengleri*	Tetraodontidae	I	1.00	3.64	37	125
	Bandtail searobin	*Prionotus ophryas*	Triglidae	I	1.00	3.64	125	125
	Cubbyu	*Pareques umbrosus*	Sciaenidae	I	1.00	3.64	91	108
	Dwarf goatfish	*Upeneus parvus*	Mullidae	I	2.00	1.82	108	108
	Goldface toby	*Canthigaster jamestyleri*	Tetraodontidae	I	2.00	1.82	52	52
	Neon goby	*Elacatinus oceanops*	Gobiidae	I	1.00	3.64	22	52
	Yellowedge grouper	*Hyporthodus flavolimbatus*	Epinephelidae	I	1.00	3.64	91	108
	Tilefish spp.	*Caulolatilus* spp.	Malacanthidae	I	1.00	1.82	125	125
	Balloonfish	*Diodon holocanthus*	Diodontidae	I	1.00	1.82	9	9
	Longsnout butterflyfish	*Prognathodes aculeatus*	Chaetodontidae	I	1.00	1.82	52	52
	Mexican flounder	*Cyclopsetta chittendeni*	Bothidae	I	1.00	1.82	125	125
	Red hind	*Epinephelus guttatus*	Epinephelidae	I	1.00	1.82	22	22
	Blue runner	*Caranx crysos*	Carangidae	P	2.67	16.36	9	91
	Crevalle jack	*Caranx hippos*	Carangidae	P	1.50	10.91	9	108
	Queen snapper	*Etelis oculatus*	Lutjanidae	P	1.00	1.82	125	125
	Rainbow runner	*Elagatis bipinnulata*	Carangidae	P	1.00	1.82	9	9
	Snowy grouper	*Hyporthodus niveatus*	Epinephelinae	P	1.00	1.82	91	91
	Vermilion snapper	*Rhomboplites aurorubens*	Lutjanidae	P	1.00	1.82	91	91
	Wenchman	*Pristipomoides aquilonaris*	Lutjanidae	P	1.00	1.82	108	108
	Twospot cardinalfish	*Apogon pseudomaculatus*	Apogonidae	PL	1.00	1.82	52	52

Status	Common Name	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Post-	Parrotfish spp.	*Scarus* spp./*Sparisoma* spp.	Labridae	H	1.00	16.67	22	72
	Cardinalfish spp.	*Apogon* spp.	Apogonidae	I	1.00	16.67	72	91
	Smooth trunkfish	*Lactophrys triqueter*	Ostraciidae	I	1.00	5.56	52	52
	Butterflyfish spp.	*Chaetodontidae*	Chaetodontidae	I	1.00	5.56	108	108
	Hamlet spp.	*Hypoplectrus* spp.	Serranidae	I	1.00	5.56	72	72
	Soapfish spp.	*Rypticus* spp.	Serranidae	I	1.00	5.56	52	52
	Squirrelfish spp.	*Holocentridae*	Holocentridae	I	1.00	5.56	72	72
	Wrasse or parrotfish spp.	Labridae	Labridae	I	1.00	5.56	72	72
	Silky shark	*Carcharhinus falciformis*	Carcharhinidae	P	1.00	5.56	52	52
	Jack spp.	*Caranx* spp.	Carangidae	P	1.00	5.56	91	91
	Regal demoiselle	*Neopomacentrus cyanomos*	Neopomacentrus	PL	1.83	33.33	22	72
	Blenny spp.	*Emblemariopsis spp.*	Chaenopsidae	PL	1.50	11.11	72	108
	Chromis spp.	*Chromis* spp.	Pomacentridae	PL	3.00	5.56	37	37

Beta diversity from roving ROV surveys was not significantly different pre- and post -removal. However, there was a significant interaction between level and removal status (pre/post) based on community composition (pseudo-F=2.56, p=<0.001); therefore, each level was independently examined for differences between pre- and post-removal community composition (Table 4.11). H1 and H8 were omitted from these analyses as no comparative data were available for these two levels. Pre- and post-removal community composition differed significantly on all levels except H6.

Table 4.11. PERMANOVA results for species composition pre- and post-removal based on ROV surveys. Bold indicates significant differences.

Level	Pseudo-F	P
H2	5.32	**0.005**
H3	2.03	**0.024**
H4	2.40	**0.024**
H5	4.72	**0.013**
H6	2.00	0.078
H7	1.79	**0.017**

Based on the comparison of DI*%SF data, no clear patterns were observed between pre- and post-removal SIMPROF clusters (Figure 4.11). Similar results were found when benthic communities were compared among horizontal levels pre- and post-removal (see Chapters 3 and 4). However, in this comparative analysis, post-removal, level H7 clustered with pre-removal seafloor data.

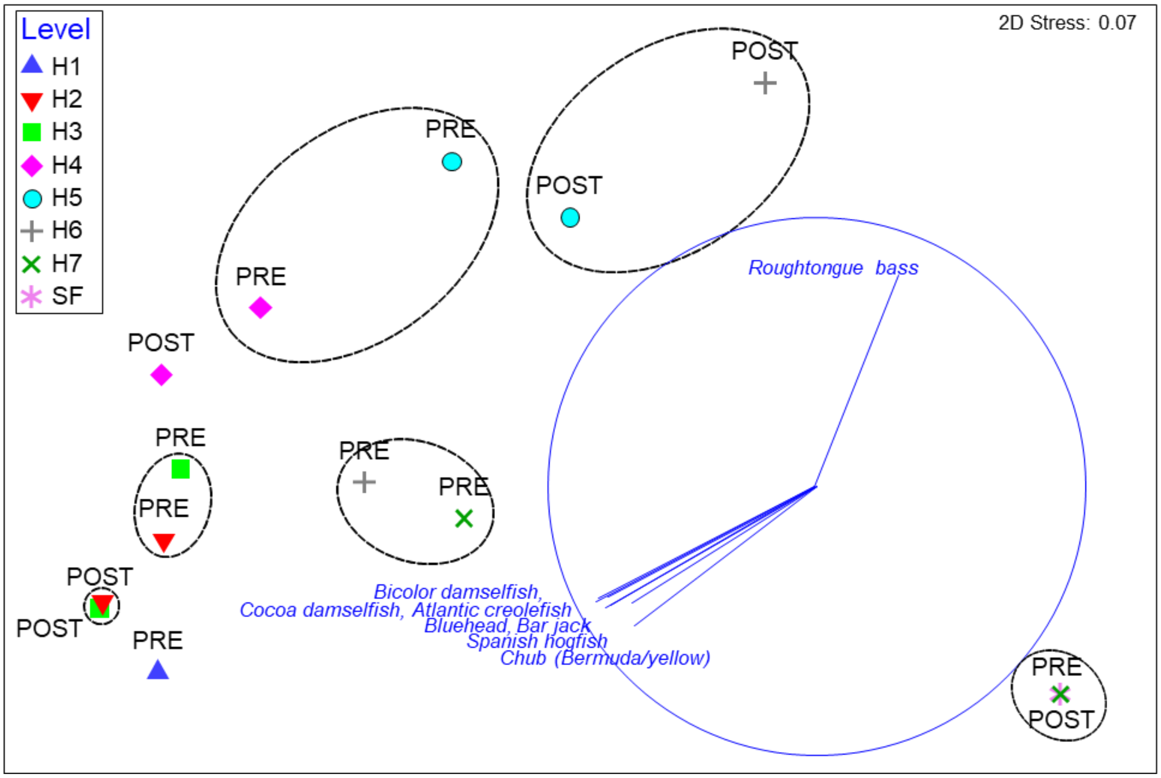


Figure 4.11. Comparison of roving ROV survey DI*%SF pre- and post-removal. Significant SIMPROF clusters are represented by the dashed lines and the species with >0.8 Pearson correlation are overlaid in a blue vector plot.

The shade plot compares the 20 most important species among all ROV pre- and post-removal surveys at each level to highlight changes in important members of the fish community (Figure 4.12). On levels H2 and H3, species that were observed in pre-removal surveys are absent in post-removal surveys. H4 and H5 are similar between pre- and post-removal. H6 shows an absence of particular groups of important species post-removal and H7 does not share any of the important species between pre- and post-removal. No comparative surveys were conducted on H1 or the seafloor.

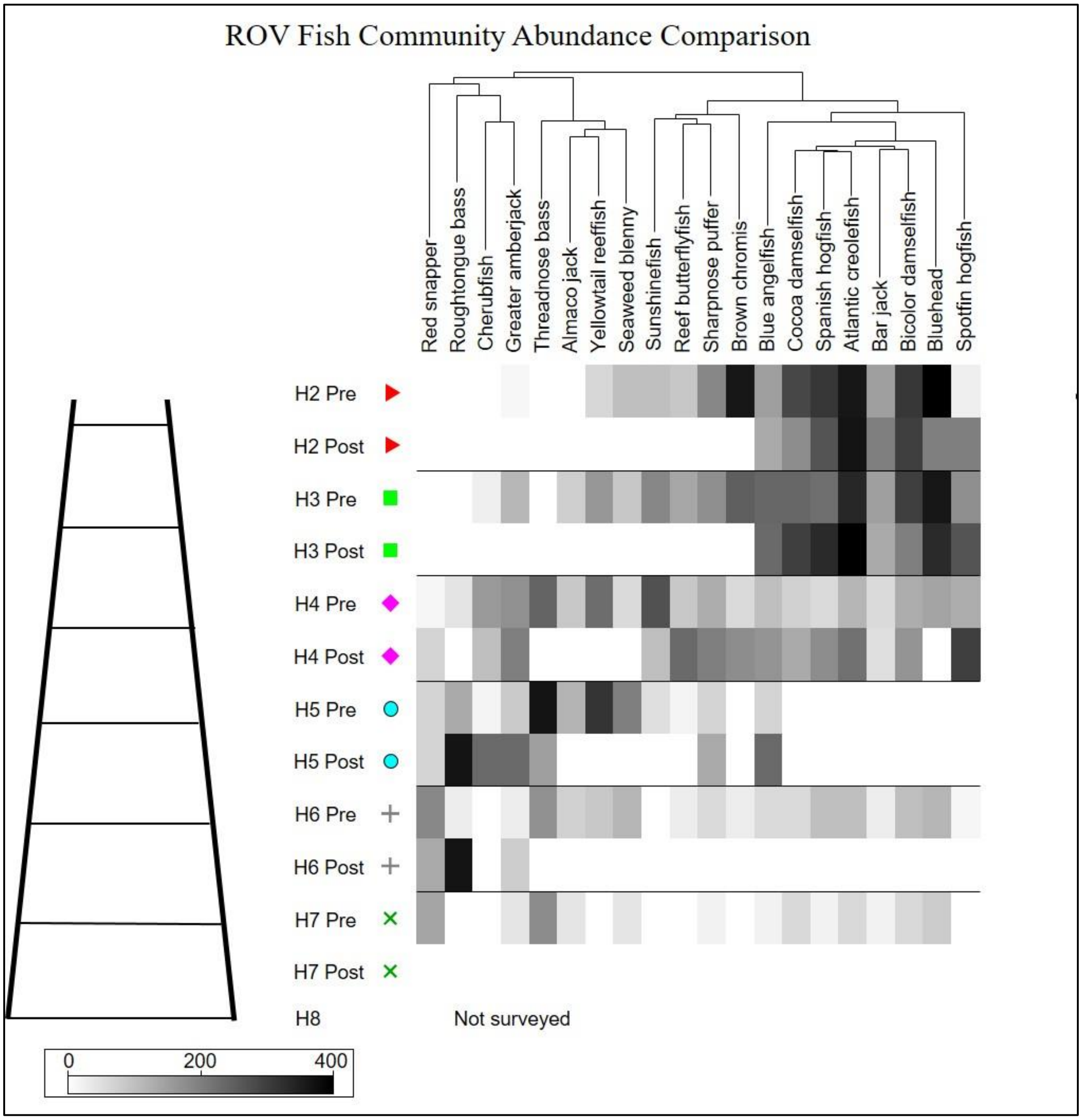


Figure 4.12. Comparison of fish community DI*%SF from ROV surveys. Shade plot based on the 20 most important species for the entire dataset. Shade represents DI*%SF value. Outline of HI-A-389-A to the left of the shade plot helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), H8 (125 m), and the seafloor (125m).

In RDT surveys, 13 unique species or groups were observed in pre-removal surveys and 11 unique species or groups were documented in post-removal surveys. These unique species are reported in Table 4.12. Similar to ROV surveys, the exotic regal demoiselle was documented only in 2019 surveys.

Table 4.12. Species observed in only pre- or post-removal roving diver surveys, along with trophic guild, density index (DI), sighting frequency (%SF), and minimum and maximum depth (m) sighted. H= herbivore, I = invertivore, PL = planktivore, and P = piscivore.

Status	Common Names	Latin Name	Family	Primary Trophic Guild	DI	%SF	Min Depth (m)	Max Depth (m)
Pre-	Redlip blenny	*Ophioblennius macclurei*	Blenniidae	H	1.27	33.33	9	22
	Greenblotch parrotfish	*Sparisoma atomarium*	Labridae	H	1.50	18.18	22	37
	Striped parrotfish	*Scarus iseri*	Labridae	H	1.00	3.03	37	37
	French angelfish	*Pomacanthus paru*	Pomacanthidae	I	1.33	9.09	37	37
	Redspotted hawkfish	*Amblycirrhitus pinos*	Cirrhitidae	I	1.00	9.09	22	22
	Ocean triggerfish	*Canthidermis sufflamen*	Balistidae	I	1.00	9.09	9	22
	Gray triggerfish	*Balistes capriscus*	Balistidae	I	1.00	6.06	22	22
	Permit	*Trachinotus falcatus*	Carangidae	I	1.00	3.03	37	37
	Little tunny	*Euthynnus alletteratus*	Scombridae	P	4.00	6.06	37	52
	Red snapper	*Lutjanus campechanus*	Lutjanidae	P	1.00	9.09	37	37
	Dusky shark	*Carcharhinus obscurus*	Carcharhinidae	P	1.50	6.06	9	37
	Atlantic trumpetfish	*Aulostomus maculatus*	Aulostomidae	P	1.00	3.03	22	22
	Spotted moray	*Gymnothorax moringa*	Muraenidae	P	1.00	3.03	22	22
Post-	Gray snapper	*Lutjanus griseus*	Lutjanidae	I	2.00	16.67	37	37
	Grouper spp.	Epinephelidae	Epinephelidae	P	1.00	5.56	9	37
	Purple reeffish	*Chromis scotti*	Pomacentridae	PL	3.00	5.56	22	22
	Red hind	*Epinephelus guttatus*	Epinephelidae	I	1.00	5.56	22	22
	Dusky squirrelfish	*Sargocentron vexillarium*	Holocentridae	I	2.00	5.56	37	37
	Gray angelfish	*Pomacanthus arcuatus*	Pomacanthidae	I	1.00	5.56	37	37
	Ocean surgeonfish	*Acanthurus tractus*	Acanthuridae	H	1.00	5.56	22	22
	Regal demoiselle	*Neopomacentrus cyanomos*	Neopomacentrus	PL	2.86	38.89	22	37
	Scalloped hammerhead	*Sphyrna lewini*	Sphyrnidae	P	3.00	5.56	37	37
	Smooth trunkfish	*Lactophrys triqueter*	Ostraciidae	I	2.00	5.56	22	22
	Yellow jack	*Caranx bartholomaei*	Carangidae	P	2.00	5.56	37	37

Community diversity from roving diver surveys was significantly different pre- and post-removal (F=8.90, p=0.017). Additionally, a significant interaction was found between level and removal status (pre/post) based on community composition (pseudo-F=4.86, p=<0.001). Therefore, community composition for each level was independently compared pre- and post-removal (Table 4.13). Community composition differed significantly between pre- and post-removal surveys for all levels.

Table 4.13. PERMANOVA results for species composition pre/post removal from roving diver surveys. Bold indicates significant findings. Post-removal surveys for H1 were completed by divers mid-water at 9m.

Level	**Pseudo-F**	**P**
H1	13.75	**<0.001**
H2	3.09	**<0.001**
H3	1.89	**0.006**

Based on abundance data, one significant SIMPROF cluster was found. Levels H2 and H3 clustered pre- and post-removal, suggesting they were similar in species composition (Figure 4.13), while H1 was unique. Abundance of rainbow runner, several pelagic fish (crevalle jack, great barracuda, rainbow runner, greater amberjack, and black jack), and several Caribbean reef fish (e.g. greenblotch parrotfish, spotfin hogfish) drove the distribution of points in the nMDS plot.

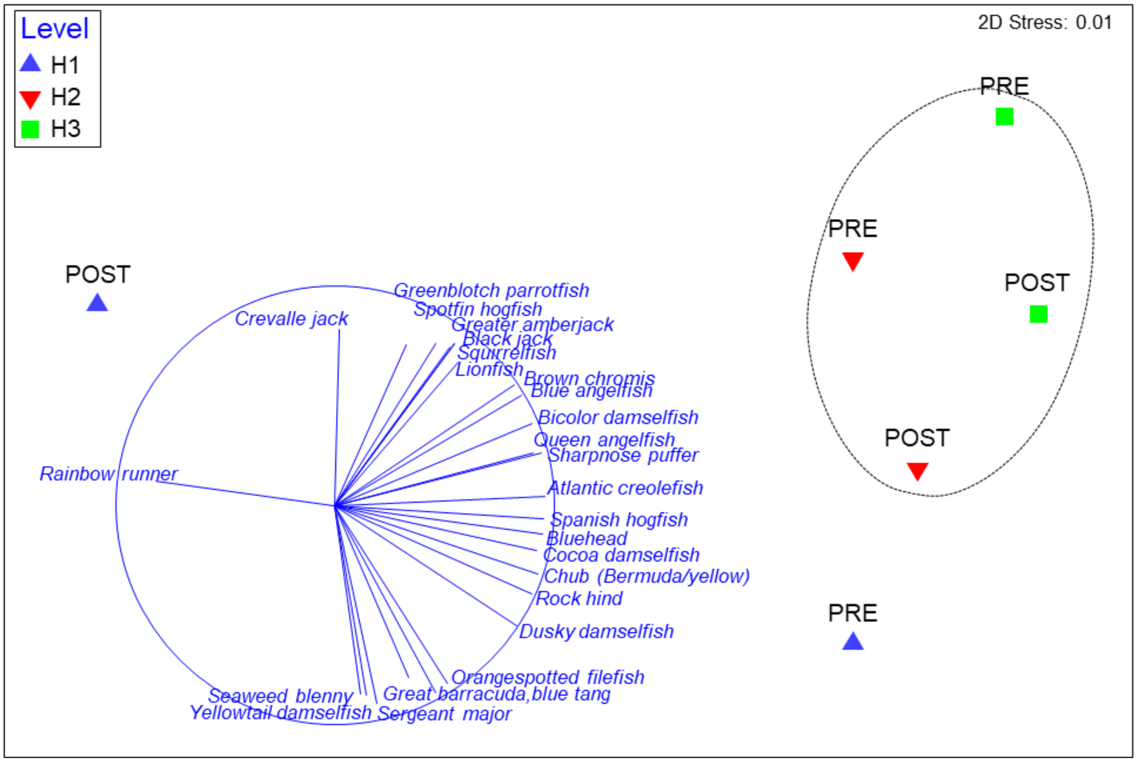


Figure 4.13. Comparison of roving diver survey DI*%SF. Significant SIMPROF clusters are represented by the dashed lines and the species with >0.8 Pearson correlation are overlaid in a blue vector plot.

A shade plot with the 20 most important species among all RDT surveys pre- and post-removal shows similar fish species represented in the nMDS vector plot (Figure 4.14). Levels H2 and H3 show similar abundance of these 20 most important species pre- and post-removal. Reef-associated species declined on level H1 when the structure was removed, while pelagic species abundance remained similar.

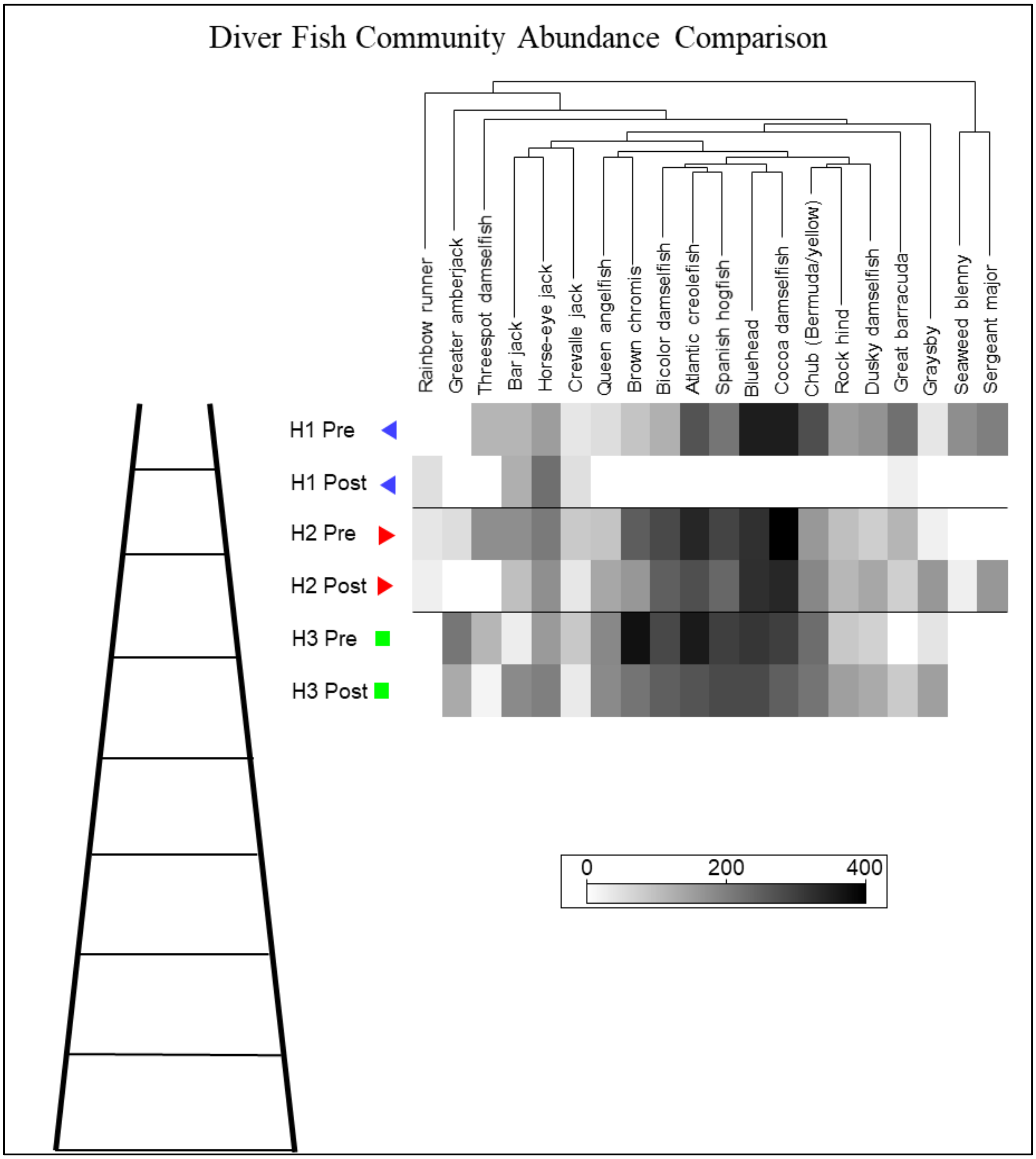


Figure 4.14. Comparison of diver survey fish community DI*%SF; shade plot based on the 20 most important species for the entire dataset. Shade represents DI*%SF value. Post-removal surveys for H1 were completed by divers mid-water at 9m. Outline of HI-A-389-A to the left of the shade plot helps to visually represent the depth delineations of the horizontal beams below the surface: H2 (22 m), H3 (37 m).

Fish Surveys Comparison and Discussion

Pre-Removal Fish Abundance

Pre-removal surveys documented a diverse fish community at HI-A-389-A in 2015 and 2017. The fish community observed during ROV surveys was less diverse than that observed during diver surveys. Fewer species were observed per survey with the ROV than with divers, and these data were therefore analyzed separately.

ROV and diver surveys documented invertivores throughout the depth levels; bluehead, Spanish hogfish, and brown chromis were the most abundant and densely populated species, and Spanish hogfish, rock hind, and queen angelfish contributed the greatest biomass. Herbivore density measured using belt transects was high on H2 due to a high density of cocoa damselfish and piscivore biomass was high due to multiple large black jack. Herbivores were present throughout the depth levels, including H7, where chub and multiple species of damselfish were documented by ROV.

Shade plots highlighted clear differences in fish communities among platform levels based on the 20 most important species. Significant clusters of levels were found using both ROV and diver surveys, where H1 was unique, H2 and H3 were similar, H4 and H5 were similar, H6 and H7 were similar, and the seafloor was unique, sharing none of the 20 most important species with the other levels. These corresponded with similar benthic community clusters by depth.

While accumulated biomass was evenly distributed between large and small species, size trends were found among trophic groups and levels. Most fish abundance was attributed to small individuals with the exception of the piscivores group, which was comprised of larger individuals than all other trophic guilds. Additionally, invertivore size decreased with depth level.

Red lionfish and tessellated blennies were the only non-native species documented in pre-removal surveys. Red lionfish were documented on levels H3 to H6 in 16% of ROV surveys, with a mean abundance code of few (2-10), and in belt transects at a mean density of <1 per 100 m^2 (±0.1 SE). Tessellated blennies were documented only on H1 in belt transects, at a mean density of ~1 per 100m^2 (±0.2 SE).

Post-Removal Fish Abundance

Post-removal surveys documented a diverse fish community at HI-A-389-A. The community observed during ROV surveys was less diverse than the community observed during diver surveys; more species per survey were documented by divers than by ROV. For this reason, surveys were analyzed separately.

ROV and diver surveys documented increasing piscivore and decreasing herbivore abundance with increasing depth level. In both survey methods, herbivores were most prevalent on H2, comprising 31% and 24% on ROV and diver surveys, respectively. However, post-removal diver surveys documented only piscivorous species present mid-water at 9 m, where H1 was located prior to removal, primarily Carangidae. Overall, horse-eye jack contributed the greatest density of piscivores and cocoa damselfish were the most prevalent herbivores in belt transects.

Shade plots highlighted clear differences in fish communities among levels, based on the 20 most important species. Significant clusters of levels were found in ROV surveys: H2 and H3 were similar, H4 was unique, H5 and H6 were similar, and H7 was unique, sharing none of the 20 most important species with the other levels. Significant clusters of levels were also found in diver surveys: H2 and H3 were similar and H1 was unique.

Non-native species documented in post-removal surveys included red lionfish and the regal demoiselle. Red lionfish were documented on levels H3 and H5 – H7 in 22% of ROV surveys, with a mean abundance code of single (1). Regal demoiselle was documented on levels H2 – H5 in 33% of ROV surveys, with a mean abundance code of few (2-10), and in belt transects with a mean density of 38 per 100 m^2 (±12 SE).

Pre- and Post-Removal Fish Abundance

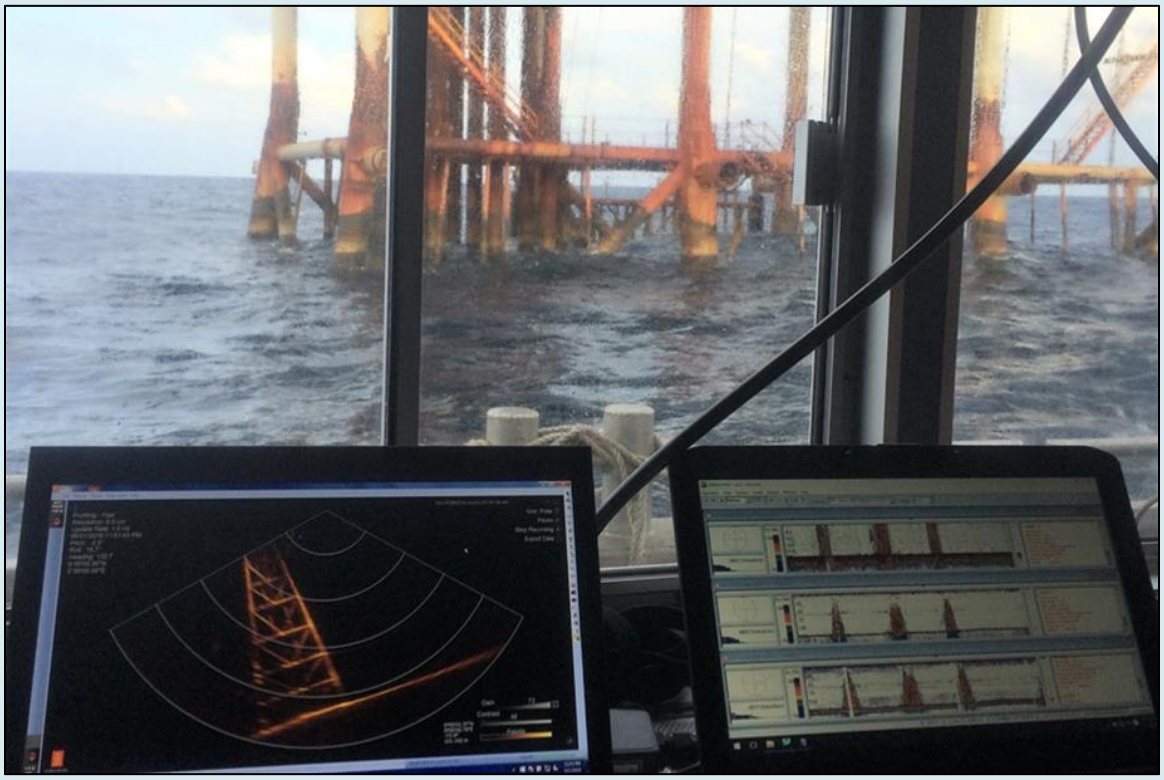
The fish community varied based on survey type, level, and pre/post-removal status. Both diver and ROV surveys identified that the fish community on level H1 was unique, while other levels grouped in various ways. Diver surveys collected pre- and post-removal data for level H1, documenting the absence of reef-associated species in post-removal surveys, while pelagic piscivores, including several species of jack, remained. ROV surveys documented declines in similar species throughout levels H1-H3 pre- to post-removal, while deeper levels (H6-H7) were almost entirely different pre- and post-removal. There was no apparent trend of individuals from level H1 moving to lower levels post-removal, with the exception of Atlantic creolefish, which increased in abundance on levels H2 and H3 post-removal. While the removal of the platform through level H1 clearly impacted the fish community on H1, care must be taken interpreting the findings.

At the nearby natural reef on EFGB, the fish community has been documented to vary significantly on an annual basis (Johnston et al. 2017). Similar temporal variability was documented at the two other banks within FGBNMS (Nuttall et al. 2019). While HI-A-389-A hosts more pelagic species than the natural banks, a similar reef-associated community was present, and a similar temporal variability in the fish community at HI-A-389-A is possible.

Non-native species, including red lionfish, regal demoiselle, and tessellated blenny, were documented. Red lionfish were more abundant on deep levels, and were not observed on level H1. The regal demoiselle was first documented on HI-A-389-A in 2019 post-removal surveys, following their arrival in the northwestern Gulf of Mexico in 2017

(Schofield and Neilson 2019). Tessellated blennies, documented only in level H1 pre-removal belt transects, were absent in post-removal belt transects. Recorded to inhabit empty barnacle tests at an average depth of <4.5 m, but rarely up to 18 m (Topolski and Szedlmayer 2004), tessellated blenny populations were likely removed along with the structure.

Chapter 5: Fish Acoustic Surveys



Pre-removal acoustic survey at HI-A-389-A. Photo: Chris Taylor/NOAA

Fish Acoustic Surveys Results

Pre-Removal Acoustic Results

Five fishery acoustic surveys were conducted around the HI-A-389-A platform in June 2016. In spite of poor weather and sea conditions, the R/V *Manta* was able to approach the platform closely on transects along the north, east, south and west sides. Fish were present throughout the water column. Both large individual fish and fish schools were in close proximity (less than 300 m) to the platform. Of particular note is the fact that fish were observed in the upper 27 m of the water column where the structure was still present (Figure 5.1). Individual fish were detected throughout the water column, with an unexplainable gap in fish around 45 m below the surface (Figure 5.2). This pattern did not correspond to any masking effect from other scattering layers at that depth. Fish were generally found in higher numbers on the western margins of the platform (Figure 5.3). Fish densities were higher in the upper two depth strata (< 45 m), exceeding densities in deeper strata by over an order of magnitude. Within depth strata, densities also varied significantly across the five surveys (Figure 5.4).

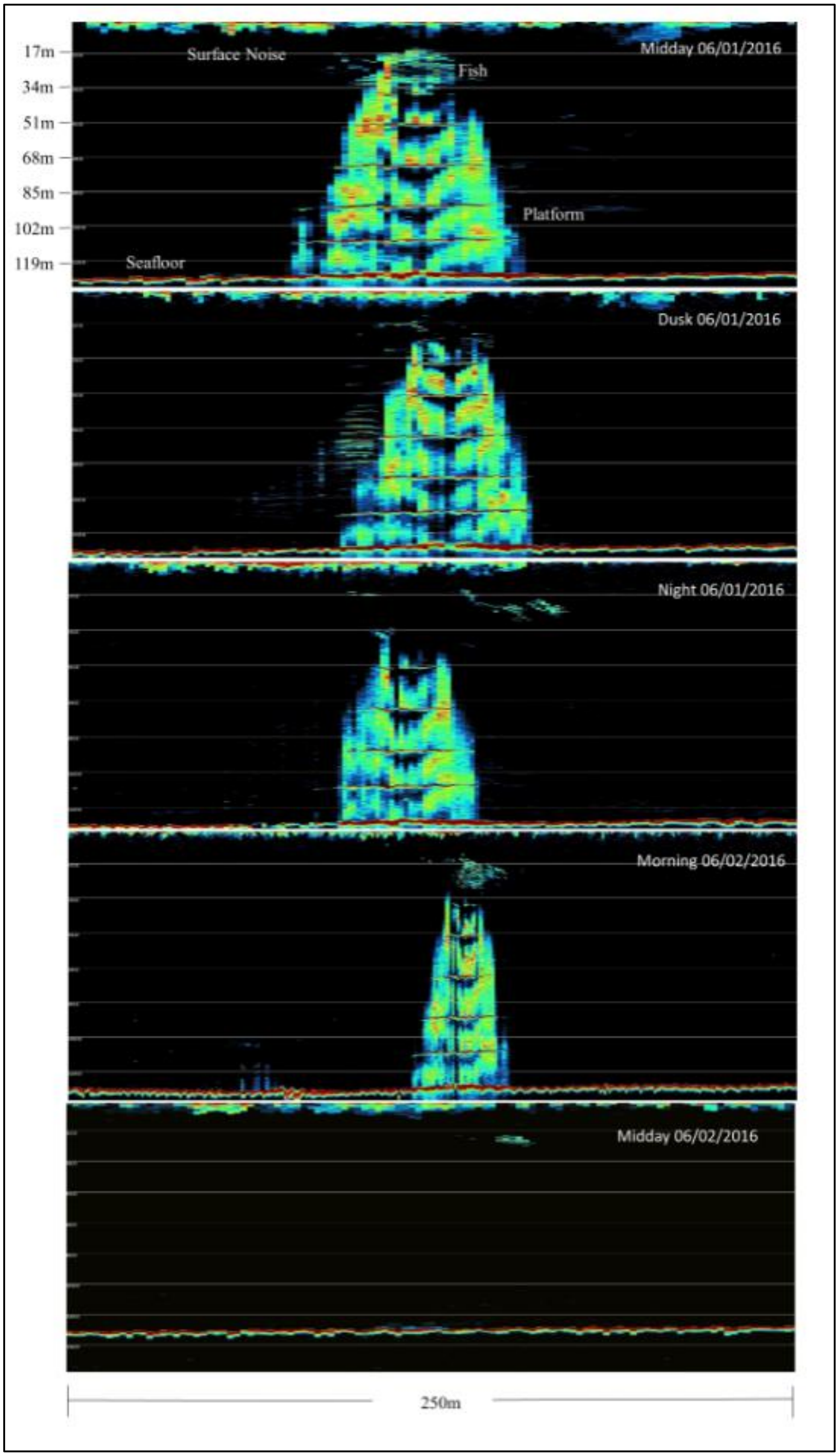


Figure 5.1. Example echograms of the northeast transect from five pre-removal surveys conducted in June 2016. Image: NOAA

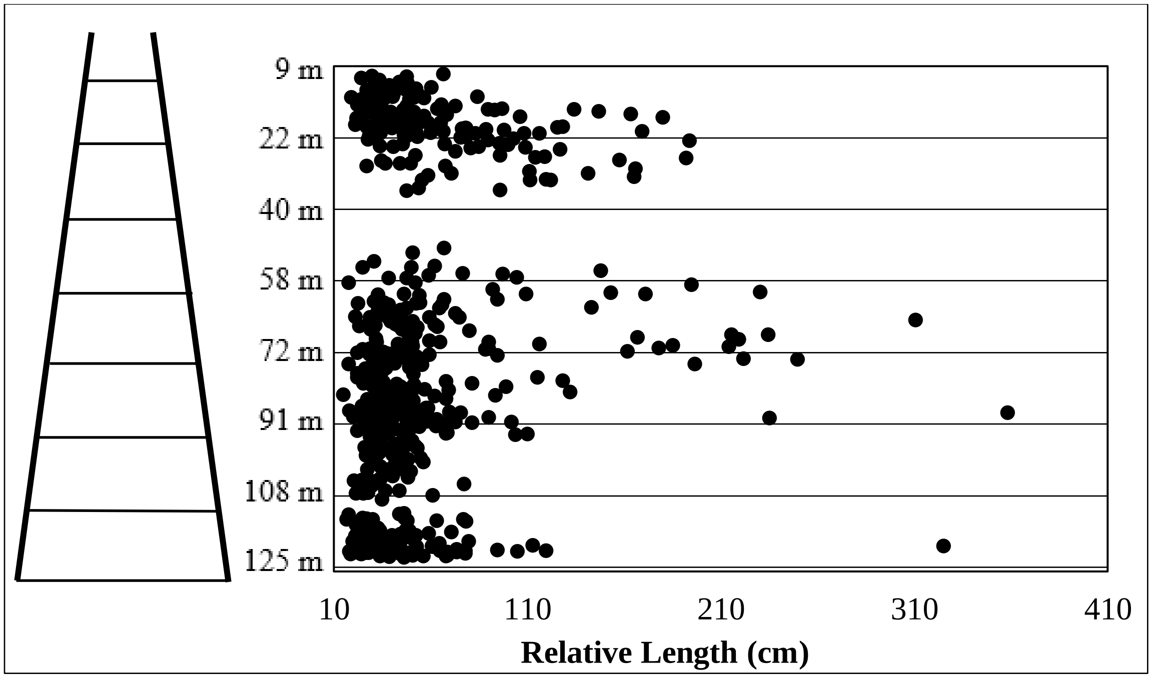


Figure 5.2. Depth distribution of individual fish targets during surveys conducted in June 2016. Each marker represents an individual fish at a given depth with estimated total length (in cm).

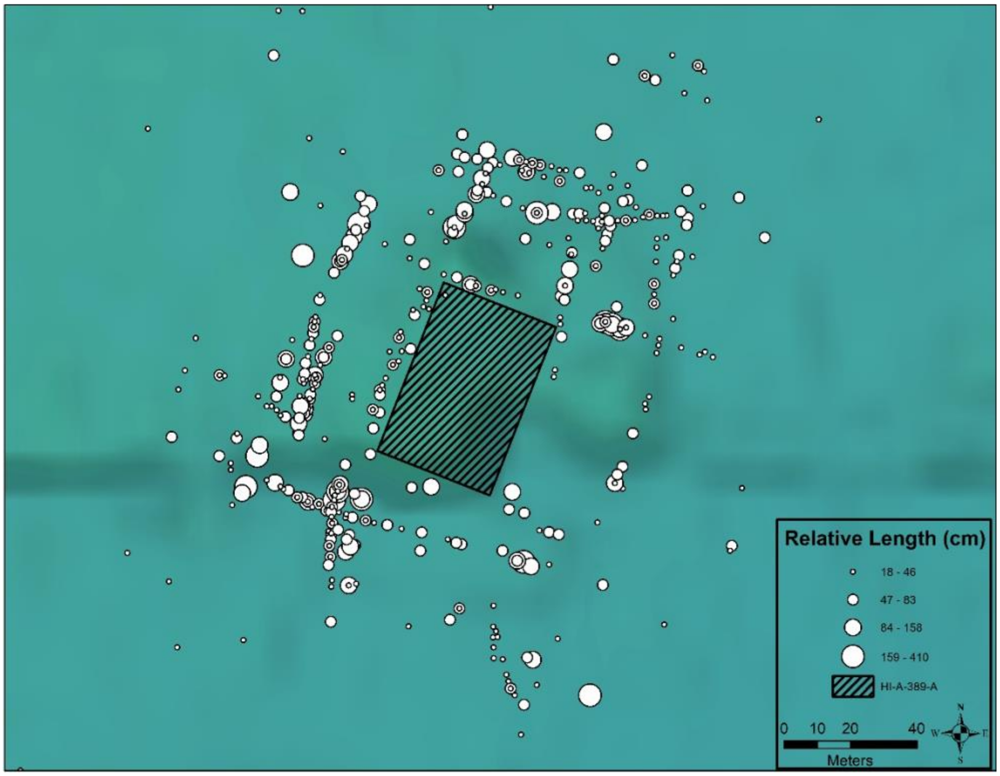


Figure 5.3. Location of individual fish targets relative to the HI-A-389-A platform footprint. Size of markers are proportional to fish size, estimated as total length (cm).

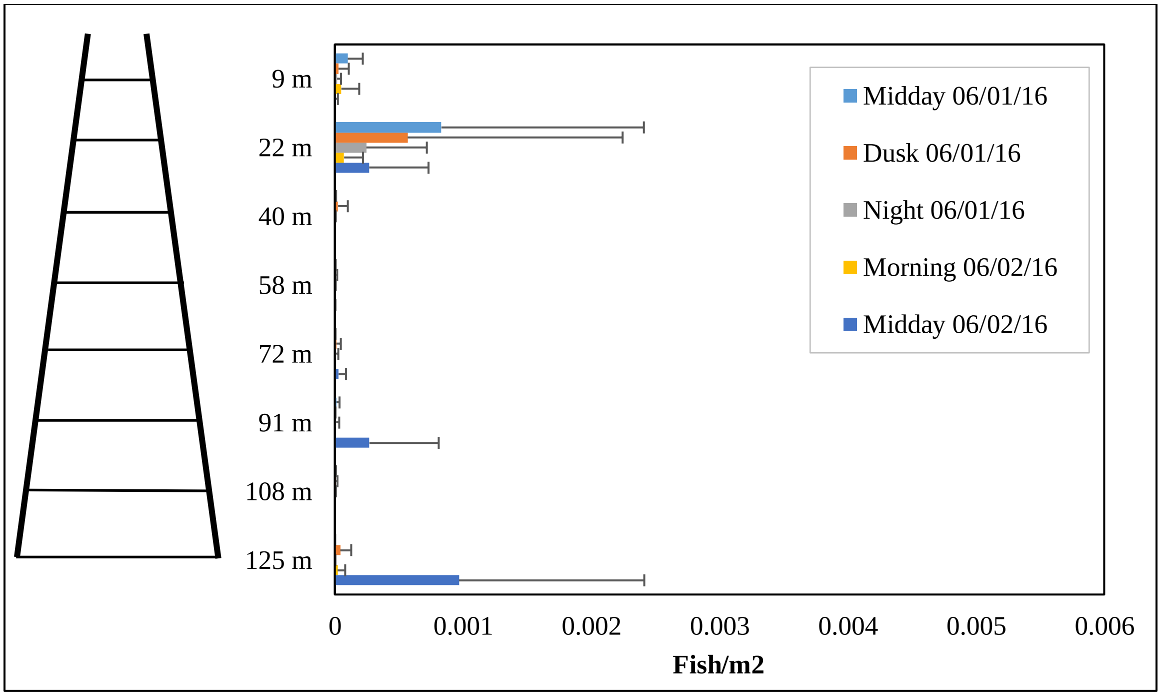


Figure 5.4. Densities of fish by depth strata for each pre-removal survey conducted in June 2016. Outline of HI-A-389-A to the left of the shade plot helps to visually represent the depth delineations of the horizontal beams below the surface: H1 (9 m), H2 (22 m), H3 (37 m), H4 (52 m), H5 (72 m), H6 (91 m), H7 (108 m), and H8 (125 m).

Post-Removal Acoustic Results

Five fishery acoustic post-removal surveys were conducted over 3 days in October 2019. Fish were observed around the platform. During this survey, a prominent scattering layer was present around 68 m below surface. Fish were absent from the upper water column after partial removal (Figure 5.5). A slight gap in fish numbers is noted at approximately 95 m below the surface (Figure 5.6). This depth did not correspond to a scattering layer that may have occluded fish detections. Fish were generally more numerous on the eastern margins of the platform during the post-removal surveys (Figure 5.7). Fish were more numerous in the upper 60 m of the water column, but there were also many individual fish enumerated near the seafloor (Figure 5.8).

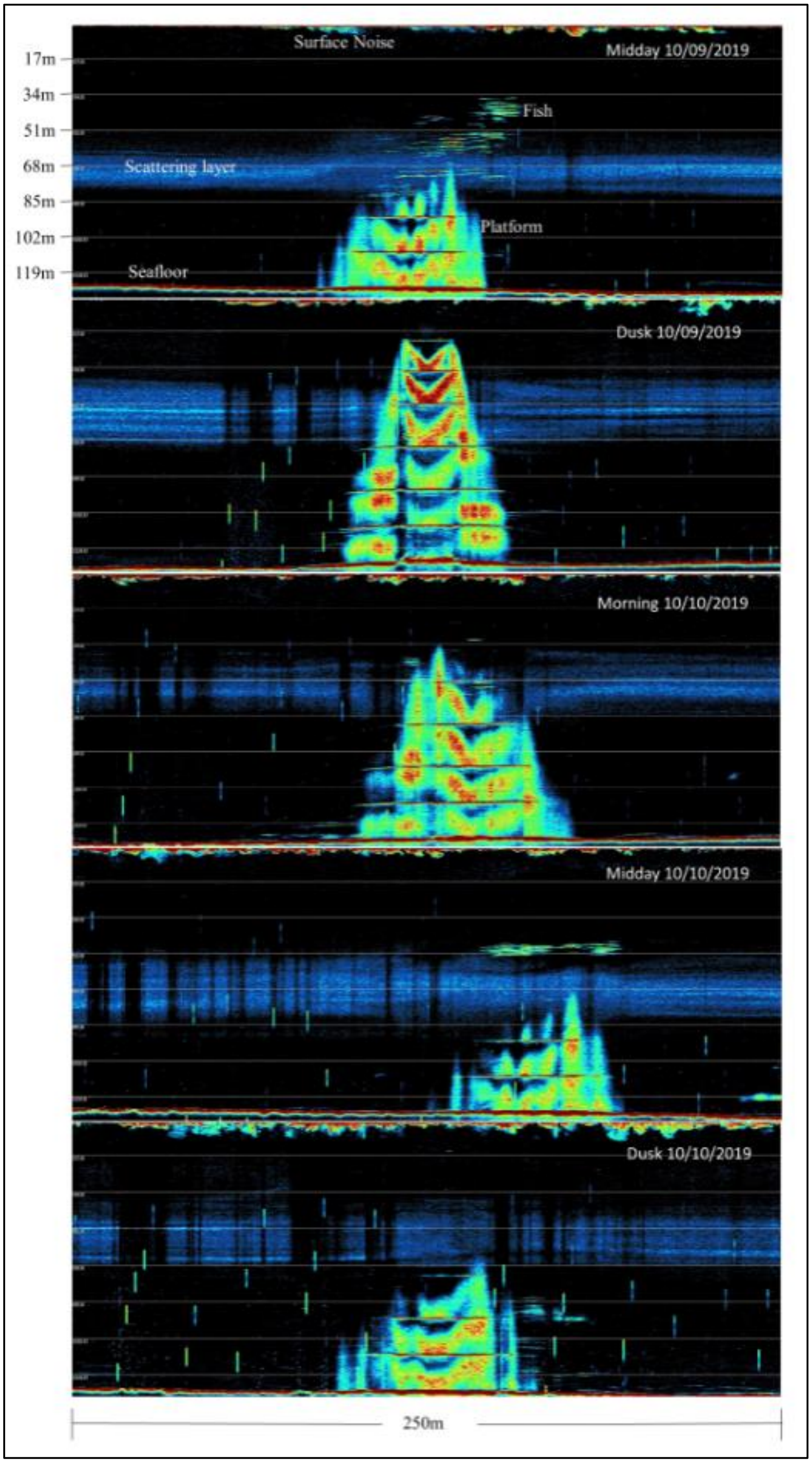


Figure 5.5. Example echograms of the northeast transect from five post-removal surveys conducted in October 2019. Image: NOAA

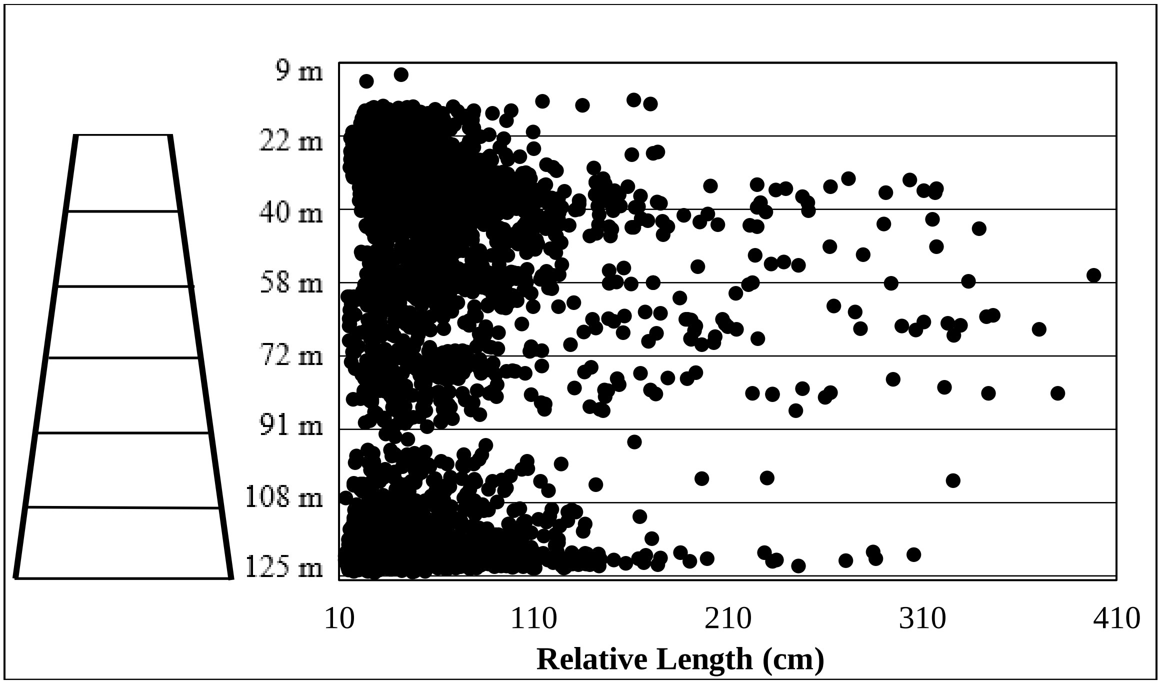


Figure 5.6. Individual fish depths and sizes. Each marker represents an individual fish located at a given depth (m) below surface with total length (in cm) estimated from acoustic target strength.

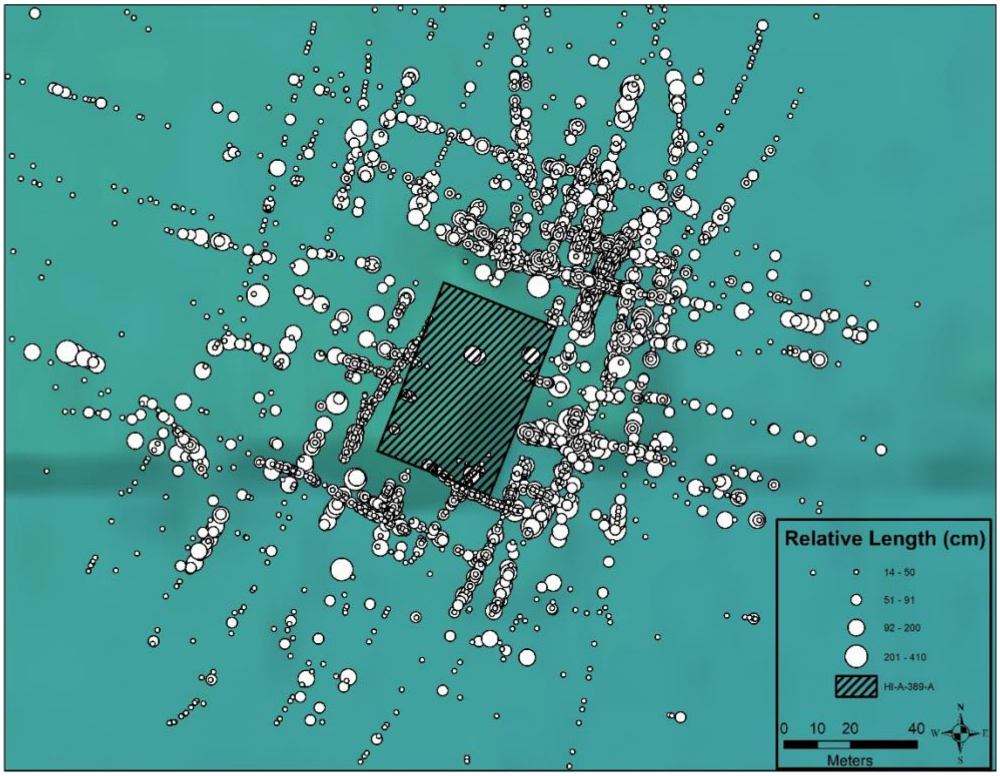


Figure 5.7. Individual fish detected during fishery acoustic surveys around the HI-A-389-A platform footprint. Each marker represents an individual fish, with marker size proportional to estimated total length (in cm).

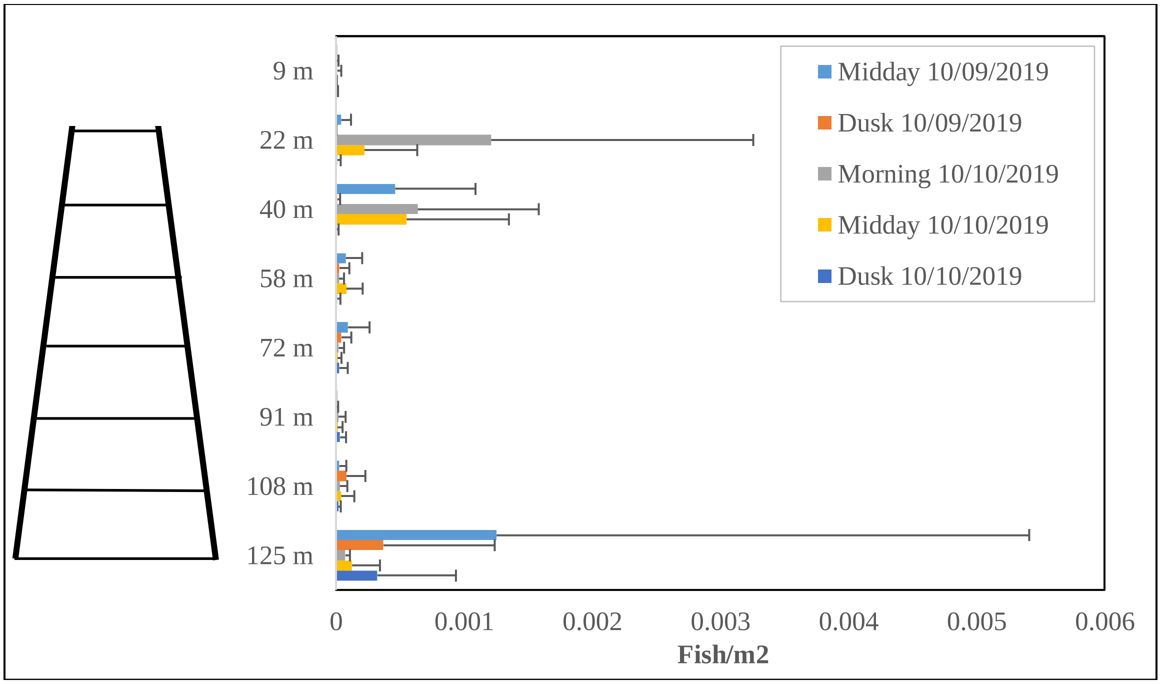


Figure 5.8. Fish densities by depth strata for each of the five post-removal surveys conducted in October 2019.

Comparison of Pre- and Post-Removal Acoustic Results

Though there was not an overall difference in the densities between pre- and post-removal surveys, fish densities were higher in the upper 27 m depth strata prior to partial removal of the structure. Densities overall were higher during post-removal surveys in the lower water column (deeper than 64 m) (Figure 5.9). Densities near the seafloor were also higher in post-removal surveys.

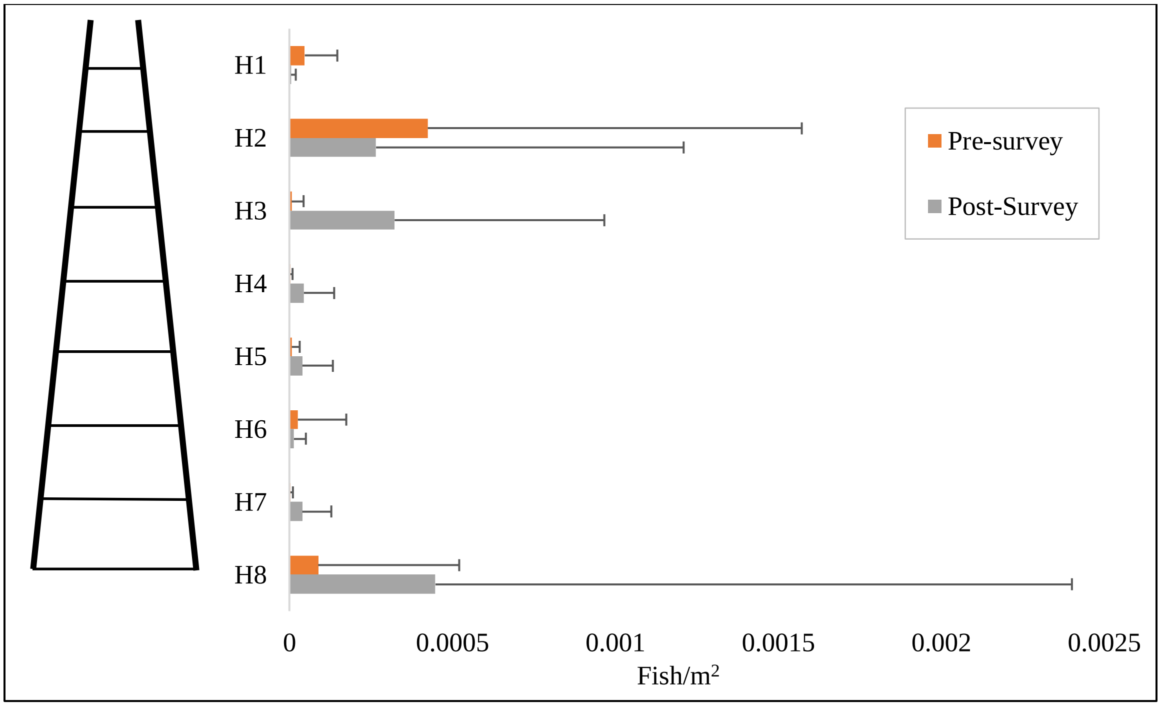


Figure 5.9. Comparison of fishery acoustics-derived densities pre- and post-removal. Data presented as mean and standard deviation.

Fish Acoustic Comparison and Discussion

Pre-Removal Acoustic Surveys

Pre-removal fishery acoustic surveys documented locations of individual fish and densities of fish around the HI-A-389-A platform. Five surveys were conducted over two days. Visual surveys were not conducted during the June 2016 fishery acoustic surveys; therefore, densities cannot be attributed to species or groups of fishes. Fish were generally more abundant on the western margins of the platform, which may be related to where fish may find shelter from currents behind the platform. We were not able to record currents during these surveys, so we can only speculate on the mechanisms driving fish distribution. Fish were detected around the platform and at all depths, but it was not possible to detect and enumerate fish within the structure due to shadowing and obstruction by the loud reflections from the platform structure. The rough and deteriorating sea conditions also caused more vessel movement as the surveys extended into 2 June 2016. It is possible that fish in close proximity to the platform were missed due to vessel movement, which could have biased estimates of density.

Post-Removal Acoustic Surveys

Fishery acoustic densities were notably low in the upper 27 m of the water column following removal of the structure; still, densities were generally higher in the upper water column. During one survey, there were relatively high fish densities close to the seafloor, possibly attributed to diel behaviors of fish in these depth strata. Variation in densities was still an order of magnitude across the five surveys.

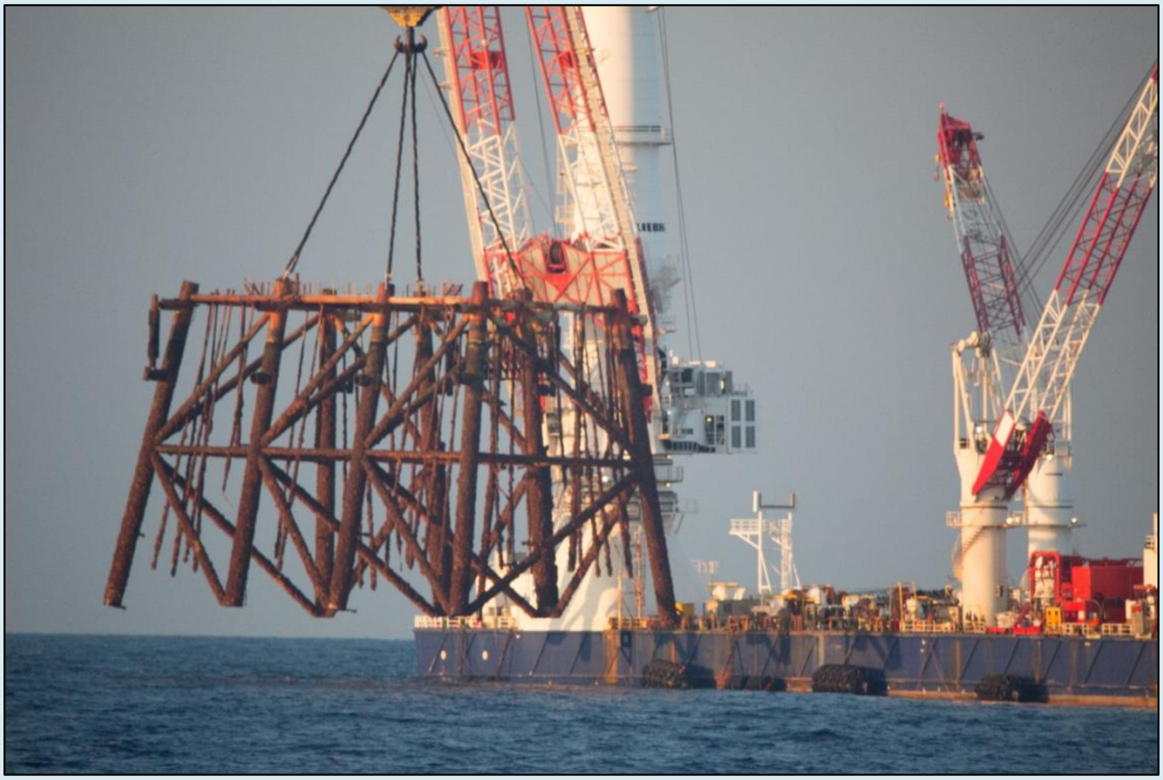
Pre- and Post-Removal Fish Acoustics

Fishery acoustic surveys were conducted during a single mission pre- and post-removal. The acoustic surveys around the platform provided a unique image of pelagic fish using the structure that cannot be adequately quantified using divers. Large schools of fish were observed during both surveys in close proximity to the platform and especially in the upper water column, however fish and fish schools were absent from the upper 27 m following removal. Oil and gas platforms throughout the Gulf of Mexico are well known for attracting large numbers of schooling species like jacks, spadefish, and some snappers, as well as abundant schools of prey fish species and structure-associated fishes (Cowan and Rose 2015). During this study, divers observed chub, several species of jack and barracuda, as well as hammerhead, silky, and blacktip sharks. While we were not able to validate fish species during the acoustic surveys, it is likely that schooling species like jacks, but also smaller-bodied prey species, dominated the fish biomass observed during the fishery acoustic surveys. Without quantified measures of these large predators and pelagic species by depth, it is difficult to determine whether the removal of the top of the jacket altered the composition of pelagic predators (jacks) versus reef-associated predators (snapper and grouper).

Observed fish densities in the present study were similar to previous surveys on other toppled or active platforms (Wilson et al. 2003) and within the order of magnitude observed during recent surveys of the coral reef habitats on EFGB (Clarke et al. 2014). Fish were also closely associated with the platform, typically within a 100 m radius, as in previous studies of platforms and artificial reefs (Stanley and Wilson 1996, 1997, 2000; dos Santos et al. 2010).

Fishery acoustic surveys were only conducted over a few days pre- and post-removal. Without repeated surveys over seasons, times of day, or to account for other environmental factors, it is challenging to draw conclusions on the potential impacts of the removal of the platform on the densities of fish around the remaining structure. Significant variation among transects within pre- and post-removal surveys further emphasizes the high variability in densities of fish that associate with the platform. During repeated surveys of EFGB in a previous ecological assessment of FGBNMS, acoustic densities integrated over the entire water column above high-relief coral reef habitats were about an order of magnitude higher, on average, compared with our observations around the HI-A-389-A platform (Caldow et al. 2009). Possible seasonal patterns may also be present with higher fish densities observed in the summer compared to the fall over EFGB (Clarke et al. 2014).

Chapter 6: Water Quality Profiles



The top section of HI-A-389-A is lifted from the water in July 2018 by *Nor Goliath*. Photo: G.P. Schmahl/NOAA

Water Quality Profiles

Pre-Removal Water Column Profile Results

Water column profiles taken from September 2015 through May 2017 exhibited similar trends, revealing that water column temperature characteristically decreased with depth and displayed seasonal variation (Figure 6.1). The warmest surface water temperatures, recorded at 28.9°C, occurred during the September 2015 profile, which coincided with the coolest water temperature at depth, logged at 17.3°C. Conversely, the lowest sea surface temperature, recorded at 20.6°C during the February 2016 profile, was only 2.9°C greater than temperature at depth (the minimum difference recorded during this study). The profile from May 2017 exhibited a stable water temperature to about 80 m before decreasing by 6°C between 80 m and 100 m. Temperatures varied seasonally by about 8.1°C at the surface and 3.5°C at a depth of 120 m.

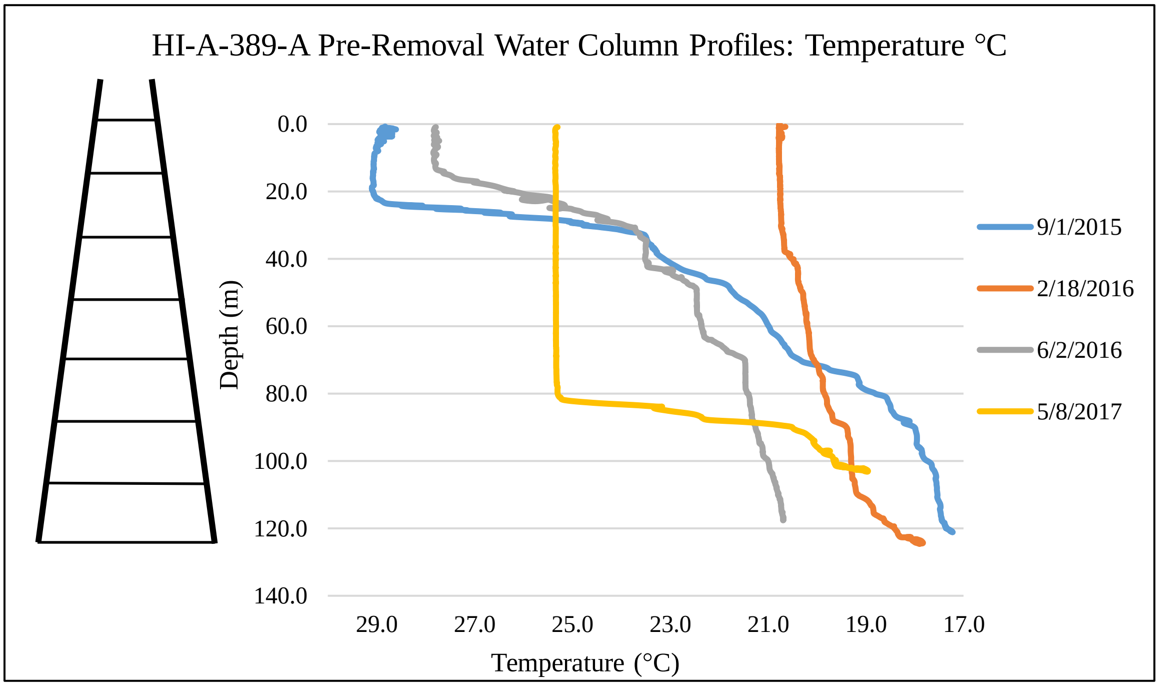


Figure 6.1. Water column temperature relative to depth from four casts occurring between September 2015 and May 2017.

Water column pH data clustered closely around a value of eight and tended to decrease slightly with depth (Figure 6.2). Average oceanic water pH is 8.1, but can range several tenths depending on local conditions (EPA 2019). The May 2017 data were slightly higher at an average pH value of 8.3, whereas the other casts exhibited average pH values of 8.1. The variable pH values in May 2017 from 80 m to 100 m may be attributed to variations in salinity that occurred within the same depth (Coles and Jokiel 1992).

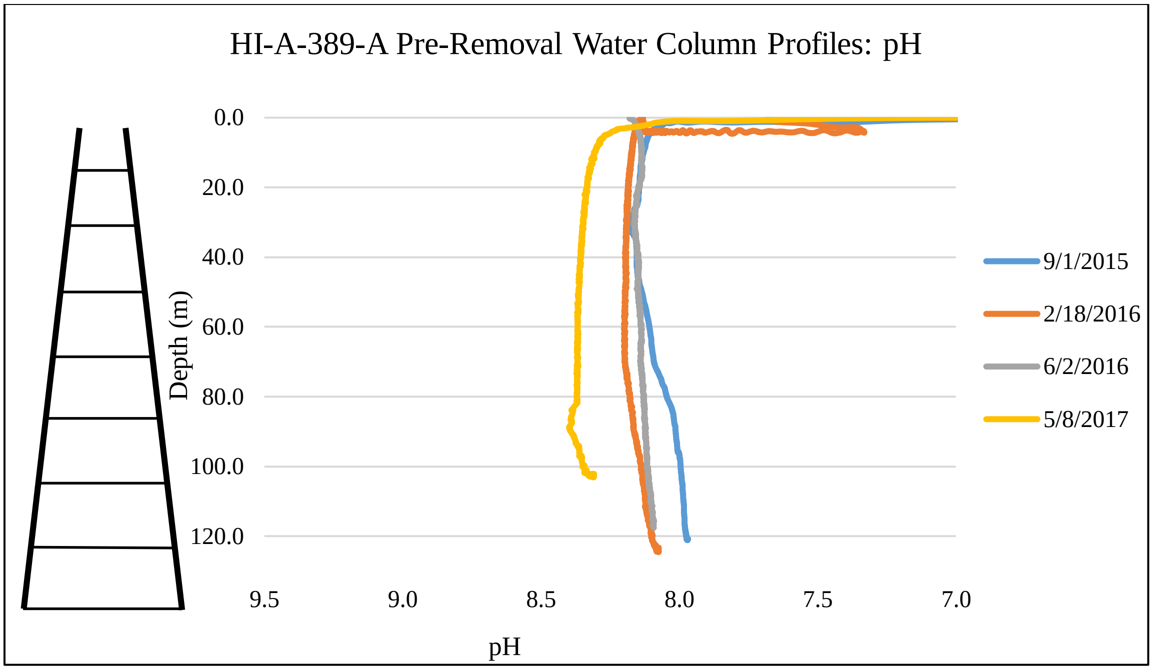


Figure 6.2. Water column pH relative to depth from four casts occurring between September 2015 and May 2017**.**

Average salinity in open ocean waters of the Gulf of Mexico is 35 to 36 practical salinity units (psu) (Coles and Jokiel 1992). Recorded salinity values throughout the water column adjacent to the platform averaged 36.3 psu. An outlier occurred during the June 2016 cast, when reduced salinity from the surface to approximately 50 m decreased the average salinity to 35.9 psu. The lowest recorded salinity of 33.6 psu was recorded at 4.8 m during the same cast (Figure 6.3). A maximum salinity value of 36.9 psu was recorded in May 2017 at a depth of 0.4 m. Salinity at the surface was much more variable compared to salinity beyond a depth of 60 m; however, differences of up to one psu between 80 m and 90 m were evident in the May 2017 cast.

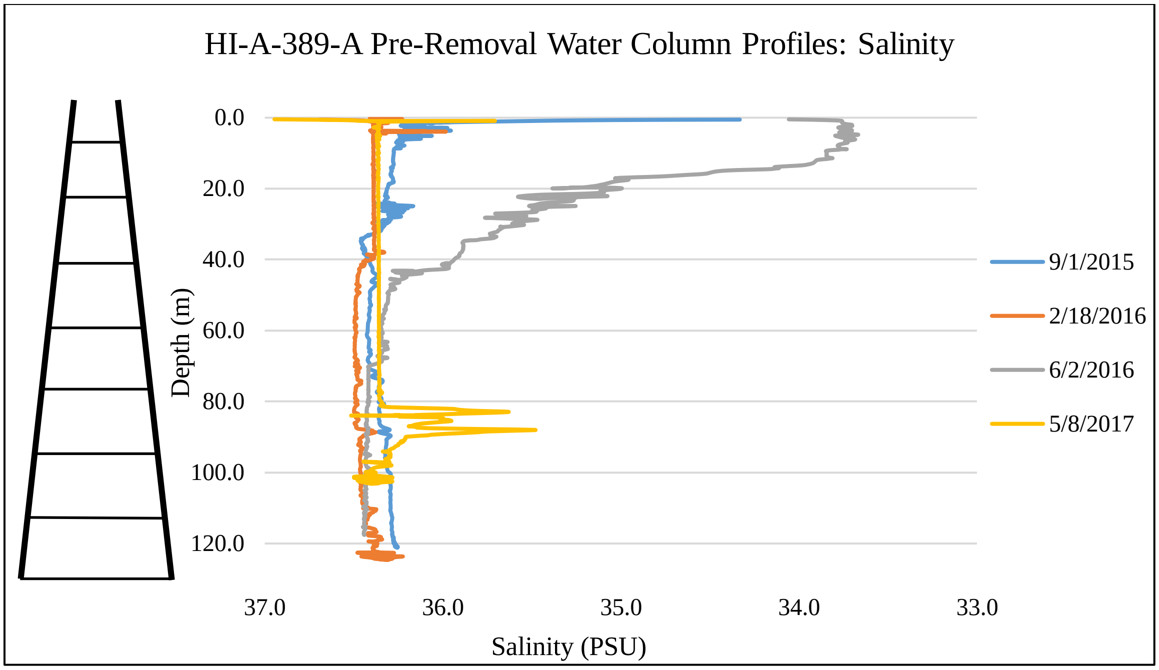


Figure 6.3. Water column salinity relative to depth from four casts occurring between September 2015 and May 2017.

Typical dissolved oxygen (DO) readings in the open ocean average 4.5 mL/L. DO profiles from September 2015 through June 2016 grouped closely at the surface and generally decreased with depth (Figure 6.4). The May 2016 cast exhibited a minimum difference of 1.42 mL/L between surface water and water at depth, whereas the profile from February 2016 exhibited a difference of 2.4 mL/L between surface and deeper water. According to the profile data, DO decreased with depth; however, the September profile exhibited a trend in which DO decreased from 30 m to 80 m, then leveled off at about 2.4 mL/L from 80 m to 120 m. DO data from the May 2017 cast were omitted due to a failure in the Sea-Bird® Electronics 43 DO sensor.

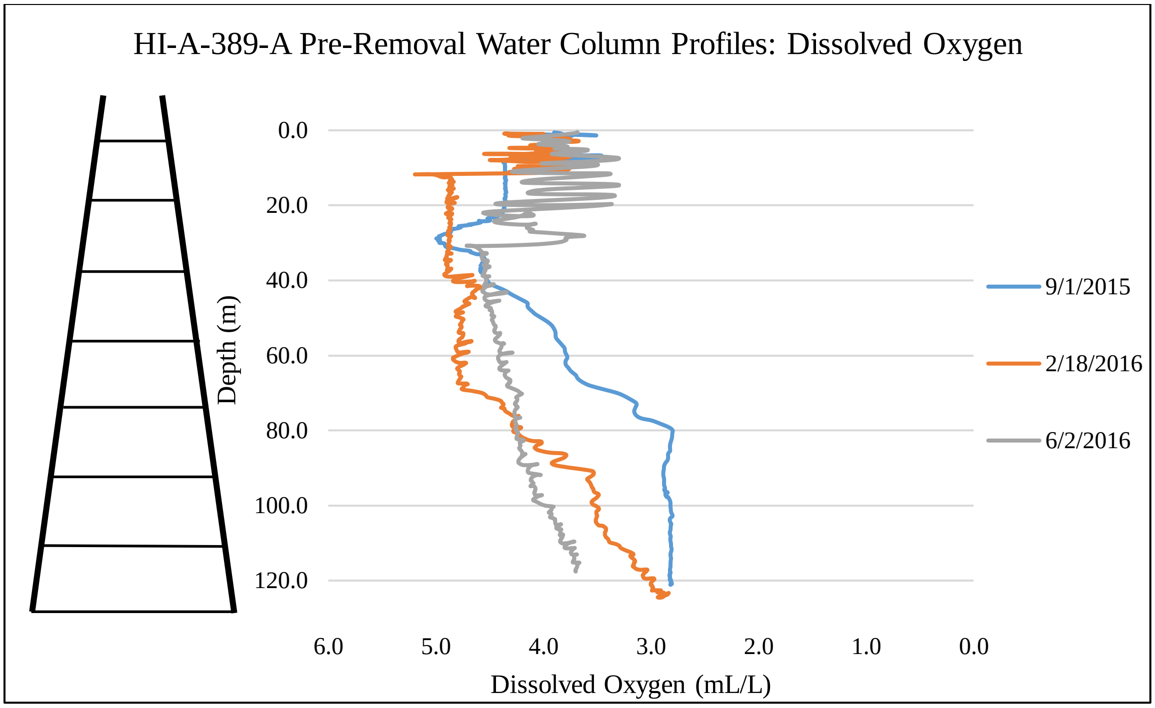


Figure 6.4. Water column dissolved oxygen relative to depth from three casts occurring between September 2015 and June 2016. Dissolved oxygen readings from May 2017 were omitted due to a defective sensor.

Turbidity data for the majority of the profiles are overlaid at -0.1 nephelometric turbidity units (ntu) from the surface to a depth of 120 m (Figure 6.5). Very small negative readings are typical of the ECO-NTU turbidity meter in clear open ocean water. These small turbidity values are characteristic of clear, open ocean water that is generally nutrient-deficient.

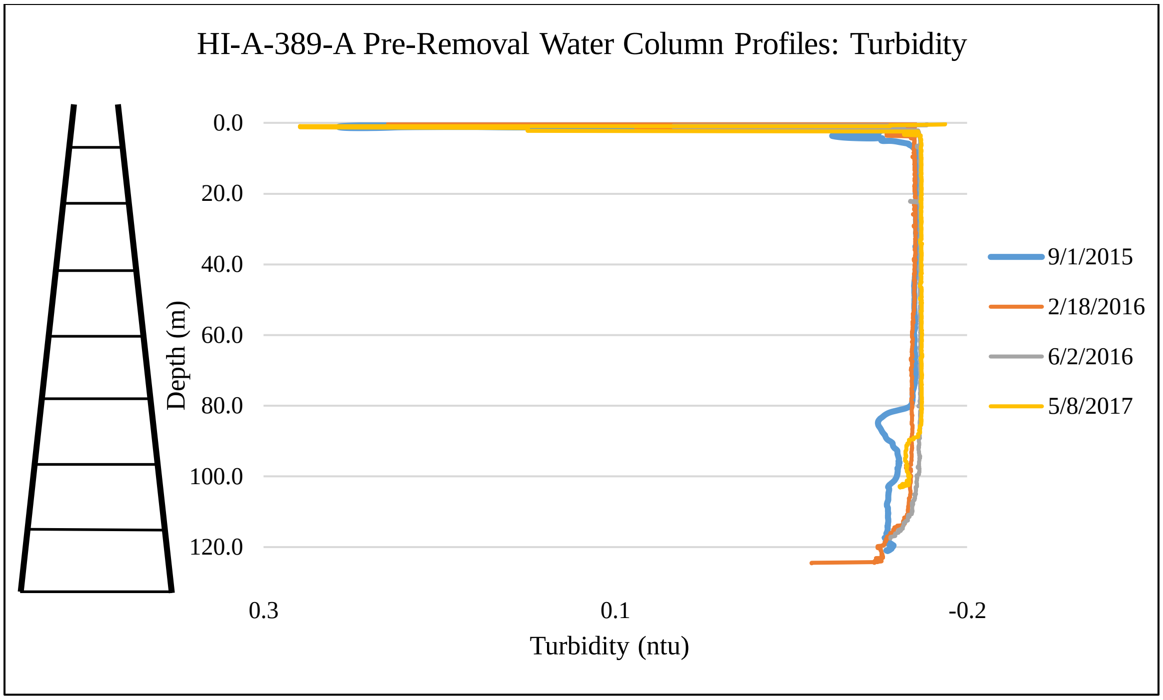


Figure 6.5. Water column turbidity relative to depth from four casts occurring between September 2015 and May 2017**.**

Fluorescence information is directly related to the concentration of photosynthetic pigments such as chlorophyll, and thereby phytoplankton, present in the water column. Across surveys, fluorescence measurements followed similar trends: values increased slightly from the surface to 40 or 60 m, markedly increase from 40 to 80 m or deeper, then decreased from ~80 to 120 m (Figure 6.6). This sudden increase and subsequent decrease in fluorescence appeared deepest in the water column during the May 2017 cast, peaking at about 90 m, whereas the other fluorescence spikes occurred between 40 and 80 m. The September 2015 cast exhibited a peak at approximately 50 m before slowly decreasing with depth.

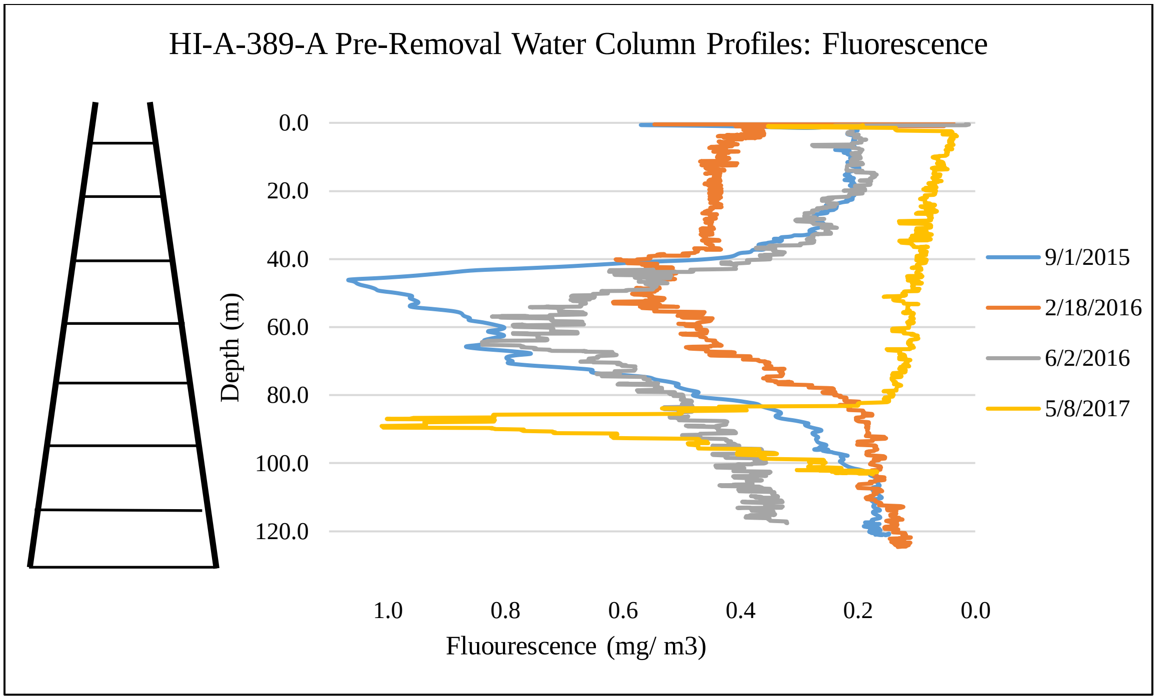


Figure 6.6. Water column fluorescence relative to depth from four casts occurring between September 2015 and May 2017**.**

Post-Removal Water Column Profile Results

Post-removal water column temperature during the May 2019 cast decreased with depth, dropping 4°C from 60 to 100 m (Figure 6.7).

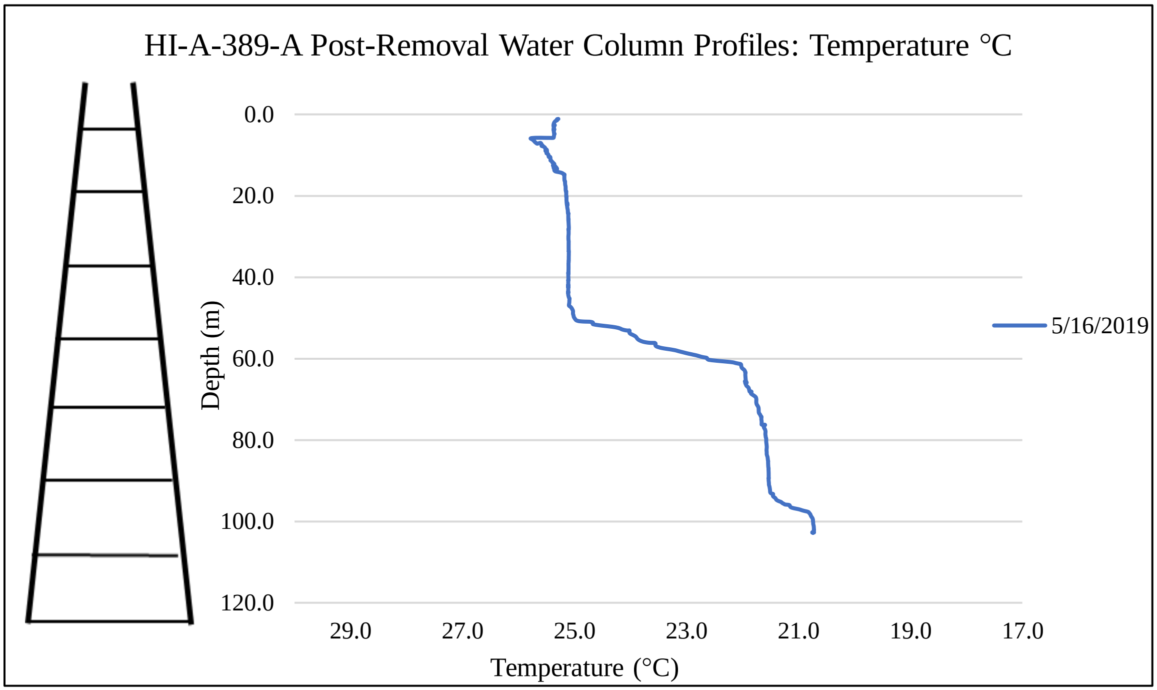


Figure 6.7. Post-removal water column profile exhibiting temperature relative to depth from cast on May 2019.

No pH data were available from the May 2019 cast due to a malfunctioning Sea-Bird® Electronics 18 pH sensor.

Salinity during the May 2019 cast was variable from the surface to approximately 15 m, then generally stabilized below 15 m (Figure 6.8). Between 50 m and 60 m, some variation in salinity corresponded to a 4°C drop in temperature within the same depth range. Salinity values throughout the water column adjacent to the platform averaged 36.3 psu, which is comparable to average salinity data in open ocean waters (typically between 35 and 36 psu).

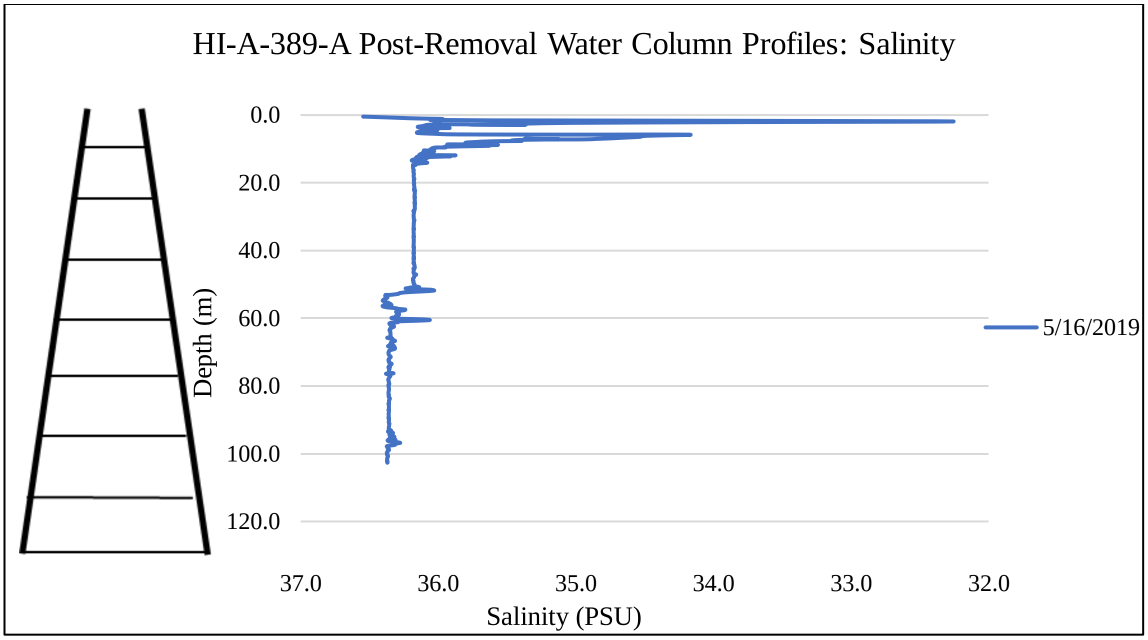


Figure 6.8. Post-removal water column salinity relative to depth from a cast in May 2019.

The DO profile from the May 2019 post-removal water column profile was more variable from the surface to 15 m, but stabilized somewhat with depth (Figure 6.9). The DO profile was similar to the salinity profile in that a relatively small spike of 0.1 mL/L was evident in the 55 m depth range.

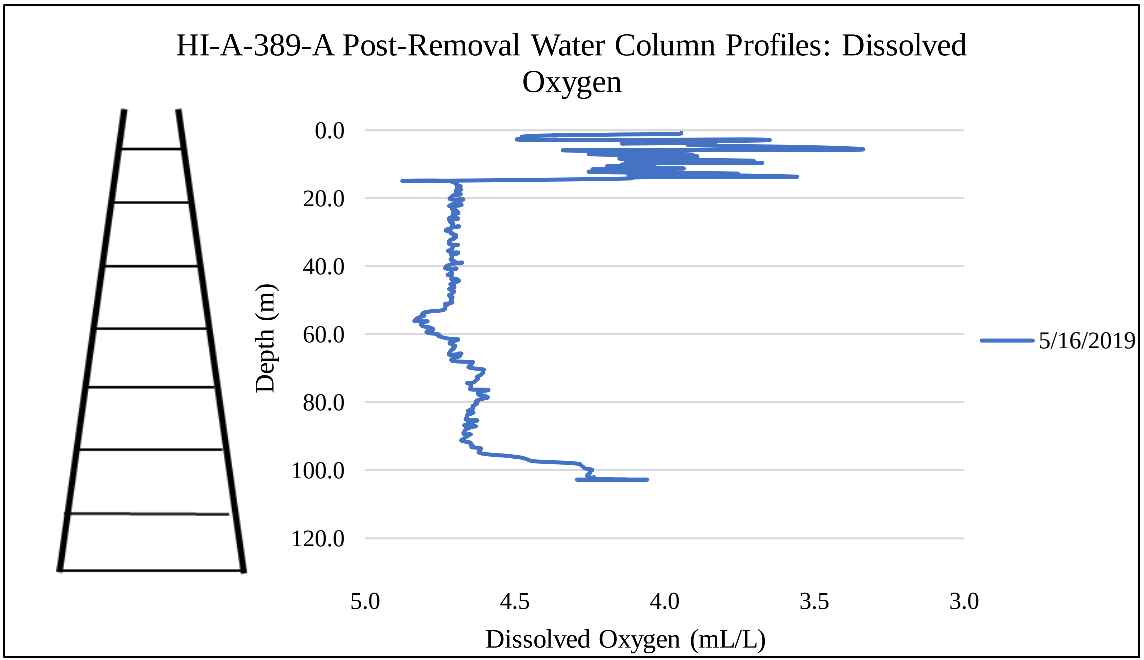


Figure 6.9. Post-removal water column dissolved oxygen relative to depth from a cast in May 2019.

May 2019 turbidity averaged 0.7 ntu. Turbidity was elevated from the surface to 7 m, where turbidity stabilized at 0.4 ntu (Figure 6.10). Slightly more turbid water appeared again between 90 and 100 m, where a similar drop in DO and temperature were also recorded.

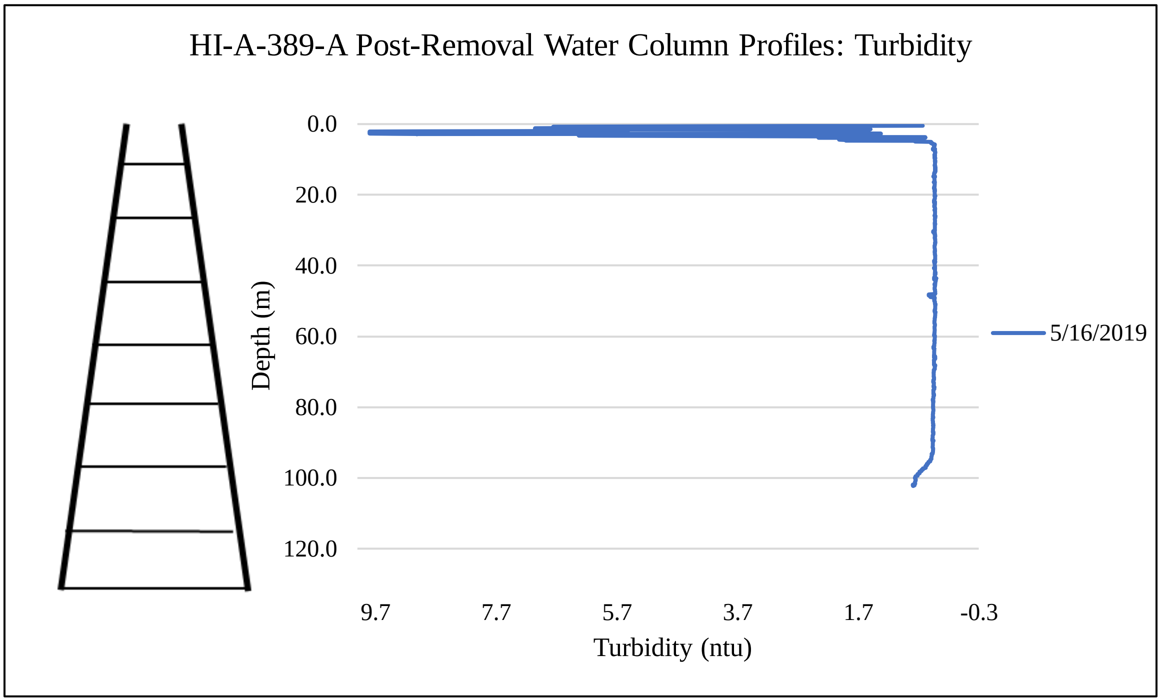


Figure 6.10. Post-removal water column turbidity relative to depth from a cast in May 2019.

Fluorescence readings are related to the amount of chlorophyll, and thereby phytoplankton, that may be present in the water column. Fluorescence measurements from the post-removal water column profile exhibited elevated sea surface readings before decreasing to a minimum of 0.01 mg/m^3 at 5.3 m (Figure 6.11). Fluorescence increased slightly from a depth of 5.3 m to 55 m before an abrupt 0.41 mg/m^3 increase at a depth of 60 m. Values remained elevated to approximately 90 m. Fluorescence then rapidly decreased from a depth of 93 m to 100 m.

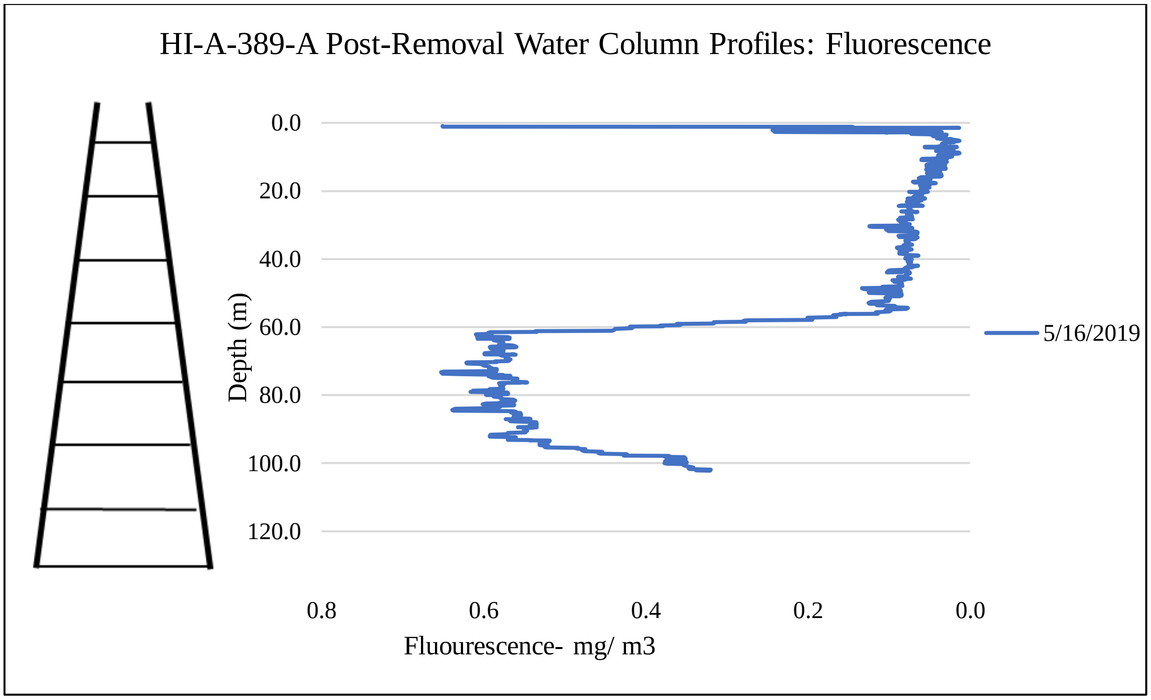


Figure 6.11. Post-removal water column fluorescence relative to depth from a cast in May 2019.

Comparison of Pre- and Post-Removal Water Column Profile Results

The profiles taken in May of 2017 and 2019 exhibited similar sea surface temperatures; however, the profile from 2017 demonstrated a stable temperature to about 80 meters before decreasing 6°C between 80 and 100 meters, whereas the 2019 profile revealed that water temperature decreased 4°C from 55 m to 100 m (Figure 6.12). Profiles in February 2016, June 2016 and September 2015 indicated more gradual changes in temperature rather than sudden, stepwise temperature changes. Temperatures varied seasonally by about 8.1°C at the surface and 3.5°C at a depth of 120 meters. This indicates that the water column adjacent to the platform tended to stratify from late spring to fall, but became more homogenous in the winter months.

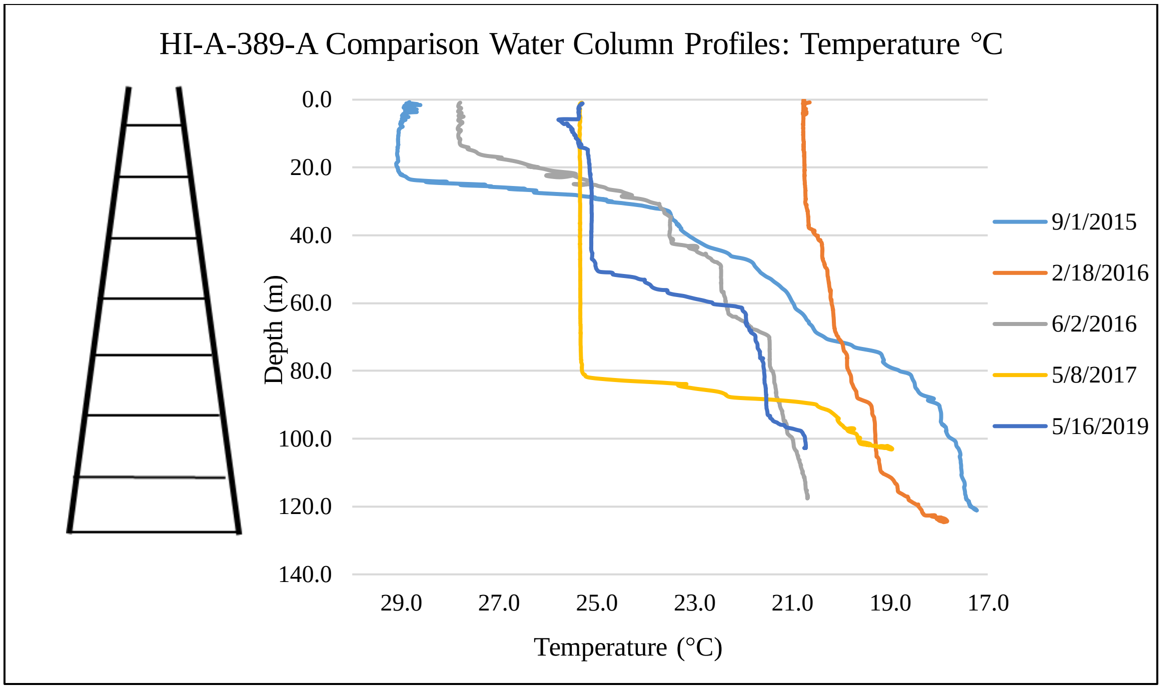


Figure 6.12. Comparison of water column temperature relative to depth from five casts occurring between September 2015 and May 2019.

No pH data were available for pre-removal/post-removal comparison due to a faulty pH sensor during May 2019 operations.

Salinity at the surface, both pre-removal and post-removal, was more variable compared to deeper salinity readings (Figure 6.13). In May 2017 and 2019, profiles were similar, with greater surface variability observed in 2019. Similar variations in salinity, temperature, DO, and fluorescence during the May 2017 and 2019 profiles indicated abrupt changes in water column characteristics by depth.

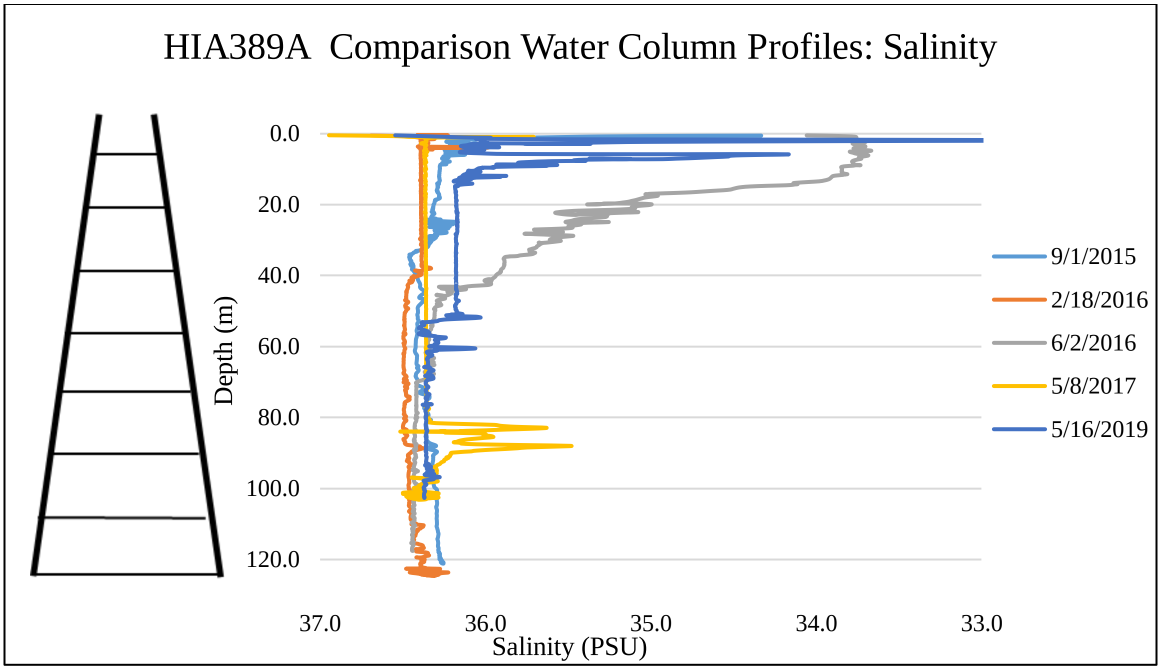


Figure 6.13. Comparison of water column salinity relative to depth from five casts occurring between September 2015 and May 2019.

DO profiles were similar pre-removal and post-removal in that greater variability was evident closer to the sea surface and DO generally decreased with depth (Figure 6.14). However, DO in September 2015 profiles decreased more rapidly from a depth of 40 m to 80 m compared to other profiles. February 2016 and September 2015 DO decreased to a value around 3 mL/L at a depth of 120 m, whereas DO values at depth were closer to 4 mL/L for the June 2016 and May 2019 profiles. DO data from the May 2017 cast were omitted due to a failure in the Sea-Bird® Electronics 43 DO sensor.

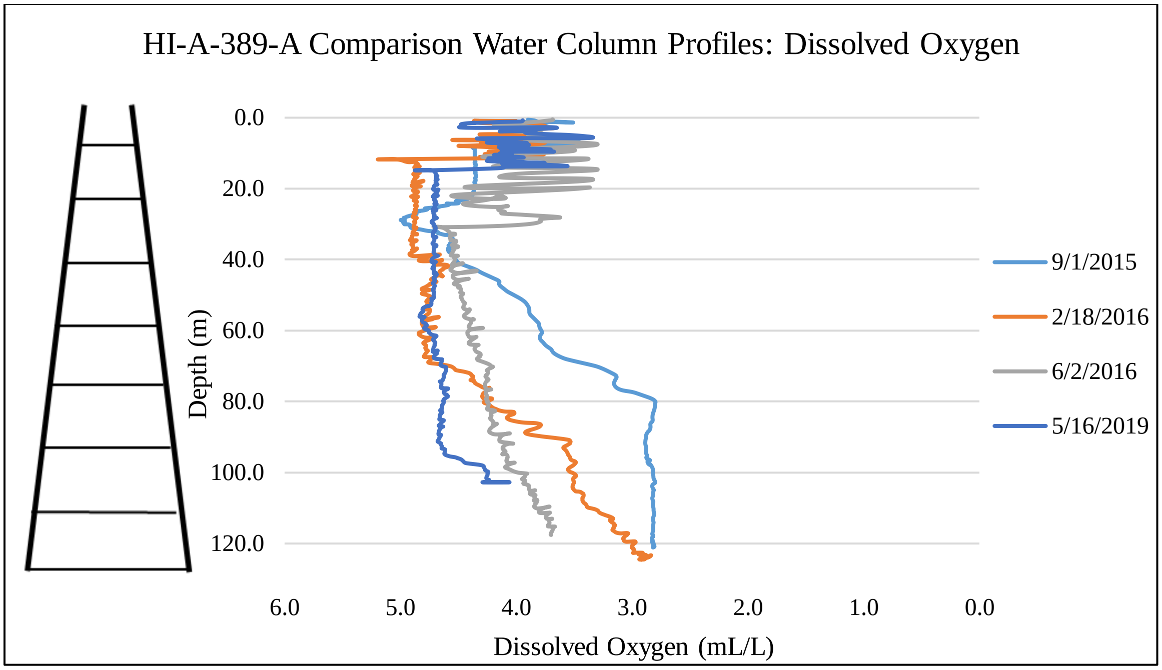


Figure 6.14. Comparison of water column dissolved oxygen relative to depth from four casts occurring between September 2015 and May 2019. Dissolved oxygen readings from May 2017 were removed due to a defective sensor.

Turbidity values pre-removal exhibited consistent values of -0.1 ntu from the sea surface to a depth of 120 m. Post-removal profile data showed increased turbidity in the water column, particularly at the sea surface, where values reached 9.8 ntu before falling to 0.4 ntu from a depth of 7.8 m to 100 m (Figure 6.15). Although turbidity values increased post-removal, this increase is negligible and indicates that the water surrounding the platform remained characteristic of clear open ocean water.

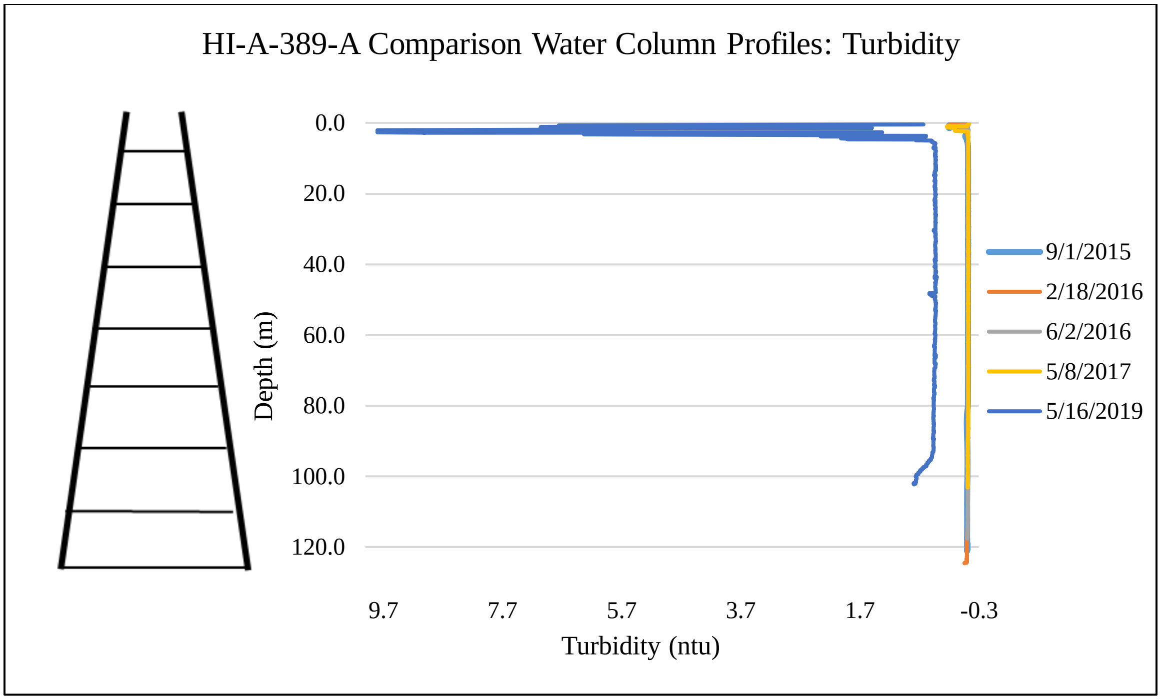


Figure 6.15. Comparison of water column turbidity relative to depth from five casts occurring between September 2015 and May 2019.

Similar trends in fluorescence were observed during both pre-removal and post-removal profiles (Figure 6.16). Values remained constant or slightly decreased from the surface to 40 or 60 m, then displayed a marked increase from 40 to 80 m (or deeper), before declining again down to a depth of 120 m. The February 2016 and May 2019 casts display similar trends, but the depth at which the May 2019 fluorescence peaked was about 35-40 m deeper compared to February 2016. The May 2019 fluorescence peak persisted through a depth range of 15 m, whereas the fluorescence peak in May 2017 covered a much smaller depth range (an extent of about 5 m).

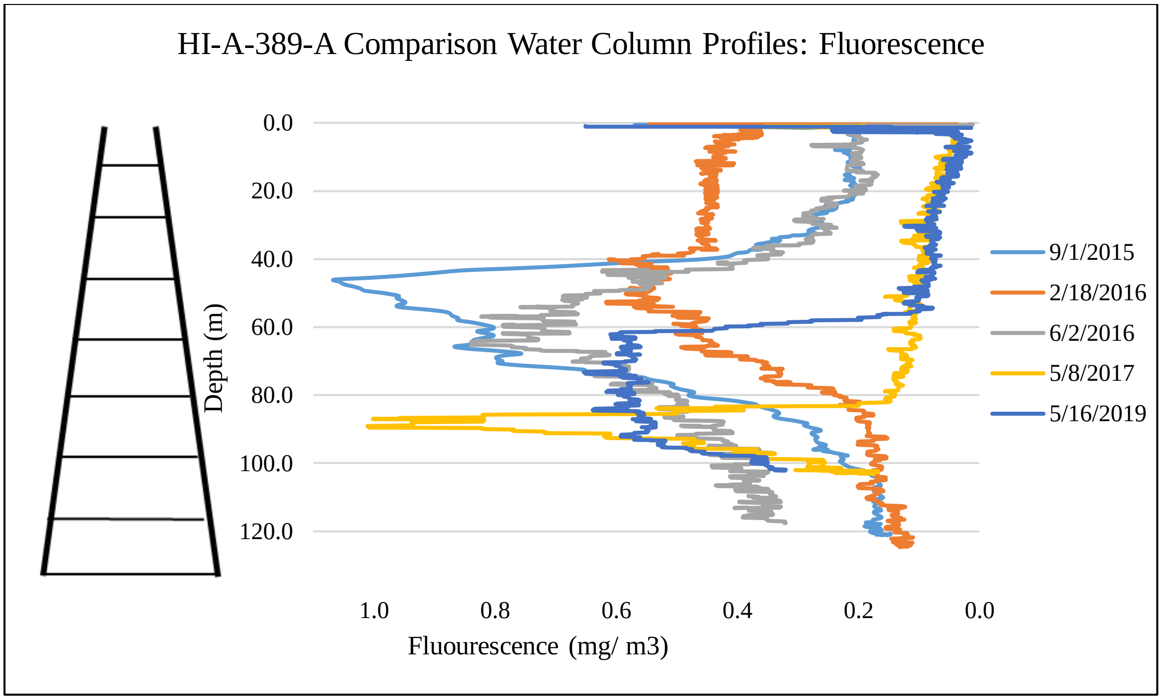


Figure 6.16. Comparison of water column fluorescence relative to depth from five casts occurring between September 2015 and May 2019.

Water Quality Comparison and Discussion

Pre-Removal Water Quality Profiles

According to water column profiles from September 2015 through May 2017, the waters surrounding the platform were characteristic of typical open ocean water: salinity averaged 36.3 psu, temperatures fluctuated seasonally and decreased with depth, DO ranged between 3 and 5 mL/L and decreased slightly with depth, and turbidity was very low, indicating clear, nutrient-poor water throughout the sampled water column. Turbidity profiles do not reflect the presence of a nepheloid layer, which may be explained by the fact that the instrument was not lowered all the way to the seafloor (125 m) to prevent entanglement. Fluorescence data from each of the four profiles exhibited similar trends, spiking between 40 m and 80 m, except for one instance where a spike occurred at 90 m. Because all pre-removal profiles were taken in the afternoon hours, the difference in the depth of the fluorescence peak in May 2017 is likely not attributable to diurnal vertical migration. Increased variation in DO from the surface to a depth of 10 m is typical in seawater at FGBNMS (Johnston et al. 2018), depending upon the effects of wind and wave action, and DO values deviate less as depth increases.

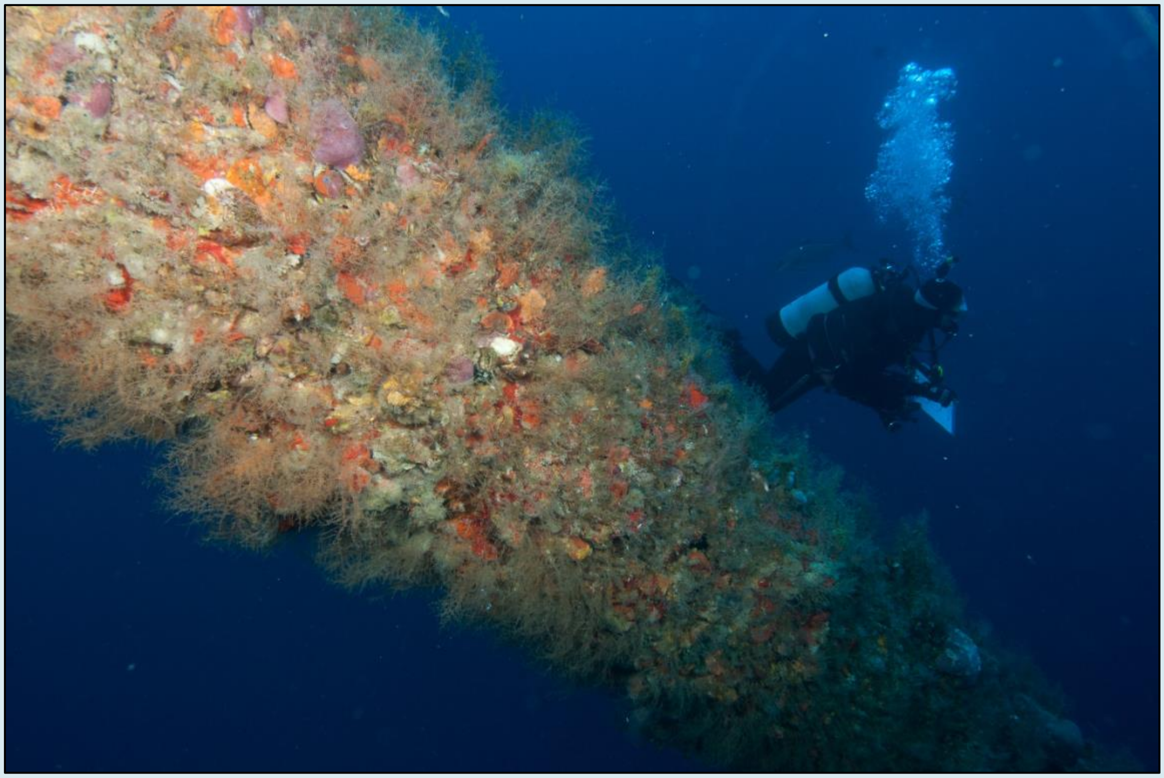
Post-Removal Water Quality Profiles

The post-removal profile from May 2019 revealed that the water surrounding the platform is behaving as open ocean water. According to the temperature profile, a thermocline was present at a depth of 55 m and corresponded to a small increase in DO, with some variability in salinity and fluorescence in the same depth range. Turbidity profiles do not reflect the presence of a nepheloid layer, which may be explained by the fact that the instrument was not lowered all the way to the seafloor (125 m) to prevent entanglement. Additional CTD casts throughout the year would provide greater resolution into seasonal variation in water column characteristics.

Pre- and Post-Removal Water Quality Profiles

Direct comparisons between pre- and post-removal water column characteristics are difficult due to a paucity of profile data adjacent to the platform, particularly post-removal. Temperature varied seasonally and similar trends were noted across all temperature profiles taken between September 2015 and May 2019. Pre-removal pH data grouped closely around a value of 8 and decreased slightly with depth. Due to a failed pH sensor during post-removal casts, comparisons to pre-removal values could not be completed. The typical salinity of the open ocean is 36 psu (Coles and Jokiel 1992), which was consistent with salinity measurements pre- and post-removal at the platform. There was more variability in salinity readings at the surface throughout the sampling period, which was expected. Dissolved oxygen values oscillated between 3 and 5 mL/L, with greater variation at the sea surface, likely due to wind and wave action. Post-removal DO data aligned with pre-removal DO data to a depth of 70 m and stayed slightly elevated compared to pre-removal DO data to a depth of 100 m. Post-removal turbidity was consistently elevated by 0.5 ntu throughout the entire water column compared to pre-removal turbidity data. Turbidity was also more variable at the surface during the May 2019 post-removal profile, possibly indicating a period of increased turbidity overall. Turbidity profiles do not show the presence of a nepheloid layer, which may be because the instrument was not lowered all the way to the seafloor (125 m) to prevent entanglement. Fluorescence maxima varied by profile, but fluorescence followed similar trends both pre- and post-removal.

Chapter 7: Conclusions



Diver conducts roving fish survey at HI-A-389-A. Photo: G.P. Schmahl/NOAA

The partial removal of the upper portion of HI-A-389-A, located within FGBNMS, provided a unique opportunity to document changes in the biological community associated with the removal of the upper portion of the artificial reef structure, including the working deck, top sections of the platform jacket, and well conductors. The platform was in place in complete formation from October 1981 until July 2018. The underwater structure of the platform provided an artificial substrate upon which organisms could settle and grow, and the working deck essentially served as a shade structure prior to its removal. The location of the platform in FGBNMS, and its close proximity to the natural coral reef of EFGB, has resulted in an elevated level of interest, historically, for this project, and also for future monitoring activities.

The benthic community that developed on and around the structure during the life of the platform is dominated by a fouling community, primarily consisting of sponges, hydroids, macroalgae, bivalves, barnacles, tunicates, zoanthids, bryozoans, and several stony coral species. The stony coral community is dominated by exotic *Tubastraea* sp., which is native to the Indo-Pacific. Analysis of the benthic community suggests four biologically distinct zones occur, likely driven by light availability, temperature, and sedimentation.

A significant change in the benthic community was documented following the removal of the upper structure of the platform; a decrease in hydroid cover was the main contributor to the observed differences in community structure pre- and post-removal. Macroalgae and hydroids exhibited an inverse response to the partial removal. Sponges and corals experienced a variety of less dramatic changes, both increasing and decreasing at different levels.

The removal of the working deck structure presumably resulted in a change in light availability on the sides of the platform. Additionally, the shadow originally cast by the deck structure may have resulted in differences in light availability depending on the location of the pilings. Differences in shadowing, in combination with the directionality of the pilings in relation to the prevailing current, could contribute to the observed differences in community structure among pilings.

Fish species observed on the platform were primarily invertivores, illustrating the strong link to available food sources in the benthic community. In general, the fish community varied by survey type, level, and pre- and post-removal status. As temporal variability of fish communities is also known to occur on the natural banks within the sanctuary, the changes between pre- and post-removal surveys cannot be attributed solely to the partial removal of the structure. There was no apparent trend of individual fish moving from level H1 after the removal of the structure, with the exception of Atlantic creolefish, which increased in abundance on levels H2 and H3 post-removal. Non-native species, including red lionfish, regal demoiselle, and tessellated blenny, were documented.

Photographed by a multitude of divers over the years, the tessellated blenny has been represented as an iconic fish species for HI-A-389-A. This non-native fish species, documented off the coast of Texas since 1979, was thought to have been brought to the northern Gulf of Mexico through shipping or transport of oil and gas platforms from South America (Schofield 2019). While the impact of this species in its invaded range is unknown, it is known to inhabit empty barnacle tests in shallow water (approximately 4.5 m). On HI-A-389-A, tessellated blennies were only documented pre-removal, on level H1 (9 m depth), and were likely removed along with the structure.

Fishery acoustic surveys revealed large schools of fish during both pre- and post-removal surveys in close proximity to the platform, especially in the upper water column.

The water surrounding the platform changed little over the course of nearly four years and was characteristic of typical open ocean water: temperature varied seasonally and decreased with depth, average salinity was in the range of 36 psu, DO ranged between 3 and 5 mL/L and decreased with depth, turbidity was consistently low, and pH values clustered around 8. A single profile taken post-removal did not indicate any abnormal departures from the representative pre-removal profile data, with the exception of a negligible increase in turbidity.

The changes presented in this study reflect a snapshot in time after removal of the upper portions of the platform, which changed factors that may have previously affected community development, including light availability, water movement, and the dynamics between the motile organisms and the benthic assemblage. The time between removal of the structure and the post-removal surveys was approximately one year. A long-term monitoring program could document continued shifts in the benthic and fish communities and ascertain causes contributing to these shifts. In addition, given the proximity to the natural reefs of FGBNMS, it will be important to monitor the status of the non-native species in the event intervention is necessary.

Literature Cited

Adams, C.L. **1996**. Species composition, abundance, and depth zonation of sponges (Phylum Porifera) on an outer continental shelf gas production platform, northwestern Gulf of Mexico. M.S. Thesis, Texas A&M Corpus Christi, TAMU-CC-9601-CCS. 130 p.

AGRRA (Atlantic and Gulf Rapid Reef Assessment). **2012**. AGRRA Protocols, version 5.4. J.C. Lang, K.W. Marks, P.A. Kramer, P.R. Kramer, and R.N. Ginsburg, ed. 31 p.

Anderson M.J., K.E. Ellingsen, and B.H. McArdle. **2006**. Multivariate Dispersion as a Measure of Beta Diversity. Ecology Letters 9:683-693.

Anderson, M.J., R.N. Gorley, and K.R. Clarke. **2008**. PERMANOVA+ for PRIMER: guide to software and statistical methods. PRIMER-E Ltd. Plymouth, United Kingdom.

Aronson, R.B., P.J. Edmunds, W.F. Precht, D.W. Swanson, and D.R. Levitan. **1994**. Large- scale, long-term monitoring of Caribbean coral reefs: simple, quick, inexpensive methods. Atoll Research Bulletin 421:1–19.

Bell, J., McGrath, E., Biggerstaff, A., Bates, T., Bennett, H., Marlow, J., and M. Shaffer **2015.** Sediment impacts on marine sponges. Marine Pollution Bulletin 94(1-2).

Bohnsack, J.A. and D.E. Harper. **1988**. Length-weight relationships of selected marine reef fishes from the southeastern United Station and the Caribbean. NOAA Technical Memorandum NMFS-SEFC-215. 37pp.

Boland, G.S. **2002**. Fish and epifaunal community observations at an artificial reef near a natural coral reef: Nineteen years at High Island platform A-389-A, from bare steel to coral habitat. Proceedings of Gulf of Mexico Fish and Fisheries: Bringing together new and recent research. New Orleans, LA, MMS 2002-004, 372-392 p.

Boland, G.S. and P.W. Sammarco. **2005**. Observations of the Antipatharian “Black Coral” *Plumapathes pennacea* (Pallas, 1766) (Cnidaria: Anthozoa), Northwestern Gulf of Mexico. Gulf of Mexico Science, 23(1):127-132.

Byers, J. E. **2002**. Impact of non-indigenous species on natives enhanced by anthropogenic alteration of selection regimes. Oikos, 97:449-458.

Calder, D. R. and S. D. Cairns. **2009.** Hydroids (Cnidaria: Hydrozoa) of the Gulf of Mexico, Pp. 381–394 in Felder, D.L. and D.K. Camp (eds.), Gulf of Mexico–Origins, Waters, and Biota. Biodiversity. Texas A&M University Press, College Station, Texas.

Caldow, C., R. Clark, K. Edwards, S.D. Hile, C. Menza, E. Hickerson, and G.P. Schmahl. **2009**. Biogeographic characterization of fish communities and associated benthic habitats within the Flower Garden Banks National Marine Sanctuary: Sampling design and implementation of SCUBA surveys on the Coral Caps. NOAA Technical Memorandum NOS NCCOS 81. Silver Spring, MD. 134 p.

Cárdenas, C.A., S.K. Davy, and J.J. Bell. **2012**. Correlations between algal abundance, environmental variables and sponge distribution patterns on southern hemisphere temperate rocky reefs. Aquatic Biology, 16:229-239.

Cartes, J.E. and Sarda, F. **1993.** Zonation of deep-sea decapod fauna in the Catalan Sea (Western Mediterranean). Marine Ecology Progress Series, 94:27-34.

Claisse, J.T., D.J. Pondella, M. Love, L.A. Zahn, C.M. Williams, and A.S. Bull. **2015.** Impacts from partial removal of decommissioned oil and gas platforms on fish biomass and production on the remaining platform structure and surrounding shell mounds. PLoS ONE, 10(9):e0135812.

Clarke, K.R. **1990**. Comparison of dominance curves. Journal of Experimental Marine Biology and Ecology 138:143-157.

Clarke, K.R., R.N. Gorley, P.J. Sommerfield, and R.M. Warwick. **2014**. Change in marine communities: an approach to statistical analysis and interpretation, 3rd edition. PRIMER-E: Plymouth, Devon, UK. 260 p.

Coles, S.L. and P.L. Jokiel. **1992**. Effects of salinity on coral reefs. In Pollution in tropical aquatic systems, eds. D.W. Connell and D.W. Hawker. Boca Raton, FL: CRC Press. 147–166 p.

Cowan, J.H. and K.A. Rose. 2015. Oil and gas platforms in the Gulf of Mexico: Their relationship to Fish and Fisheries. p. 95-122. *In:* Fisheries and Aquaculture in the Modern World. H. Mikkola (ed.). InTech, Rijeka, Croatia.

Demer, D.A., L. Berger, M. Bernasconi, E. Bethke, K. Boswell, D. Chu, R. Domokos, *et al*. **2015**. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326. 133 p.

dos Santos, L. N., D.S. Brott, and I.R. Zalmon. **2010**. Fish responses to increasing distance from artificial reefs on the Southeastern Brazilian Coast. Journal of Experimental Marine Biology and Ecology 386(1): 54-60.

Embesi, J.A., R.J. Eckert, E.L. Hickerson, M.A. Johnston, M.F. Nuttall, and G.P. Schmahl. **2013**. Benthic community composition associated with a gas platform, High Island A-389-A, located within the Flower Garden Banks National Marine Sanctuary. Proceedings of the 66th Annual Gulf and Caribbean Fisheries Institute. Corpus Christy, TX. Volume 66: 538 p.

Embesi, J.A. **2020**. High Island A-389-A Historical Report, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Flower Garden Banks National Marine Sanctuary. *In preparation*.

EPA. **2019**. Ocean Acidification. World Wide Web electronic publication. United States Environmental Protection Agency. Accessed 12/29/2019. https://www.epa.gov/ocean-acidification/understanding-science-ocean-and-coastal-acidification

Fenner, D. **2001**. Biogeography of three Caribbean corals (Scleractinia) and the invasion of *Tubastraea coccniea* into the Gulf of Mexico. Bulletin of Marine Science. 69(3): 1175-1189.

Fenner, D. and K. Banks. **2004**. Orange Cup Coral *Tubastraea coccinea* invades Florida and the Flower Garden Banks, Northwestern Gulf of Mexico. Coral Reefs 23: 505-507 DOI 10.1007/x00338-004-0422-x.

Foote, K.G., H.P. Knudsen, G. Vestnes, D.N. MacLennan, and E.J. Simmonds. **1987**. Calibration of acoustic instruments for fish density estimation: a practical guide. ICES Cooperative Research Report Number 144. 63 p.

Froese, R. and D. Pauly. Editors. **2019**. FishBase. World Wide Web electronic publication. Accessed 12/10/2019. www.fishbase.org

Gallaway, B.J. and G.S. Lewbel. **1982**. Ecology of petroleum platforms in the northwestern Gulf of Mexico: a community profile. U.S. Fish and Wildlife Service, Office of Biological Sciences, Washington, D.C. FWS/OBS-82/27. Bureau of Land Management, Gulf of Mexico OCS Regional Office, 92 pp.

Gili, J.M. and Hughes, R.G. **1995.** The ecology of marine benthic hydroids. Oceanography and Marine Biology 33: 351-426.

Hickerson, E.L. and G.P. Schmahl. **2005.** The state of coral reef ecosystems of the Flower Garden Banks, Stetson Bank, and other banks in the northwestern Gulf of Mexico, p. 201-221. *In:* The state of coral reef ecosystems of the United States and Pacific Freely Associated States. D.D. Turgeon (ed.). U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science, Washington, DC. Http://ccma.nos.noaa.gov/ecosystems/coralreef/coral_report_2005/

Humann, P. and N. DeLoach. **2014**. Reef fish identification 4th Edition: Florida, Caribbean, Bahamas. New World Publications, Inc., Jacksonville, Florida. 548 p.

Johnston, M.A., M.F. Nuttall, R.J. Eckert, J.A. Embesi, T.K. Sterne, E.L. Hickerson, and G.P. Schmahl. **2016**. Persistence of Coral Assemblages in Flower Garden Banks National Marine Sanctuary, Gulf of Mexico. Coral Reefs 35: 821-826.

Johnston, M.A., R.J. Eckert, M.F. Nuttall, T.K. Sterne, J.A. Embesi, D.P. Manzello, E.L. Hickerson, and G.P. Schmahl. **2017**. Long-term monitoring at East and West Flower Garden Banks, 2013–2015, volume 1: technical report. U.S. Dept. of Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region, New Orleans, Louisiana. OCS Study BOEM 2017-058. 186 p.

Johnston, M.A., T.K. Sterne, R.D. Blakeway, J. MacMillan, M.F. Nuttall, X. Hu, J.A. Embesi, E.L. Hickerson, and G.P. Schmahl. **2018**. Long-term monitoring at East and West Flower Garden Banks, 2017 Annual Report. Marine Sanctuaries Conservation Series ONMS-18-02. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Flower Garden Banks National Marine Sanctuary, Galveston, TX. 124 p.

Johnston, M.A., M.F. Nuttall, R.J. Eckert, R.D. Blakeway, T.K. Sterne, E.L. Hickerson, G.P. Schmahl, M.T. Lee, J. MacMillan, and J.A. Embesi. **2019**. Localized coral reef mortality event at East Flower Garden Bank, Gulf of Mexico. Bulletin of Marine Science. 95(2):239–250.

Kohler, K.E. and S.M. Gill. **2006**. Coral point count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences 32: 1259–1269.

Kolian, S.R., P.W. Sammarco, and S.A. Porter. **2017**. Abundance of Corals on Offshore Oil and Gas Platforms in the Gulf of Mexico. Environmental Management 60: 357–366.

Lewbel, G.S., R.L. Howard, and B.J. Gallaway. **1987.** Zonation of dominant fouling organisms on northern Gulf of Mexico petroleum platforms. Marine Environmental Research 21: 199–224.

Love, R. **1977**. Target strength of an individual fish at an aspect. Journal of the Acoustical Society of America. 62(6): 1397.

Macreadie, P.I., Fowler, A.M., Booth, D.J. **2011**. Rigs-to-reefs: will the deep sea benefit from artificial habitat? Frontiers in Ecology and the Environment, 9(8): 455-461.

Maldonado, M. and C.M. Young. **1996**. Bathymetric patterns of sponge distribution on the Bahamian slope. Deep Sea Research Part I: Oceanographic Research Papers, 43(6), 897-915.

Nuttall, M.F., P.J. Somerfield, T.K. Sterne, J.T. MacMillan, J. Sinclair, E.L. Hickerson, J.A. Embesi, M.A. Johnston, and G.P. Schmahl. **2019**. Long-Term Monitoring at Stetson Bank, Flower Garden Banks National Marine Sanctuary, 1993-2015 Historical Report. National Marine Sanctuaries Conservation Series ONMS-XX-XX. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Flower Garden Banks National Marine Sanctuary, Galveston, TX. 155 p.

Precht, W. F., E.L. Hickerson, G.P. Schmahl, and R. B. Aronson. **2014.** The Invasive Coral Tubastraea coccinea (Lesson, 1829): Implications for Natural Habitats in the Gulf of Mexico and the Florida Keys. Gulf of Mexico Science 32 (1).

Puce, S., G. Bavestrello, A. Arillo, F. Azzini, and C. Cerrano. **2002.** Morpho-functional adaptation to suspension feeding in Eudendrium (Cnidaria, Hydrozoa). Italian Journal of Zoology 69(4): 301-304

REEF. **2019**. Reef Environmental Education Foundation interpreting REEF data. Accessed 12/9/2019. https://www.reef.org/interpreting-reef-data.

Rezak, R., S.R. Gittings, and T.J. Bright. **1990**. Biological Assemblages and Ecological Controls on Reefs and Banks in the Northwestern Gulf of Mexico. American Zoologist. 30:23-35.

Roberson, K. S. Viehman, and R. Clark. **2014**. Development of Benthic and Fish Monitoring Protocols for the Atlantic/Caribbean Biological Team: National Coral Reef Monitoring Program. NOAA Coral Reef Conservation Program. 8 p.

Sammarco, P.W., A.D. Atchison, and G.S. Boland. **2004**. Expansion of coral communities within the Northern Gulf of Mexico via offshore oil and gas platforms. Mar Ecol Prog Ser. 280: 129–143.

Sammarco, P.W., D.A. Brazeau, and J. Sinclair. **2012.** Genetic Connectivity in Scleractinian Corals across the Northern Gulf of Mexico: Oil/Gas Platforms, and Relationship to the Flower Garden Banks. PLOS ONE 7(4): e30144.

Sammarco, P.W., A. Lirette, Y.F. Tung, G.S. Boland, M. Genazzio, and J. Sinclair. **2014.** Coral communities on artificial reefs in the Gulf of Mexico: standing vs. toppled oil platforms. ICES J Mar Sci. 71: 417–426.

Sammarco, P.W. and K.B. Strychar. **2016**. Ecological and Evolutionary Considerations Regarding Corals in a Rapidly Changing Environment. In: Goffredo S., Dubinsky Z. (eds) The Cnidaria, Past, Present and Future. Springer, Cham.

Schmitt E.F. and K.M Sullivan. **1996**. Analysis of a volunteer method for collecting fish presence and abundance data in the Florida Keys. Bulletin of Marine Science 59(2): 404-416.

Schofield, P.J. **2019**. *Hypsoblennius invemar* Smith-Vaniz and Acero P. in Smith-Vaniz, 1980: U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=2638, Revision Date: 2/2/2015, Peer Review Date: 4/1/2016, Access Date: 12/23/2019

Schofield, P.J. and M.E. Neilson. **2019**. *Neopomacentrus cyanomos* (Bleeker, 1856): U.S. Geological Survey, Nonindigenous Aquatic Species Database, Gainesville, FL, https://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=2936, Revision Date: 10/24/2019, Peer Review Date: 4/1/2016, Access Date: 12/17/2019

Sheehy, D.J. and Vik, S.F. **2010**. The role of constructed reefs in non-indigenous species introductions and range expansions. Ecological Engineering, 36:1-11.

Shideler, G.L. **1981**. Development of the benthic nepheloid layer on the south Texas continental shelf, western Gulf of Mexico. USGS. Marine Geology, 41(1-2): 37-61.

Stanley, D.R. and C.A Wilson. **1996**. The use of hydroacoustics to determine abundance and size distribution of fishes associated with a petroleum platform. International Council on the Exploration of the Sea. Journal of Marine Science 202: 473–475.

Stanley, D.R. and C.A. Wilson. **1997**. Seasonal and spatial variation in the abundance and size distribution of fishes associated with a petroleum platform in the northern Gulf of Mexico. Canadian Journal of Fisheries Aquatic Sciences 54: 1166-1176.

Stanley, D.R. and C.A. Wilson. **2000**. Variation in the density and species composition of fishes associated with three petroleum platforms using dual beam hydroacoustics. Fisheries Research 47: 161-172. 29.

Topolski, M.F. and S.T. Szedlmayer. **2004**. Vertical distribution, size structure, and habitat associations of four Blenniidae species on gas platforms in the northcentral Gulf of Mexico. Environmental Biology of Fishes 70: 193-201.

Turon, X., I. Tarjuelo, and M.J. Uriz. **2002**. Growth dynamics and mortality of the encrusting sponge *Crambe crambe* (Poecilosclerida) in contrasting habitats: correlation with population structure and investment in defence. Functional Ecology, 12(4): 631-639.

Venugopalan, V.P. and A.B. Wagh. **1990**. Biofouling of an offshore oil platform: Faunal composition and biomass. Indian Journal of Geo-Marine Sciences 19(1): 53-56.

Weber, J.N. and E.W. White. **1977**. Caribbean Reef Corals Montastrea annularis and Montastrea cavernosa – Long-Term Growth Data as Determined by Skeletal X-radiography: Reef Biota. Reefs and Related Carbonates -- Ecology and Sedimentology. 171-179.

Whalan, S. **2018**. Not just corals – sponges are bleaching too! Frontiers in Ecology and the Environment, 16(8), 471.

Wilson, C.A., A. Pierce, and M.W. Miller. **2003**. Rigs and Reefs: a Comparison of the Fish Communities at Two Artificial Reefs, a Production Platform, and a Natural Reef in the Northern Gulf of Mexico. Prepared by the Coastal Fisheries Institute, School of the Coast and Environment. Louisiana State University. U.S. Dept. of the Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2003-009. 95 p.

Zea, S. **2001**. Patterns of sponge (Porifera, Demospongiae) distribution in remote, oceanic reef complexes of the Southwestern Caribbean. Revista de la Academia Colombiana de Ciencias Exactas, Fisicas y Naturales, 25(97), 579+.

Acknowledgments

Flower Garden Banks National Marine Sanctuary (FGBNMS) would like to acknowledge the many groups and individuals that provided invaluable support to make this monitoring effort successful, including the Bureau of Safety and Environmental Enforcement (BSEE), Cardinal Point Captains, University of North Carolina-Wilmington Undersea Vehicles Program (UNCW-UVP), Texas A&M University Galveston (TAMUG), Moody Gardens Aquarium, the National Marine Sanctuary Foundation, the NOAA Dive Center, and the numerous volunteer researchers and divers who assisted and collected data for this monitoring project. In particular, we acknowledge BSEE COR, Douglas Peter, for his support and dedication to this project. Finally, our sincere thanks are extended to the editors and reviewers of this document who helped improve this report. This study was funded through an interagency agreement between the Bureau of Safety and Environmental Enforcement and the National Oceanic and Atmospheric Administration's National Ocean Service, Office of National Marine Sanctuaries, through Flower Garden Banks National Marine Sanctuary under BSEE IA number E14PG00057 and ONMS contract number M14PG00020. Fieldwork in from 2015 to 2019 was carried out under permits FGBNMS-2014-001 and FGBNMS-2019-001.

Glossary of Acronyms

%SF – percent sighting frequency
ABC – area backscatter coefficient
BOEM – Bureau of Ocean Energy Management
BSEE – Bureau of Safety and Environmental Enforcement
CPC – Cardinal Point Captains
CPCe – Coral Point Count® with Excel® extensions
CTD – conductivity, temperature, and depth
DI – density index
DO – dissolved oxygen
EFGB – East Flower Garden Bank
FGBNMS – Flower Garden Banks National Marine Sanctuary
HI-A-389-A – High Island A-389-A
MDS – multi-dimensional scaling plots
NCCOS – National Center for Coastal Ocean Science
NOAA – National Oceanic and Atmospheric Administration
ntu – nephelometric turbidity units
PERMANOVA – permutational multivariate analysis of variance
psu – practical salinity units
QA/QC – quality assurance/quality control
RDT – roving diver technique
ROV – remotely operated vehicle
SBE – Sea-Bird® Electronics

SIMPER – Similarity percentages
SIMPROF – Similarity profiles
TAMUG – Texas A&M University Galveston
TPWD – Texas Parks & Wildlife Department
UNCW-UVP – University of North Carolina-Wilmington Undersea Vehicles Program

NATIONAL MARINE
SANCTUARIES

AMERICA'S UNDERWATER TREASURES