STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
Division of Aquatic Resources
Honolulu, Hawaii 96813

November 9, 2018

Board of Land and Natural Resources
State of Hawaii
Honolulu, Hawaii

Subject: Enforcement Action against TWOL, LLC for Stony Coral and Live Rock Damage Resulting from the October 10, 2017 CFV *Pacific Paradise* Grounding within the Waikiki-Diamond Head Shoreline Fisheries Management Area, Oahu

Summary: This submittal requests the Board to find that TWOL, LLC violated Hawaii Administrative Rules §§13-95-70 and -71 by breaking and damaging approximately 18 specimens of stony coral and approximately 1,361 square meters of live rock when the vessel, the CFV *Pacific Paradise*, ran aground within the Waikiki-Diamond Head Shoreline Fisheries Management Area on October 10, 2017. To compensate the State of Hawai'i for the damage to natural resources on public lands, cost of investigation, and temporary loss of public use, DAR recommends that the Board approve the proposed administrative penalty of **$300,493.59**.

Date of Incident: October 10, 2017

Against: TWOL, LLC.
1200 Queen Emma Street, Unit 3311
Honolulu, HI 96813

Location of Incident: Within the Waikiki-Diamond Head Shoreline Fisheries Management Area, approximately 300 meters offshore of Kaimana Beach, O'ahu, Hawai'i

I. INTRODUCTION

At approximately 10:30 pm on October 10, 2017, the Commercial Fishing Vessel (CFV) *Pacific Paradise*, a 79' longline fishing vessel owned by TWOL, LLC ran aground in shallow waters of the Waikiki-Diamond Head Shoreline Fisheries Management Area (FMA). Over the next several days, multiple towing operations proved unsuccessful and resulted in a fire on board that lasted for two days. The vessel was eventually removed 58 days later on December 7, 2017. Division of Aquatic Resources (DAR) biologists and technicians conducted a series of three different investigative surveys at the vessel grounding impact site to carefully document the impact to the State's protected resources. Approximately 1,964 square meters of submerged lands were impacted during this event, including fully protected stony coral and live rock. The final CFV *Pacific Paradise* Injury Report is attached as **Exhibit A**.

DAR recommends that the Board of Land and Natural Resources ("Board") approve the proposed administrative penalty of **$300,493.59** in satisfaction of the damage to natural resources on public lands, cost of investigation, and temporary loss of public use of the nearshore coral reef area during the time the vessel remained aground.

II. FACTUAL BACKGROUND

A. TWOL, LLC owned and controlled the CFV *Pacific Paradise*

At the time of the incident, the CFV *Pacific Paradise* was owned and operated by TWOL, LLC. TWOL, LLC is a domestic Limited Liability Company incorporated in Hawai'i on February 4, 2015. The Company's listed managers are Loi Chi Hang and Nguyen Ngoc Tran.[1]

B. The October 10, 2017 incident

On October 10, 2017, at approximately 10:30 p.m., the CFV *Pacific Paradise* ran aground on the shallow reef approximately 300 meters offshore of Kaimana Beach, O'ahu within the Waikiki-Diamond Head Shoreline Fisheries Management Area. At the time of the incident, the vessel was being used to transport fishing crew members between American Samoa and Honolulu. Twenty people were on board at the time of impact. All were safely evacuated and screened with U.S. Customs and Border Protection.

This event prompted an investigation into the cause of the grounding by the United States Coast Guard, the enactment of the Unified Command to monitor and advise salvors throughout removal operations, and the establishment of a 500-yard safety zone around the vessel.

C. Salvage and removal operations

On October 13th, Cates Marine and the tug American Contender first attempted to remove the vessel. The effort was unsuccessful, but moved the vessel approximately 20 – 40 meters. While preparing the vessel for another attempt on October 14th a de-watering pump ignited, setting fire

[1] See Hawaii Department of Commerce & Consumer Affairs (DCCA) Business Registration Division (BREG) website at: https://hbe.ehawaii.gov/documents/business.html?fileNumber=125882C5&view=officers (8/2/18)

to the vessel. The Honolulu Fire Department Helicopter Air 1 unsuccessfully attempted to put out the fire by air dropping water. Vessel removal operations were subsequently postponed while the fire smoldered throughout the next day.

On October 20th, Cates Marine, using a tug boat from Foss, unsuccessfully attempted a second tow evolution consisting of five tow attempts (four bow tows, and one stern tow), prompting a new tow or salvage plan evaluation. On November 2nd TWOL LLC., the responsible party, elected to "refloat and remove" the vessel using Resolve-Magone Marine Services (Alaska), Inc. This salvage operation plan was decided based on the likelihood of success and projected least amount of environmental damage over the other two options of dead-towing the vessel or cutting and removing in place.

On December 6th, a third removal attempt was conducted and they managed to move the vessel approximately 75 meters, where it ran aground again. The vessel was anchored in this location overnight and successfully removed on the morning of December 7th during the high tide. The vessel was transported and scuttled approximately 15 miles offshore.

D. Ecological assessments of habitat damage

DAR biologists and technicians conducted three separate investigative surveys over a series of five site visits to the *Pacific Paradise* grounding site. The three surveys included a Preliminary Assessment survey, an Impact Assessment survey, and a Rapid Ecological Assessment (REA). The purpose of these surveys was to thoroughly document the impact to State submerged lands. Timing for these surveys was dependent on favorable weather and sea conditions and to prevent hindering salvage operations.

On November 29, 2017 (day 51), the preliminary assessment and a partial impact assessment were conducted by DAR at the grounding site, while the vessel was still in place. Measurements and GPS points were taken of the damage caused by the initial removal attempt, debris, current location of the vessel, and the ingress scar that was associated with the grounding.

On December 7th, the preliminary assessment and partial impact assessment was conducted at the tertiary (egress) scar, where the vessel was aground on the final tow. Due to extreme low visibility created by the salvage operations, which clouded the water column with suspended sediments, the remaining impact assessment of the primary/secondary and tertiary impact was completed on December 11th.

On January 29th and February 6th, 2018 (53 and 61 days after removal, respectively), a team of four divers conducted the REA surveys to characterize damage from the vessel grounding and to obtain reference data from the adjacent reefs. The initial and secondary damage sites were surveyed as a single impact site, given their relative proximity to each other and inability to distinguish the exact delineation between the two impacts. Five 10-m transects were surveyed in the primary/secondary impact site and twelve reference transects were conducted. Two transect surveys were conducted in the tertiary impact site, due to size of the area, along with six reference transects.

E. Habitat damage quantification

1. Coral

During preliminary and impact assessment surveys, fifteen coral colonies of two species (*Pocillopora* spp. and *Porites* spp.) were documented by survey teams as being broken. However, the subsequent Rapid Ecological Assessment did not detect any of these broken corals within the survey transects; they are presumed to have died or washed away. The majority of damaged coral colonies observed by DAR biologists occurred at the end of the egress scar, where the vessel was bouncing along the bottom as it was towed offshore. Most of the coral colonies at the impact sites had either died and become overgrown with algae or were pulverized past the point of recognition by the time the vessel was removed.

Two stony coral of the genera *Pocillopora* spp. and *Cyphastrea* spp., in addition to a zoanthid (*Palythoa* spp.), were detected in the impact sites. Reference transects documented six stony coral genera, (*Pocillopora* spp., *Montipora* spp., *Porites* spp., *Leptastrea* spp., *Psammocora* spp., and *Cyphastrea* spp.) along with zoanthids and soft coral (*Palythoa* spp. and *Sarcothelia* spp.). Reference sites had more live coral colonies per square meter present (453 coral colonies, 0.50 colonies/m^2) compared to the impact areas (14 coral colonies, 0.04 colonies/m^2), suggesting a significant loss of live coral from this impact event.

REA results were used to estimate what coral colonies would have been in the impact area pre-incident. To be conservative, only the primary/secondary and tertiary impact areas were analyzed; the ingress, initial egress, and final egress scars were not included. A 90% confidence limit was calculated and used to determine a lower and a higher estimate of total coral colonies damaged. The mean estimated number of stony coral colonies impacted was 1,745 with a lower range of 18 colonies and a higher range of 2,403 colonies.

2. Live Rock

The total area of submerged lands impacted by the event was measured to be 1,964 m^2 (0.53 acres). These measurements do not include all the damage caused by scattering debris, nor was the full length of the egress scar, which extends over 400 meters, accounted for. Only the solid scar path was accounted for in the egress scar, since the remainder of the scar was areas where the vessel bounced along the bottom creating varying degrees of damage.

Conservative estimates of damaged live rock within the primary/secondary and tertiary impact areas (not including the ingress and egress scars and areas of sand cover) was calculated to be 1,361 m^2. Of this, 301 m^2 was considered high value live rock, and 1,060 m^2 was considered lower value live rock. The State differentiates between high value and lower value live rock based in part upon the complexity of the live rock; complexity includes the biodiversity of life attached to the substrate, the three-dimensional structure of the substrate with the attached

organisms, and the dense presence of key native sessile[2] species which are known to have important ecological relationships with other important reef constituents.

III. LEGAL AUTHORITY FOR ENFORCEMENT

A. Statutory and regulatory protection of stony coral and live rock

Stony coral and live rock are protected by Hawaii Administrative Rules ("HAR") Title 13, Chapter 95, Sections 70 and 71.

HAR §13-95-70(a)(1) states in relevant part that "it is unlawful for any person to take, break, or damage any stony coral."

"Stony coral" is defined as "any invertebrate species belonging to the Order Scleractinia, characterized by having a hard, calcareous skeleton, that are native to the Hawaiian islands." HAR §13-95-1.

HAR §13-95-71(a)(1) states in relevant part that "it is unlawful for any person to take, break, or damage any live rock."

"Live rock" is defined as "any natural hard substrate to which marine life is visibly attached or affixed." HAR §13-95-1.

"Break" means "to hit with, or to apply sufficient force to reduce to smaller pieces or to crack without actually separating into pieces." HAR §13-95-1 (emphasis added).

"Damage" means "to scrape, smother, poison, or otherwise cause any physical or physiological harm to the living portion of a stony coral or live rock." *Id.* (emphasis added).

B. Administrative fines authorized for violations of HAR Title 13, Chapter 95

HRS §187A-12.5(c) provides the administrative penalties for violations relating to aquatic resources,[3] including HAR §§ 13-95-70 and 71 (stony coral and live rock), as follows:

> (1) For a first violation, a fine of not more than $1,000; (2) For a second violation within five years of a previous violation, a fine of not more than $2,000; and (3) For a third or subsequent violation within five years of the last violation, a fine of not more than $3,000.

[2] Sessile is defined as permanently attached or established, not free to move about, such as sponges and corals.

[3] HRS § 187A-12.5(b) specifically addresses violations involving threatened or endangered species. Subsection (c) covers "all other violations."

HRS §187A-12.5(e) also provides that "[i]n addition to subsection (c), a fine of up to $1,000 may be levied for each specimen of all other aquatic life taken, killed, or injured in violation of subtitle 5 of title 12 or any rule adopted thereunder." The definition of "aquatic life" includes coral as well as all the sessile plant and animal species that are attached to live rock. *See* HRS §187A-1.

HAR §13-95-2(b)(4) provides that for colonial stony corals, such as the colonies damaged in the grounding event, per specimen fines may be imposed on the basis of each damaged head or colony less than one square meter in surface area or, for a colony greater than one square meter in surface area, each square meter of colony surface area and any fraction remaining constituting an additional specimen.

HAR §13-95-2(b)(5) provides that for live rocks, per specimen fines may be imposed on the basis of each individual live rock or, if the violation involves greater than one square meter of bottom area, each square meter of live rock.

Additionally, HRS §187A-12.5(a) authorizes the Board "to recover administrative fees and costs… or payment for damages or for the cost to correct damages resulting from a violation of" the statutes and rules pertaining to aquatic resources.

IV. APPLICATION OF LAW AND RECOMMENDED FINE

A. Maximum authorized fines

HRS §187A-12.5 authorizes an administrative fine of $1,000 for a first-time stony coral damage violation, as well as an additional $1,000 per coral specimen injured.

Given the conservative estimate of 18 coral colony specimens impacted by the CFV *Pacific Paradise* grounding, the maximum administrative fine authorized for stony coral damage would be $19,000.[4]

HRS §187A-12.5 authorizes an administrative fine of $1,000 for a first-time live rock damage violation, as well as an additional $1,000 per live rock specimen injured.

Given the conservative estimate of 1,361 square meters of damaged live rock, the maximum authorized administrative fine for live rock damage would be $1,362,000.[5]

HRS §187A-12.5 further authorizes the Board to assess administrative fees and costs, including attorneys' fees relating to a violation of stony coral and live rock protection rules.

[4] $1,000 for the violation (damaging coral) + $18,000 for 18 damaged specimens = $19,000. *See* HRS §187A-12.5(c) and (e).

[5] $1,000 for the violation (damaging live rock) + $1,361,000 for 1361 damaged specimens = $1,362,000. *See* HRS §187A-12.5(c) and (e).

B. Factors to be considered in assessing fines

The Board has broad discretion in assessing administrative fines for a natural resource violation. Some of the factors that the Board may take into consideration include the value of the resource damaged, costs for the State to investigate and process the violation, level of damages to the public for whom the State holds a public trust of the resource involved, extent of the respondent's cooperation, and voluntary actions taken by the respondent to mitigate or avoid damages.[6]

1. Resource Value

The reef where the *Pacific Paradise* ran aground was located within a Fisheries Management Area (FMA) established by the State in 1978. This FMA adjoins the Waikiki Marine Life Conservation District (MLCD). The area is known to have relatively low coral coverage after years of heavy use associated with anthropogenic impacts, which makes all remaining corals and live rock in this FMA a higher value. DAR staff has recently created a set of stony coral and live rock penalty matrices to standardize coral reef damage valuation based on coral morphology, size, rarity, benthic structure, benthic species composition, and location within a managed area. See **Exhibit B**. These matrices provide a comparable, but more detailed, categorization of stony coral values compared to the coral value table included in the Administrative Penalty Guidelines adopted by the Board on July 22, 2009. They also add live rock values, which were not included in the 2009 Penalty Guidelines. Based on these updated matrices, a conservative estimate of the value of the damaged resources is as follows:

Stony Coral (each colony constitutes a specimen)

Encrusting, in FMA, non-rare		
Montipora	0 – 5 cm	6 colonies x $15 = $90
	10 – 20 cm	1 colony x $75 = $75
	40 – 80 cm	1 colony x $300 = $300
Leptastraea	10 – 20 cm	1 colony x $75 = $75
	20 – 40 cm	3 colonies x $150 = $450
Cyphastraea	5 – 10 cm	3 colonies x $30 = $90
		Subtotal Encrusting: $1,080
Branching, in FMA, non-rare		
Pocillopora	0 – 5 cm	1 colony x $35
		Subtotal Branching: $35
Massive, in FMA, non-rare		
Porites	10 – 20 cm	1colony x $150
	40 – 80 cm	1 colony x $750
		Subtotal Massive: $900

Total Stony Coral Value (based on conservative estimate of 18 colonies): $2,015

[6] *See* HAW. ADMIN. R. §13-1-70

Live Rock (each square meter or fraction thereof constitutes a specimen[7])

Low Value Live Rock (i.e. FMA reef with turf, etc.):
Turf 1,060 m^2 x \$60/m^2 = \$63,600

High Value Live Rock:
CCA 221 m^2 x \$800/m^2 = \$176,800
Macroalgae 74 m^2 x \$300/m^2 = \$22,200
Cnidarians 6 m^2 x \$600/m^2 = \$3,600
Subtotal High Value: \$202,600

Total Live Rock Value (based on conservative estimates): \$266,200

TOTAL VALUE: \$2,015 (Stony Coral) + \$266,200 (Live Rock) = \$268,215

2. Level of Damages to the Public

In addition to loss of stony coral and live rock resulting from the *Pacific Paradise* grounding, the public was also adversely affected by the temporary loss of use of the nearshore waters fronting Kaimana Beach due to the 500-yard safety zone established by the Coast Guard. During this time, the public was cautioned to remain clear of the safety zone to prevent injury or impact to operations. The safety zone encompassed approximately 150 acres of nearshore coral reef area, and this loss of use lasted for almost two months.

A 2004 study funded by NOAA[8] conservatively estimated the average annual economic value of Hawai'i's 410,000 acres of coral reef area to be \$364 million. This figure includes reef-related recreational value (\$304 million), property value (\$40 million), biodiversity value (\$17 million), and fishery value (\$2.5 million). The public uses directly affected by the 500-yard safety zone were recreation and fishing. Based on the values established in the 2004 study, reef-related recreation and fishing throughout the State's 410,000 acres of coral reef area are valued at \$306.5 million annually, or \$748/acre/year, or \$2.05/acre/day. Accordingly, a conservative estimate of the public's loss of use of 150 acres of nearshore coral reef area for recreation and fishing over the 58 days the safety zone was in place amounts to **\$17,835**.[9]

3. Cost of Investigation

Nine DAR staff members spent a total of 446.0 hours investigating and processing the violation. This includes the Preliminary Assessment survey, Impact Assessment survey, and Rapid Ecological Assessment described in Section II.D., above. Staff time was carefully tracked using a distinct accounting code on employee time sheets. The total cost of this staff time was \$11,879.59, as shown in **Table 1**, below.

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[7] *See* HAW. ADMIN. R. §13-95-2(b)(5)
[8] Cesar, S.J.C. and P. J.H. van Beukering. 2004. Economic Valuation of the Coral Reefs of Hawaii. Pacific Science, 58(2), 2:231-242. Available at https://scholarspace.manoa.hawaii.edu/bitstream/10125/2723/1/vol58n2-231-242.pdf (Accessed September 18, 2018).
[9] (\$2.05/acre/day) (150 acres) (58 days) = \$17,835

Table 1. Staff hours and costs for *Pacific Paradise* marine injury assessments.

2017	Staff hours	Cost
October	47.5	$1,485.83
November	171.0	$4,483.99
December	100.5	$2,644.14
2018		
January	53.0	$1,345.93
February	56.0	$1,420.56
March	18.0	$499.14
Total 2017-2018	**446.0**	**$11,879.59**

Operational costs for five boat trips to the site for surveys and REAs (5 days @ $500/day = $2,500) and filling SCUBA tanks (2 days x 8 tanks/day @ $4/tank = $64) totaled **$2,564**.

Accordingly, the total administrative cost incurred by the Department in investigating and processing this incident was **$14,443.59**.

4. Respondent's Cooperation and Voluntary Mitigative Actions

Although the respondent TWOL, LLC's initial efforts to remove the vessel resulted in two failed salvage attempts and the vessel catching on fire, which significantly prolonged the removal process, the respondent was cooperative in providing Coast Guard investigators with information regarding the grounding. Further, when choosing between alternative salvage plan options for the third attempt, the respondent elected to "refloat and remove" the vessel based on the likelihood of success and projected least amount of environmental damage over the other two options of continued attempts to dead-tow the vessel or cutting and removing in place. In light of the respondent's reasonable cooperation and mitigative actions which offset exacerbating factors, no increase in the assessed fine is warranted.

C. Recommended fines and costs

Based on the foregoing considerations, DAR recommends fines of $286,050, and costs in the amount of $14,443.59 for a total assessment of **$300,493.59**, as shown in **Table 2**, below. This figure reflects a conservative estimate of the amount required to compensate the State for the damage to natural resources on public lands, the public's temporary loss of use of the nearshore area, and the cost of investigation.

Table 2. Summary of fines and costs.

Category of Fines and Costs	Amount
Resource Value	$268,215.00
Public Loss of Use	$17,835.00
Cost of Investigation	$14,443.59
TOTAL	**$300,493.59**

V. RECOMMENDATIONS

1. That the Board find that TWOL, LLC violated HAR §§13-95-70 and -71 when its vessel, the CFV *Pacific Paradise*, ran aground within the Waikiki-Diamond Head Shoreline Fisheries Management Area on October 10, 2017 and damaged approximately 18 coral colonies and 1,361 square meters of live rock; and

2. That the Board assess an administrative fine of $286,050 and costs in the amount of $14,443.59 for a total assessment of **$300,493.59** against TWOL, LLC to be paid within 60 days of the date of this submittal.

Respectfully Submitted,

Brian Nielson, Acting Administrator
Division of Aquatic Resources

APPROVED FOR SUBMITTAL:

Suzanne D. Case, Chairperson
Department of Land and Natural Resources

ATTORNEY-CLIENT PRIVILEGE-DRAFT

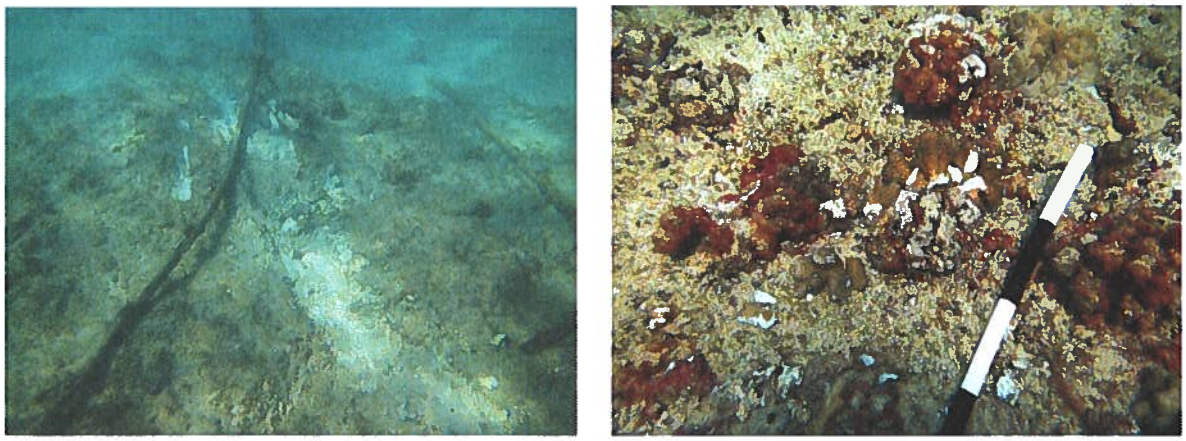
CFV *Pacific Paradise* Injury Report Waikīkī – Diamond Head Fisheries Management Area, October 10th, 2017 – December 7th, 2017

Field Investigative Report

Justin Goggins • Paul Murakawa • Ryan Okano • Kimberly Fuller • Brian Neilson • Dave Gulko
Division of Aquatic Resource • March 2018

Executive Summary

On October 10, 2017, the CFV *Pacific Paradise* ran aground in shallow waters of the Waikīkī Fisheries Management Area. Over the next several days, multiple towing operations proved unsuccessful and resulted in a fire on board that lasted for 2 days. The Division of Aquatic Resources (DAR) Biologists responded to the incident by participating as resource trustees in Unified Command meetings throughout the duration of the salvage operation which were completed when the vessel was removed 59 days later, on December 7, 2017. DAR biologists and technicians conducted a series of three different investigative surveys at the vessel grounding impact site to carefully document the impact to the State's protected resources. Surveys were conducted on adjacent unimpacted reef areas and used as a reference for determining the number of coral colonies damaged during the grounding. The data collected showed that approximately 1,964 m^2 of submerged lands were damaged or destroyed during this event, including fully protected coral and live rock. Fish density, algal biomass, reef accreting substrate, and coral species were all found to be less in the vessel grounding impact site versus reference sites on the adjacent reefs.



Live rock and coral damage as the result of the CFV *Pacific Paradise* Grounding.

Overview

The CFV *Pacific Paradise* ran aground approximately 300 meters offshore of Kaimana Beach, O'ahu in the late evening (10:30 pm) of October 10, 2017. At the timing of the grounding, the vessel was believed to be carrying 4,500 gallons of diesel fuel, 65 gallons of lube oil and four marine batteries. The owner was TWOL, LLC.

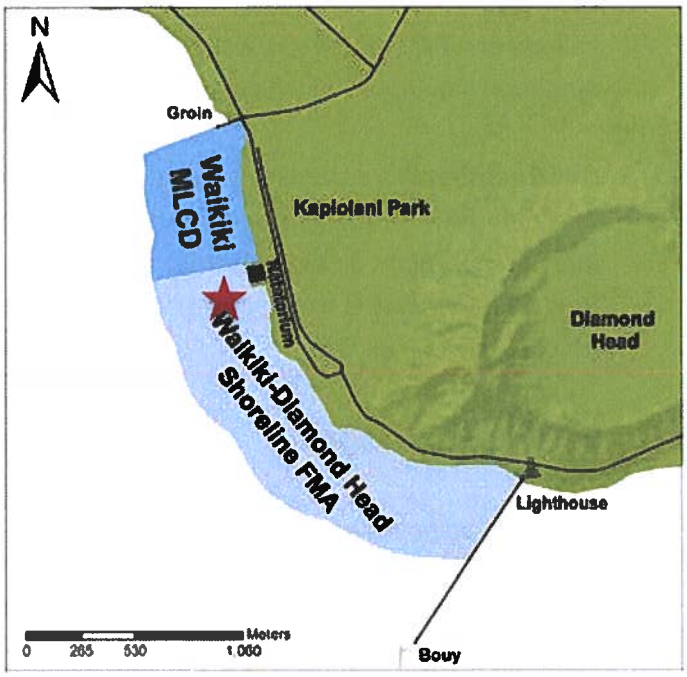


Figure 1. Map of Waikīkī – Diamond Head Shoreline Fisheries Management Area. Star indicates approximate grounding location. Source: www.dlnr.hawaii.gov

This event prompted an investigation into the cause of the grounding by the United States Coast Guard, the enactment of the Unified Command to monitor and advise salvors throughout removal operations, and the establishment of a 500-yard safety zone in all directions from position 21°15.69N, 157°49.49W. This grounding occurred within the Waikīkī – Diamond Head Shoreline Fisheries Management Area (Figure 1). Unified Command consisted of the U.S. Coast Guard, Hawai'i Department of Health, Hawai'i Division of Aquatic Resource, National Oceanic and Atmospheric Administration, and the U.S. Fish and Wildlife Services.

An estimated 3,000 gallons of diesel fuel was removed by October 13th in preparation for towing the vessel. The first removal attempt by Cates Marine and the tug American Contender was not successful, but it did move the vessel approximately 20 – 40 meters. While preparing the vessel for another attempt on October 14th a de-watering pump ignited, setting fire to the vessel. The Honolulu Fire Department Helicopter Air 1 unsuccessfully attempted to put out the fire by air dropping water. Vessel removal operations were subsequently postponed while the fire smoldered throughout the next day. Approximately 200 gallons of diesel fuel was released into the environment as a result of the fire, presumed to be through a fuel tank vent.

On October 20th, Cates Marine, using a tug boat from Foss, unsuccessfully attempted a second tow evolution consisting of five tow attempts (four bow tows, and one stern tow), prompting a new tow or salvage plan evaluation. On November 2nd TWOL LLC., the responsible party, elected to "refloat and remove" the vessel using Resolve-Magone Marine Services (Alaska), Inc.

This salvage operation plan was decided based on the likelihood of success and projected least amount of environmental damage over the other two options of dead-towing the vessel or cutting and removing in place. During the removal preparations, approximately 1200 – 1300 gallons of a fuel/water mix was removed November 28th. The mix was estimated to contain 60% fuel, leaving an approximately 600 gallons of diesel fuel on board.

On December 6th, a third removal attempt was conducted and they managed to move the vessel approximately 75 meters, where it ran aground again. The vessel was anchored in this location overnight and successfully removed on the morning of December 7th during the high tide. The vessel was transported and scuttled approximately 15 miles offshore at position 21°05.87N, 157°58.3W.

Vessel Information

The CFV *Pacific Paradise* is an 80' longline fishing vessel that was being used to transport fishing crew members between American Samoa and Honolulu. Twenty personnel were on board at the time of impact. All were safely evacuated and screened with Customs and Border Protection.

Injury Scene Assessments

DAR biologists and technicians conducted three separate investigative surveys over a series of five site visits to the *Pacific Paradise* grounding site (Figure 2). The three surveys included a Preliminary Assessment survey, an Impact Assessment survey, and a Rapid Ecological Assessment (REA). The purpose of these surveys was to thoroughly document the impact to State submerged lands. Timing for these surveys was dependent on favorable weather and sea conditions and to prevent hindering salvage operations.

A preliminary assessment was conducted to determine the extent of habitat damage that occurred during the vessel grounding and removal events, as well as document current boundaries of the event and potential hazards surveyors should avoid. These findings were used to plan the impact assessment and the REA.

An impact assessment was conducted in the damaged area to carefully measure all damage events and collect physical evidence. DAR divers measured the impacted reef area with a transect tape, collected GPS location points, photo documented the grounding site and collected physical evidence.

A Rapid Ecological Assessment (REA) was used to quantify what biological resources have been lost or affected resulting from the *Pacific Paradise* grounding. During REA surveys, DAR divers collected biological information in both the impact areas and in adjacent reef habitats with similar depth, geomorphology, currents, visibility, and benthic species. These adjacent reef habitats are used as reference sites to demonstrate what would have been present in the impact area.

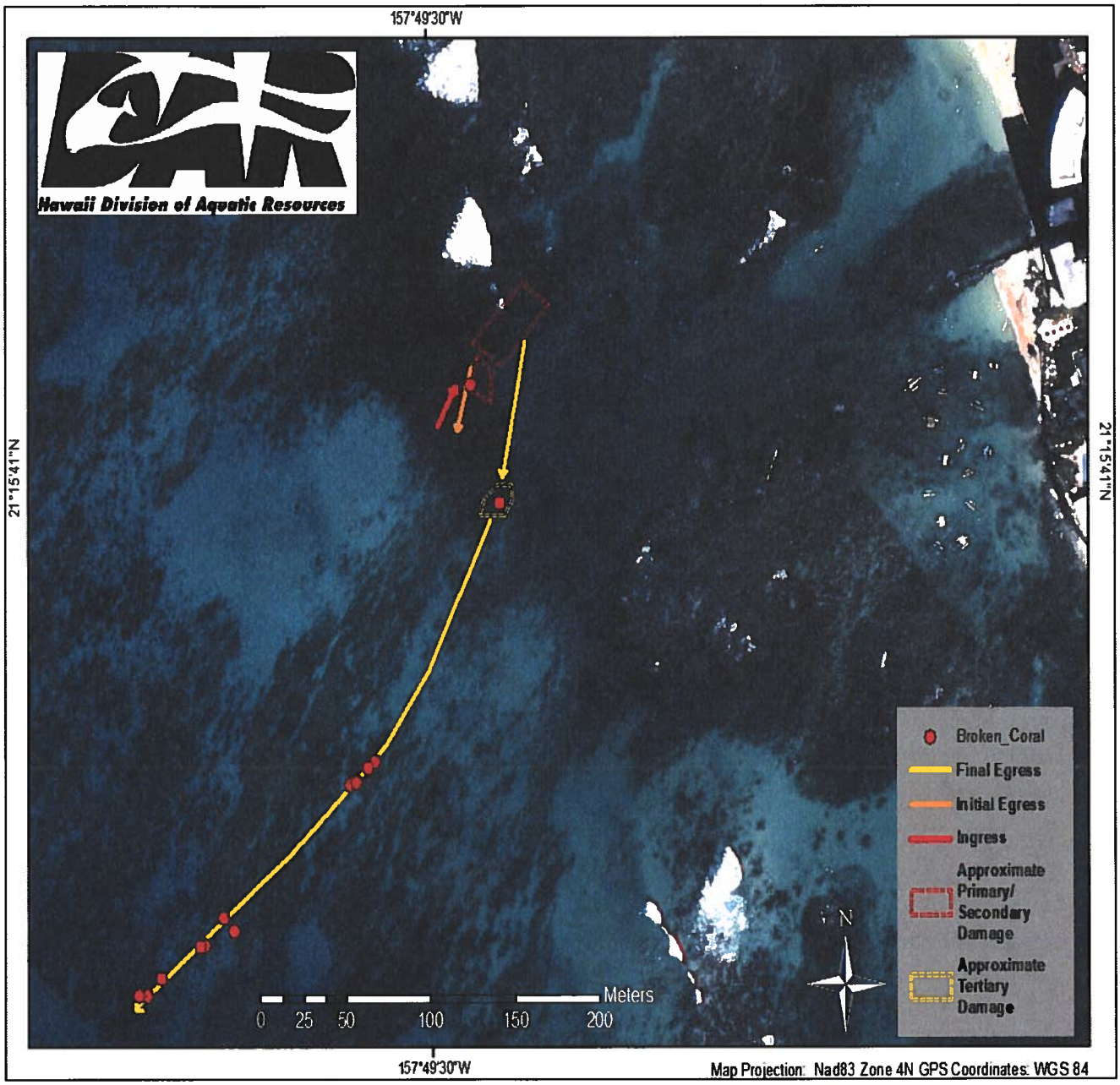


Figure 2. CFV *Pacific Paradise* Grounding site, depicting the ingress, primary/secondary impact, egress path, tertiary impact, and documented broken coral colonies.

Preliminary Assessment and Impact Assessment

On November 29, 2017 (day 51), the preliminary assessment and a partial impact assessment were conducted by DAR at the grounding site, while the vessel was still in place. DAR originally planned to conduct impact assessments after the vessel was removed, but after multiple failed removal attempts it was decided to begin surveys while the vessel remained in place while the damage was still fresh and obvious. Measurements and GPS points were taken of the initial removal attempt damage, debris (Figure 3), current location of the vessel (Figure 4), and the ingress scar (Figure 5) that was associated with the grounding. All data sheets were photographed at the end of the dive to substantiate the record. All photographs were burned to non-rerecordable CDs and secured in tamper proof evidence bags at the DAR office.

Following the vessel removal, the comprehensive impact assessment was completed (Figures 6 – 10). On December 7th, the preliminary assessment and partial impact assessment was conducted at the tertiary (egress) scar, where the vessel was aground on the final tow. Due to extreme low visibility created by the salvage operations, which clouded the water column with suspended sediments, the remaining impact assessment of the primary/secondary and tertiary impact was completed on December 11th. A debris list was created and shared with Cates Marine to aid clean-up efforts.

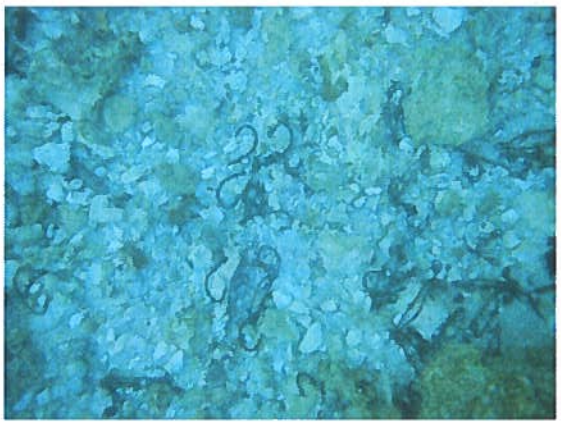


Figure 3. Pulverized substrate with fishing hooks and tackle.

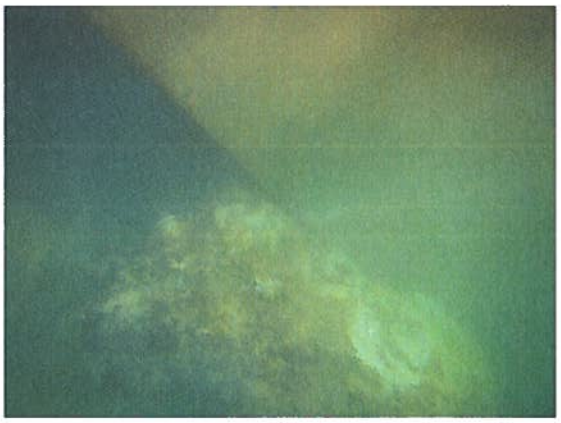


Figure 4. The vessel's bow hard aground.

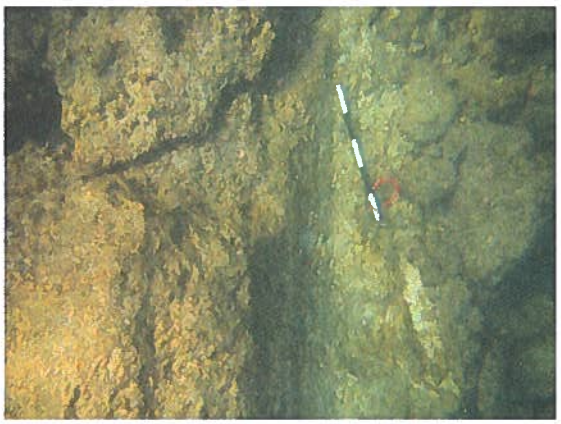


Figure 5. Ingress scar (scale bar is 0.5 m long in 10 cm increments).

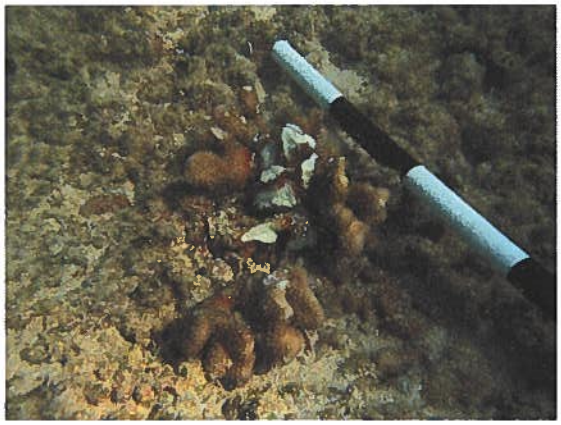


Figure 6. Broken *Pocillopora meandrina*.

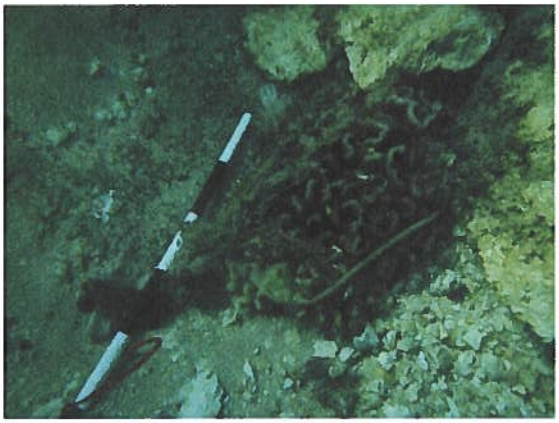


Figure 7. *Pocillopora meandrina* colony covered with rope.

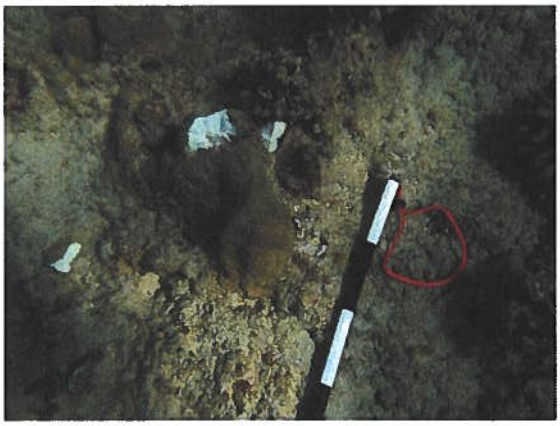


Figure 8. Broken *Porites lobata* colony.

Figure 9. Tertiary (egress) scar.

Figure 10. Metal debris covering the substrate.

Rapid Ecological Assessments (REAs)

A series of REAs were used to characterize damage from the vessel grounding and to obtain reference data from the adjacent reefs. The primary/secondary impact was treated as one event since it was not clearly distinguishable between where the vessel originally ran aground, what was damaged during the failed towing attempts, and the area it sat grounded during the majority of the operation. The tertiary impact was treated as a separate event. Each impact event had its own representative reference survey locations (Figures 11, 12). REA surveys were not dependent on the timing of the impact, given that the data was used to compare the current conditions between impacts and reference locations. Therefore, survey dates were determined by favorable weather, calm sea conditions and DAR staff availability.

Reference sites are unimpacted areas adjacent to the impact site that demonstrate the pre-grounding condition of the reef, with similar substrate and depth. Reference site starting locations for the primary/secondary impacts were pre-selected using ArcGIS NCCOS (National Centers for Coastal Ocean Science) bathymetry habitat mapping data to identify depths between the impact and reference sites. In the field, transects were laid out by following similar isobathymetric depths as the start point. Reference sites directly north and west of the primary/secondary impact site were ruled out due to shallow depths and turbulent waters created by the surf break. Areas to the north and east of the primary/secondary impact were not considered because they consisted mostly of deeper sand habitat which did not represent the grounding site. The surrounding area of the tertiary impact site had uniform depth and substrate so the reference sites were determined by using a standardized 25 fin kicks north of the impact site (Figure 11).

The REAs surveyed fish, algae, coral, and benthic habitat along 10-m transects in the impact and reference sites. The fish diver identified, counted, and estimated size (to the nearest cm) by species of all fish in a belt transect measuring 10-m by 5-m wide. A phycologist identified and quantified the algae present on each transect (Figure 13). The phycologist followed behind the fish diver on the same transect using a 0.5-m by 0.5-m quadrat to capture primarily algal richness and secondarily in-situ benthic cover. Three quadrat drops were systematically surveyed at each transect by placing the quadrat on the first, fifth, and ninth meter on the transect. All algal species within the quadrat were documented to the highest possible taxonomic resolution (lowest taxonomic unit). Benthic cover of each quadrat was assessed using 10 randomly selected points within the quadrat. A total of 16 evenly spaced points exist within the quadrat, 10 of these 16 points were selected to be surveyed by using a random number generator.

A coral diver identified, counted and sized all corals observed within each 10-m by 5-m belt transect, to the nearest centimeter (Figure 14). In addition, each transect was photo documented by taking photo quadrats (61 cm by 81 cm) every 1 meter at each transect.

On January 29th and February 6th, 2018 (53 and 61 days after removal, respectively), a team of four divers surveyed the CFV *Pacific Paradise* grounding site (Figure 12). The initial and secondary damage site was surveyed as a single impact site, given its relative proximity to each other and inability to distinguish the exact delineation between the two impacts. Five 10-m transects were surveyed in the primary/secondary impact site and twelve reference transects were conducted (Figure 12). Two transect surveys were conducted in the tertiary impact, due to size of the area, and six reference transects.

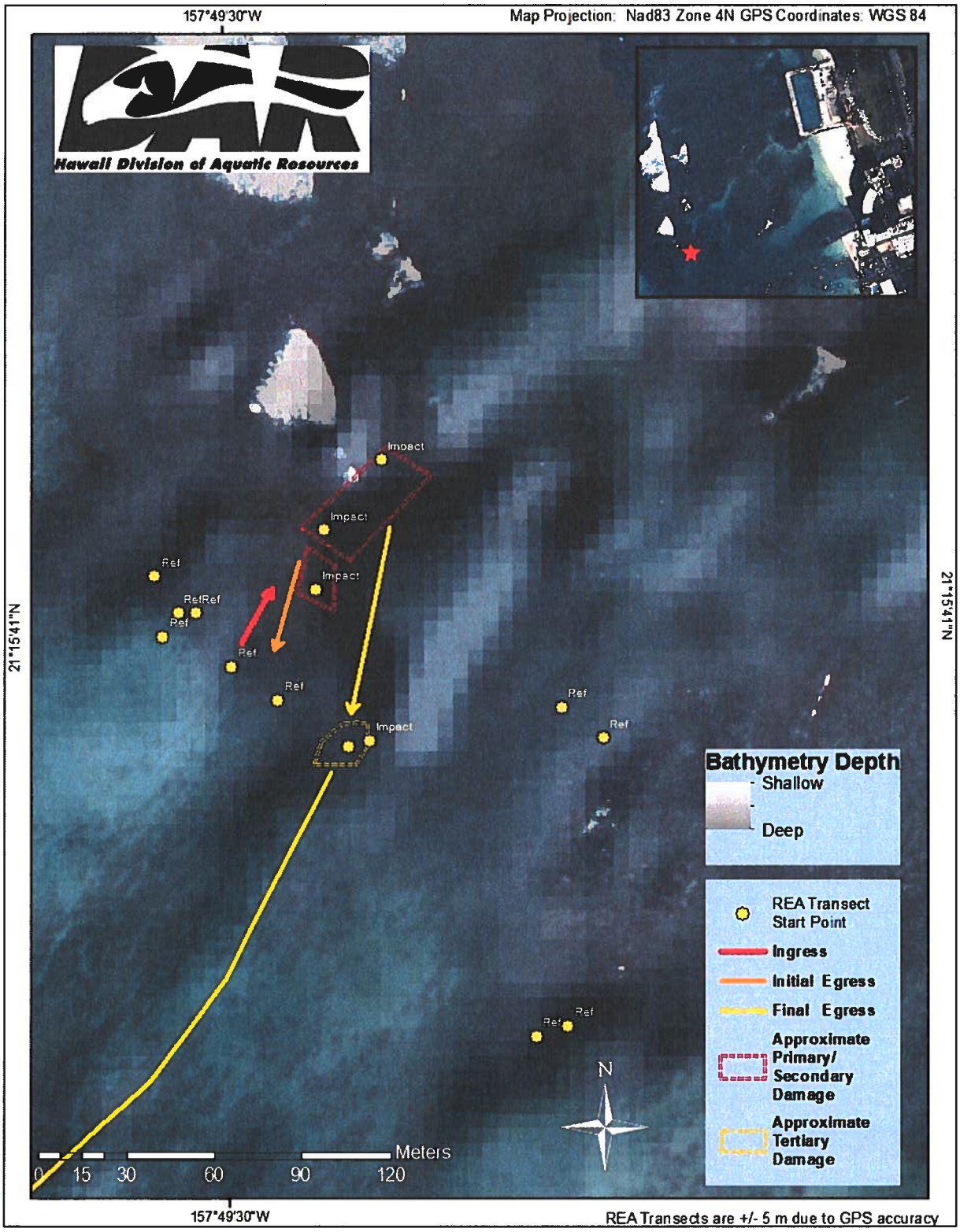


Figure 11. Bathymetry data layer used to identify similar habitat for determining reference survey locations. (Impact = vessel impact events, Ref = reference sites).

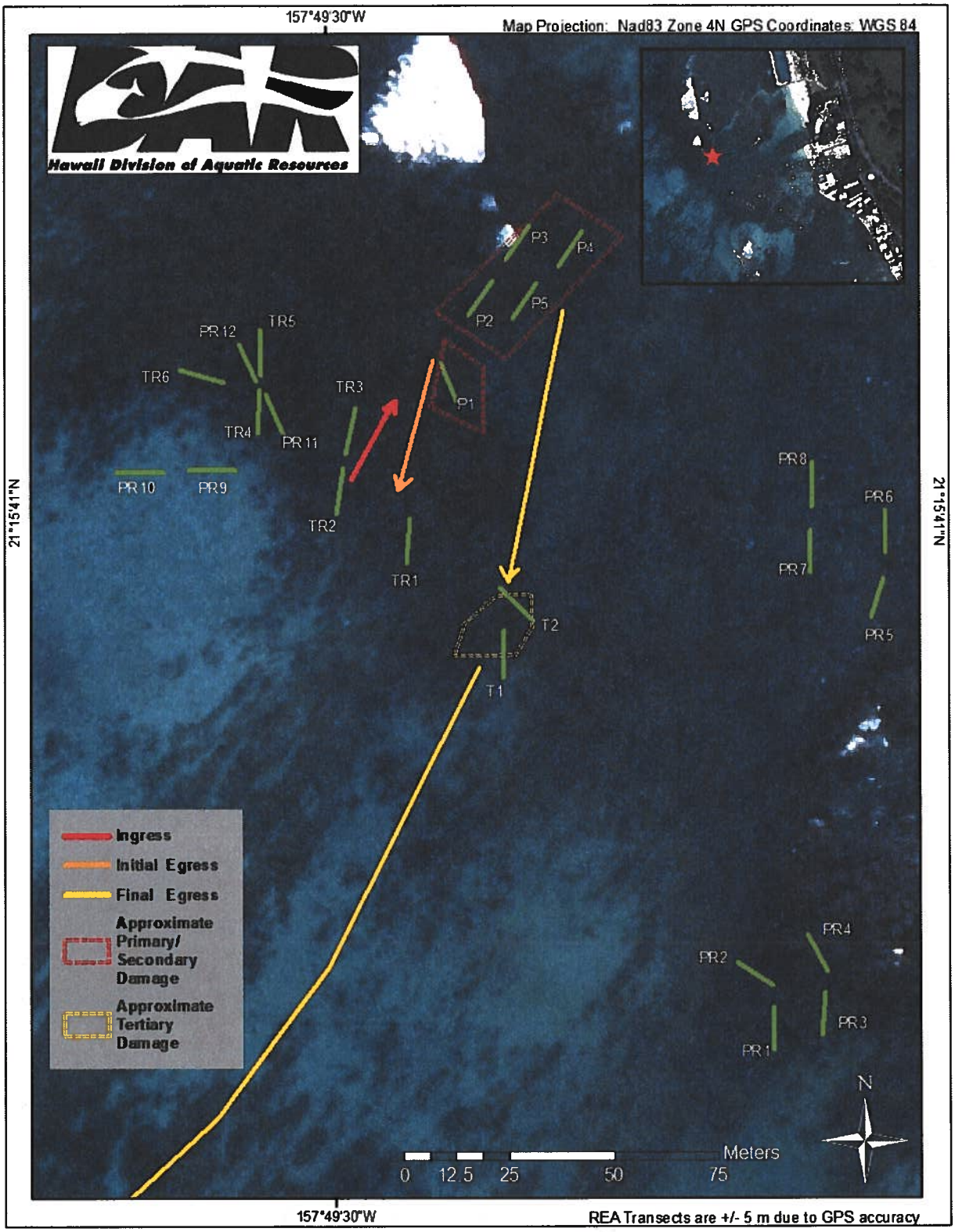


Figure 12. CFV *Pacific Paradise* Grounding site, depicting the primary/secondary impact, ingress, egress path, tertiary impact, and subsequent Rapid Ecological Assessment (REA) transects. (P = Primary/ Secondary Impact Sites, PR = Primary/Secondary Reference Sites, T = Tertiary Impact Sites, TR = Tertiary Reference Sites).

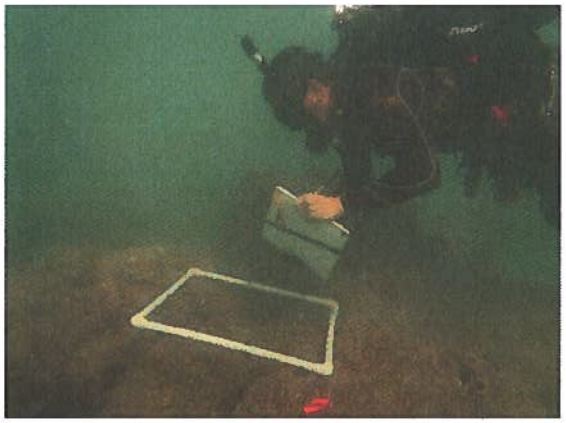


Figure 13. Diver conducting benthic cover quadrats.

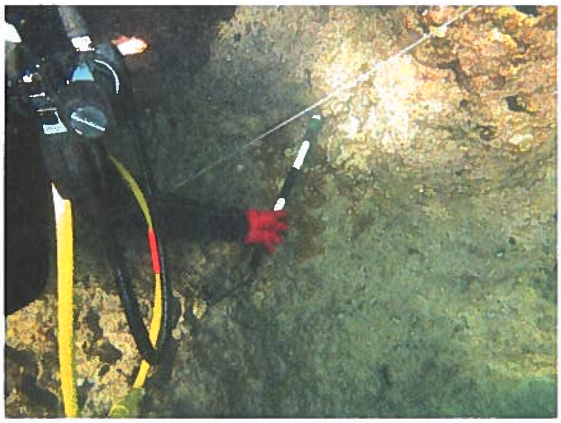
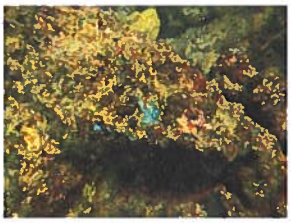


Figure 14. Diver conducting coral colony counts and sizing.

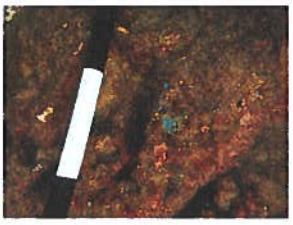
Evidence Collection

Certain physical evidence was collected during the impact assessment which could be used to directly tie the grounded vessel to the areas of documented damage. Paint samples were collected atop the reef and transferred to sealed evidence bags. All photographs and datasheets were immediately transferred to a non-rerecordable CD upon return to the DAR office. The CD was placed in sealed evidence bags and held in a locked safe by Dave Gulko at the DAR office. The maintenance of all CDs, datasheets, and evidence collected by DAR follows established chain-of-custody procedures. Figures 15a – 15h show the sequence of events for collecting evidence of the ships' paint.



(15a)

(15b)



(15c)

(15d)

(15e)

(15f)

(15g)

(15h)

Figure 15a – 15h. Photographs demonstrating the sequence of collecting paint scraping. (a – paint scrape of unaltered evidence; b – paint sample wide angle view with 0.5 m scale bar; c – close up view; d – evidence collection jar and bag with a unique identification code; e – DAR diver collecting sample from substrate; f – paint chip placed into sample bag with same sample code; g – paint chip in the sample jar and place in the labeled sample bag; h – post-evidence collection photograph to demonstrate that the sample pictured above came from that site).

RESULTS

FISH

Mean fish density was lower at damaged impact sites (primary/secondary impact site = 69.4 g/m^2, tertiary impact = 48.0 g/m^2) than at non-impacted reference sites (primary/secondary reference sites = 116.4 g/m^2, tertiary reference sites= 77.1 g/m^2) (Figure 16). Species diversity was similar between reference and impact sites. In the primary/secondary impact site, the yellowfin goatfish (*Mulloidichthys vanicolensis*) made up the bulk of the biomass (Table 1). While the brown surgeonfish (*Acanthurus nigrofuscus*) was second, but made up the bulk of the biomass in the other three survey area.

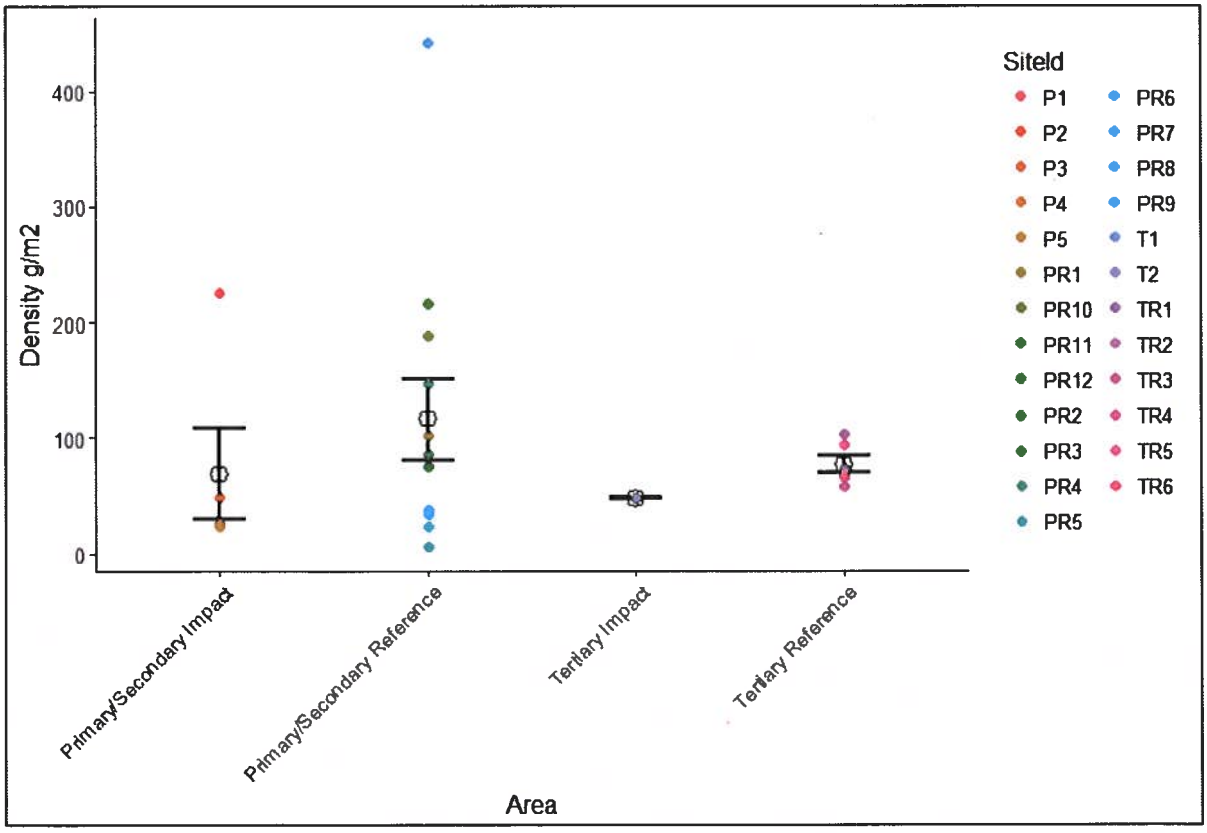


Figure 16. Fish density (g/m²) at primary/secondary impact site, primary/secondary reference sites, tertiary impact site, and tertiary reference sites. Each point represent density for each transect surveyed. Center circle shows the mean density estimated for each area with standard error bars.

Table 1. Top five fish species by biomass (g/m²) in each surveyed area.

	SPECIES	BIOMASS (g/m²)
PRIMARY/SECONDARY IMPACT	*Mulloidichthys vanicolensis*	1580.62
	Acanthurus nigrofuscus	806.56
	Thalassoma duperrey	100.92
	Naso lituratus	56.88
	Acanthurus leucopareius	56.54
PRIMARY/SECONDARY REFERENCE	*A. nigrofuscus*	1658.42
	Chlorurus spilurus	759.84
	M. vanicolensis	658.59
	Melichthys niger	251.05
	N. lituratus	249.61
TERTIARY IMPACT	*A. nigrofuscus*	1181.39
	Acanthurus triostegus	409.54
	Scarus rubroviolaceus	179.71
	T. duperrey	149.71
TERTIARY REFERENCE	*A. nigrofuscus*	1644.87
	A. triostegus	626.43
	M. niger	306.34
	T. duperrey	111.03
	Rhinecanthus rectangulus	102.39

ALGAE

There was higher algal richness for both non-impacted reference sites, when compared to the impacted sites (Figure 17).

Figure 17. Algal richness at primary/secondary impact site (solid red bar, n=5), primary/secondary reference sites (solid green bar, n=12), tertiary impact site (red bar with white dots, n=2), and tertiary reference sites (green bar with white dots, n=6). Bars represent the average number of algal species or algal functional group detected within quadrats at each of the four sites. Error bar depicts standard error.

BENTHIC COVER

Reef accreting substrate includes calcified benthic organisms that build tropical reefs, such as coral, crustose coralline algae, and branching coralline algae. In this case only crustose coralline algae were detected during the surveys. Often reef accreting substrate is considered desirable relative to non-accreting substrate. Reef non-accreting substrate would be represented by macro-algae, turf algae, and fleshy crustose algae. There was a higher percent cover of reef accreting substrate for both non-impacted reference sites, when compared to their impacted counterparts (Figure 18).

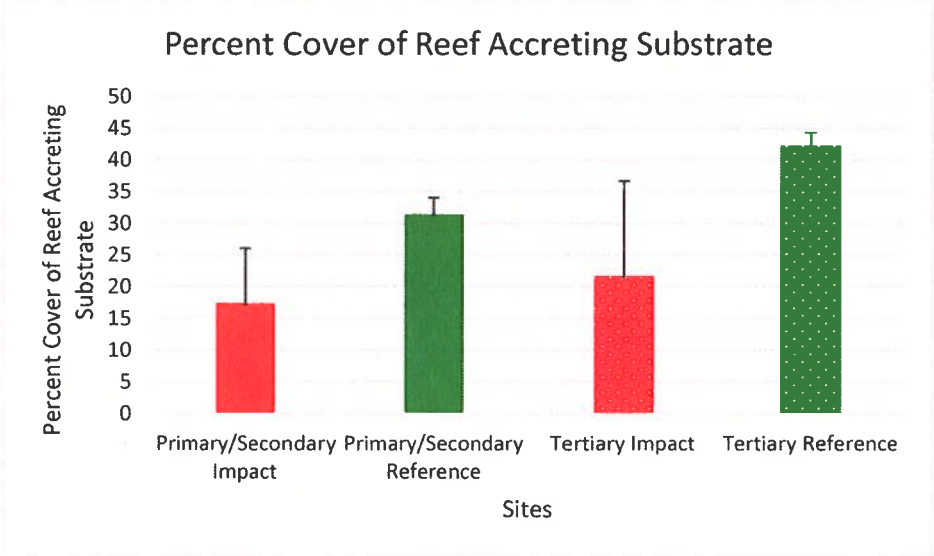


Figure 18. Percent cover of reef accreting substrate at primary/secondary impact site (solid red bar, n=5), primary/secondary reference sites (solid green bar, n=12), tertiary impact site (red bar with white dots, n=2), and tertiary reference sites (green bar with white dots, n=6). Bars represent the average percent cover of reef accreting substrate at each of the four sites. Error bar depicts standard error.

CORAL/LIVE ROCK

During preliminary and impact assessment surveys, fifteen coral colonies of two species (*Pocillopora* spp. and *Porites* spp.) were documented by survey teams as being broken. However, the Rapid Ecological Assessment did not detect any of these broken corals within the survey transects; they are presumed to have died or washed away. As depicted in Figure 2, the majority of damaged coral colonies observed by DAR biologists occurred at the end of the egress scar, where the vessel was bouncing along the bottom as it was towed offshore. Most of the coral colonies at the impact sites had either died and become overgrown with algae or were pulverized past the point of recognition by the time the vessel was removed.

Two stony coral of the genera *Pocillopora* spp. and *Cyphastrea* spp., in addition to a zoanthid (*Palythoa* spp.), were detected in the impact sites (Tables 2 & 3). Reference transects documented six stony coral genera, (*Pocillopora* spp., *Montipora* spp., *Porites* spp., *Leptastrea* spp., *Psammocora* spp., and *Cyphastrea* spp.) along with zoanthids and soft coral (*Palythoa* spp. and *Sarcothelia* spp.). Reference sites had more live coral colonies per square meter present (453 coral colonies, 0.50 coral/m^2) compared to the impact areas (14 coral colonies, 0.04 coral/m^2), suggesting a significant loss of live coral from this impact event.

Table 2. Stony coral genera documented at each survey site.

Survey Site	*Pocillopora* spp.	*Montipora* spp.	*Porites* spp.	*Cyphastraea* spp.	*Leptastrea* spp.	*Psammacora* spp.	Total
Primary/ Secondary Impact	X						1
Primary/ Secondary Reference	X	X	X	X	X	X	6
Tertiary Impact	X			X			2
Tertiary Reference	X	X	X	X			4

Table 3. Soft coral and zoanthids documented at each survey site.

Survey Site	*Palythoa* spp.	Octocorals	Total
Primary/ Secondary Impact	X		1
Primary/ Secondary Reference	X	X	2
Tertiary Impact			0
Tertiary Reference		X	1

No corals in the size ranges 0 – 5 cm and 5 – 10 cm were documented in the primary/secondary impact sites, whereas this size class had the most colonies in reference sites. The average number of coral colonies (± standard error) at each site were: primary/secondary impact (0.24 ± 0.09 colonies, 0.001 colonies/m^2), primary/secondary reference (6.22 ± 0.99 colonies, 0.01 colonies/m^2), tertiary impact (0.80 ± 0.33 colonies, 0.008 colonies/m^2), tertiary reference (2.67 ± 0.56 colonies, 0.009 colonies/m^2) (Figure 19).

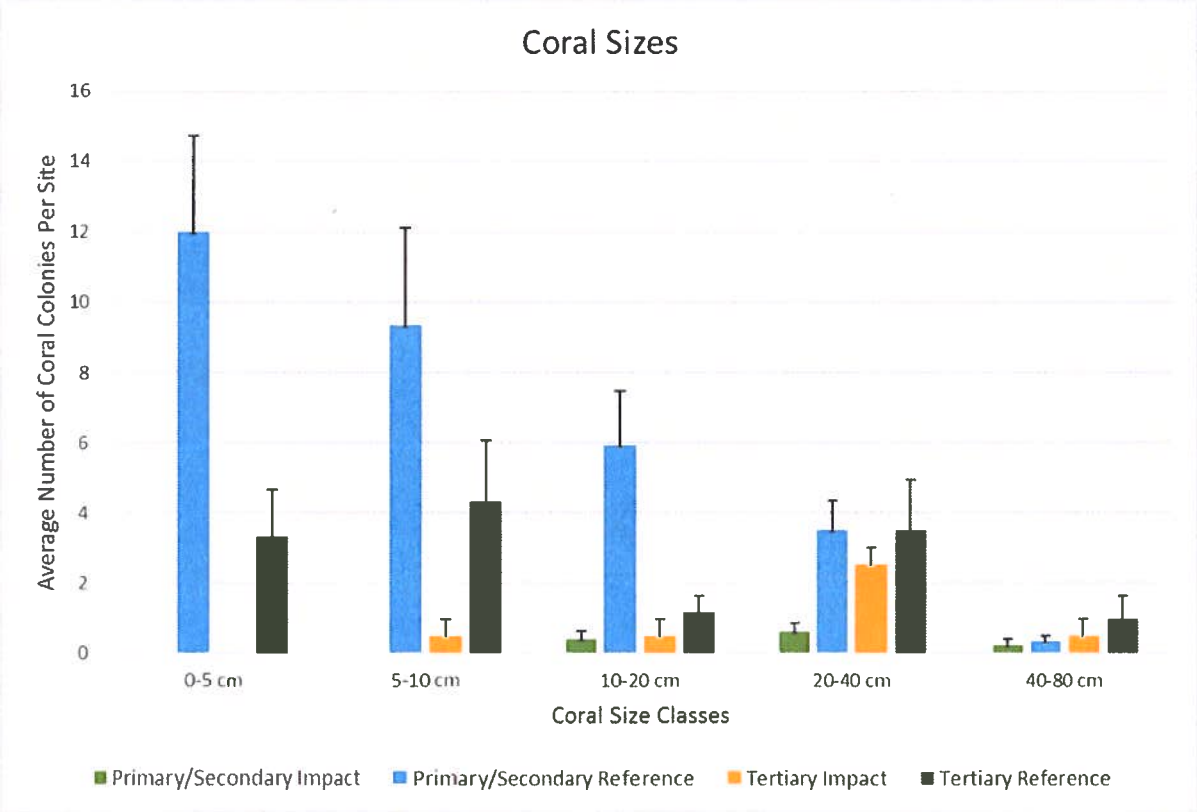


Figure 19. Average coral colonies by size classes at primary/secondary impact site, primary/secondary reference sites, tertiary impact site, and tertiary reference sites. Error bars represent the standard error.

Primarily only bare substrate remained at the primary/secondary and tertiary impact areas. Therefore, REA results were used to further analyze what coral colonies by individual genus and size class would have been in the area pre-incident. The individual size classes per genus were extrapolated to determine an estimated number of colonies in each damage event. The transect area surveyed was used to determine the total colonies per m^2 and then multiplied by the total area damaged. A 90% confidence limit was calculated and used to determine a lower and a higher estimate of total coral colonies damaged. Stony corals were analyzed and summed by colony genus and size; zoanthids and octocorals were analyzed in a similar method and then converted to percent coverage and counted as live rock.

To be conservative, only the primary/secondary and tertiary impacts were analyzed and the ingress, initial egress, and final egress scars were not included. Corals previously documented as broken or damaged were also not included since this data was an analysis of the reference transects which are outside of the damaged areas. The mean estimated number of coral colonies in the primary/secondary impact was 1,720 with a lower range of 15 and a higher range of 2,209 (Table 4). The mean estimated number of coral colonies in the tertiary impact

was 25 with a lower range of 3 and a higher range of 194 (Table 5). Values in the lower range with negative numbers are rounded to zero.

Table 4. Analysis of damaged coral genera and size ranges documented at primary/secondary impact reference sites.

A	B	C	D	E		F	G	H
Coral Genus	Average # Colonies Primary/ Secondary Impact Reference Sites per m^2	St. Dev	Primary Impact Damage Area (m^2)	Estimated # Coral Colonies Damaged (B x D)		90% Confidence Limits	Lower Range # Colonies Damaged (E – F)	Higher Range # Colonies Damaged (E + F)
Pocillopora								
0 – 5 cm	0.033333	1.9518	848 m^2	28		+/- 62	0 (-33)	90
5 – 10 cm	0.026667	1.20185	848 m^2	23		+/- 37	0 (-15)	60
10 – 20 cm	0.016667	1.032796	848 m^2	12		+/- 33	0 (-20)	45
20 – 40 cm	0.023333	1.643168	848 m^2	18		+/- 52	0 (-34)	70
40 – 80 cm	0.001667	0	848 m^2	0		+/- 0	0	0
80+ cm	0	0	848 m^2	0		+/- 0	0	0
Montipora								
0 – 5 cm	0.006667	0	848 m^2	6		+/- 0	6	6
5 – 10 cm	0.038333	8.845903	848 m^2	33		+/- 278	0 (-245)	311
10 – 20 cm	0.02	4	848 m^2	17		+/- 126	0 (-109)	143
20 – 40 cm	0.013333	2.081666	848 m^2	11		+/- 66	0 (-55)	77
40 – 80 cm	0.001667	0	848 m^2	1		+/- 0	1	1
80+ cm	0	0	848 m^2	0		+/- 0	0	0
Porites								
0 – 5 cm	0.161667	9.333929	848 m^2	137		+/- 294	0 (-157)	431
5 – 10 cm	0.1	12.506	848 m^2	85		+/- 393	0 (-309)	478
10 – 20 cm	0.071667	6.039552	848 m^2	61		+/- 190	0 (-129)	251
20 – 40 cm	0.03	3	848 m^2	25		+/- 95	0 (-69)	120
40 – 80 cm	0.001667	0	848 m^2	1		+/- 0	1	1
80+ cm	0	0	848 m^2	0		+/- 0	0	0
Leptastraea								
0 – 5 cm	0.006667	1.414214	848 m^2	6		+/- 44	0 (-38)	50
5 – 10 cm	0	0	848 m^2	0		+/- 0	0	0
10 – 20 cm	0.001667	0	848 m^2	1		+/- 0	1	1
20 – 40 cm	0.003333	0	848 m^2	3		+/- 0	3	3
40 – 80 cm	0	0	848 m^2	0		+/- 0	0	0
80+ cm	0	0	848 m^2	0		+/- 0	0	0
Cyphastraea								
0 – 5 cm	0.021667	1.573592	848 m^2	18		+/- 50	0 (-31)	68
5 – 10 cm	0.003333	0	848 m^2	3		+/- 0	3	3
10 – 20 cm	0	0	848 m^2	0		+/- 0	0	0
20 – 40 cm	0	0	848 m^2	0		+/- 0	0	0
40 – 80 cm	0	0	848 m^2	0		+/- 0	0	0
80+ cm	0	0	848 m^2	0		+/- 0	0	0
		Total Colonies Damaged		**1,720**			**15**	**2,209**

Table 5. Analysis of damaged coral genera and size ranges documented at tertiary impact reference sites.

A	B	C	D	E		F	G	H
Coral Genus	Average # Colonies Tertiary Impact Reference Sites per m^2	St. Dev	Tertiary Impact Damage Area (m^2)	Estimated # Coral Colonies Damaged (B x D)		90% Confidence Limits	Lower Range # Colonies Damaged (E – F)	Higher Range # Colonies Damaged (E + F)
Pocillopora								
0 – 5 cm	0.005	0	277 m^2	1		+/- 0	1	1
5 – 10 cm	0.0125	1.7320508	277 m^2	3		+/- 26	0 (-22)	29
10 – 20 cm	0.00125	0	277 m^2	0		+/- 0	0	0
20 – 40 cm	0.75	1.0954451	277 m^2	4		+/- 17	0 (-12)	21
40 – 80 cm	0.00125	0	277 m^2	0		+/- 0	0	0
80+ cm	0	0	277 m^2	0		+/- 0	0	0
Montipora								
0 – 5 cm	0	0	277 m^2	0		+/- 0	0	0
5 – 10 cm	0.00375	0.7071068	277 m^2	1		+/- 11	0 (-10)	12
10 – 20 cm	0.0025	0	277 m^2	1		+/- 0	1	1
20 – 40 cm	0.01	0.155769938	277 m^2	3		+/- 43	0 (-40)	46
40 – 80 cm	0.006257	0.11446706	277 m^2	2		+/- 31	0 (-30)	33
80+ cm	0	0	277 m^2	0		+/- 0	0	0
Porites								
0 – 5 cm	0.01875	0.167044648	277 m^2	5		+/- 46	0 (-41)	51
5 – 10 cm	0.01375	0.164851407	277 m^2	4		+/- 45	0 (-42)	49
10 – 20 cm	0.0025	0	277 m^2	1		+/- 0	1	1
20 – 40 cm	0.00125	0	277 m^2	0		+/- 0	0	0
40 – 80 cm	0	0	277 m^2	0		+/- 0	0	0
80+ cm	0	0	277 m^2	0		+/- 0	0	0
Leptastraea								
0 – 5 cm	0.006667	0	277 m^2	0		+/- 0	0	0
5 – 10 cm	0	0	277 m^2	0		+/- 0	0	0
10 – 20 cm	0.001667	0	277 m^2	0		+/- 0	0	0
20 – 40 cm	0.003333	0	277 m^2	0		+/- 0	0	0
40 – 80 cm	0	0	277 m^2	0		+/- 0	0	0
80+ cm	0	0	277 m^2	0		+/- 0	0	0
Cyphastraea								
0 – 5 cm	0.00125	0	277 m^2	0		+/- 0	0	0
5 – 10 cm	0.00125	0	277 m^2	0		+/- 0	0	0
10 – 20 cm	0	0	277 m^2	0		+/- 0	0	0
20 – 40 cm	0	0	277 m^2	0		+/- 0	0	0
40 – 80 cm	0	0	277 m^2	0		+/- 0	0	0
80+ cm	0	0	277 m^2	0		+/- 0	0	0
		Total Colonies Damaged		**25**			**3**	**194**

LIVE ROCK

The total area of live rock damaged was calculated to be 1,964 m^2 (0.53 acres) (Table 6). These measurements are hard measurements taken with a tape measure, as opposed to GPS points that have an estimated margin of error. These measurements do not include all the damage

caused by scattering debris. Nor was the full length of the egress scar, which extends over 400 m, accounted for. Only the solid scar path was accounted for in the egress scar, since the remainder of the scar was areas where the vessel bounced along the bottom creating varying degrees of damage.

Table 6. Total area of damaged submerged lands due to the CFV *Pacific Paradise*. Tertiary egress scar was calculated using the area of a trapezoid (Area = ($Base_1$ + $Base_2$)/2 x Height).

Impact Area	Width (m)	Lenth (m)	Total Area (m^2)
Primary/Secondary Impacts	16.9 17.4	50.2 22.3	848 388 **(Total 1,236)**
Ingress Scar	4.9	27.1	133
Initial Egress Scar	4.7	21.6	102
Tertiary Impact	9.7	28.6	277
Tertiary Egress Scar	10.4, 1	37.9	216
Total Damaged Substrate			**1,964 m^2**

Conservative estimates of live rock, excluding the ingress and egress scars, within the primary/secondary and tertiary impact areas total 1,513 m^2. Subtraction of sand (i.e. non-live rock) determined to be within both the primary/secondary and tertiary scars (128.34 m^2 and 23.08 m^2 respectively) (Tables 7 & 8) resulted in an estimate of 1,361.58 m^2 of damaged live rock. The State differentiates between high value and lower value live rock based in part upon the complexity of the live rock; complexity includes the biodiversity of life attached to the substrate, the three-dimensional structure of the substrate with the attached organisms and the dense presence of key native sessile species which are known to have important ecological relationships with other important reef constituents. DAR estimated the impact to high value live rock in both the primary/secondary impact scar (Table 7) and the tertiary impact scar (Table 8). Conservative estimates of live rock damage (i.e. primary/secondary and tertiary scars only) includes 1,060.35 m^2 of lower value live rock and 301.23 m^2 of high value live rock.

Table 7. Analysis of damaged high value live rock and estimate of sand within primary/secondary impact damaged area. * Minus existing unimpacted cover in impacted area. ** Applies only to soft corals and zoanthids.

A	B	C	D	E	F	G	H
High Value Live Rock Primary Component	Average % Cover* per m^2 Primary /Secondary Impact Sites	St Dev	Upper 90% Conf.	Lower 90% Conf.	Primary Impact Damage Area (m^2)	Estimated # Live Rock (per size category) damaged**	Conservative Estimated High Value Live Rock Damaged (m^2) (E x F)
Algae							
Crustose Coralline Algae (CCA)	0.136464	0.90901	0.139839	0.13309	1,236 m^2		164.50 m^2
Gelidium spp.	0.026667	0.034816	0.027959	0.025374	1,236 m^2		31.36 m^2
Melanamansia glomerata	0.036364	0.045837	0.038065	0.034662	1,236 m^2		42.84 m^2
Portiera hornemanni	-0.10111 (0)	0.019425	-0.1004 (0)	-0.10183 (0)	1,236 m^2		-125.86 (0 m^2)
Cnidarians							
Sarcothelia spp.							2.19 m^2
0 - <5 cm	0.006667	1.414214			1,236 m^2	5.65	
5 - <10 cm	0.013333	2.081666			1,236 m^2	11.31	
10 - <20 cm	0.001667	0			1,236 m^2	1.41	
Palythoa spp.							4.15 m^2
0 - <5 cm	0.003333	0			1,236 m^2	2.82	
5 - <10 cm	0.005	0.707107			1,236 m^2	4.24	
10 - <20 cm	0.006667	0.57735			1,236 m^2	5.65	
20 - <40 cm	0	0			1,236 m^2	0	
40 - <80 cm	0.001667	0			1,236 m^2	1.41	
				Total High Value Live Rock Damaged			**245.04 m^2**
Sand	0.103831	0.132975			1,236 m^2		128.34 m^2

Table 8. Analysis of damaged high value live rock and estimate of sand within tertiary impact damaged area. * Minus existing unimpacted cover in impacted area. ** Applies only to soft corals and zoanthids.

A	B	C	D	E	F	G	H
High Value Live Rock Primary Component	Average % Cover* per m^2 Tertiary Impact Sites	St Dev	Upper 90% Conf.	Lower 90% Conf.	Tertiary Impact Damage Area (m^2)	Estimated # Live Rock (per size category) damaged**	Conservative Estimated High Value Live Rock Damaged (m^2) (E x F)
Algae							
Crustose Coralline Algae (CCA)	0.205556	0.050185	0.208264	0.202848	277 m^2		56.19 m^2
Gelidium spp.	-0.04444	0.013608	-0.04371	-0.04518	277 m^2		-12.51 (0 m^2)
Melanamansia glomerata	-0.00556	0.017213	-0.00463	-0.00648	277 m^2		-1.80 m^2 (0 m^2)
Cnidarians							
Sarcothelia spp.							0 m^2
0 - <5 cm	0	0			277 m^2	0	
5 - <10 cm	0.00125	0			277 m^2	0.34	
10 - <20 cm	0.0025	0			277 m^2	0.69	
Palythoa spp.							0 m^2
0 - <5 cm	0	0			277 m^2	0	
5 - <10 cm	0	0			277 m^2	0	
10 - <20 cm	0	0			277 m^2	0	
20 - <40 cm	0	0			277 m^2	0	
40 - <80 cm	0	0			277 m^2	0	
				Total High Value Live Rock Damaged			**56.19 m^2**
Sand	0.083333	0.117851			277 m^2		23.08 m^2

DISCUSSION/RECOMMENDATIONS

REA surveys suggest higher fish biomass at reference sites in comparison to impact sites. Benthic cover data suggest a loss of algal richness and reef accreting substrate at impact sites. Coral data suggest that very little live coral remains in the damaged area, and the reference sites have substantially more coral colonies and higher biodiversity.

It is worth noting that the location the CFV *Pacific Paradise* ran aground was a previously established Fisheries Management Area (FMA) delineated by the State of Hawai'i. This FMA is

adjoined to the Waikīkī Marine Life Conservation District. This area is known to have low coral coverage after years of heavy use associated with anthropogenic impacts, which makes all corals and live rock in this management area a higher value.

This report documents that a net ecological loss of services and functions has occurred to the State of Hawai'i within a legally protected Marine Managed Area as a result of the CFV *Pacific Paradise* grounding. The corals, algae, and reef accreting fauna that existed prior to the incident provided habitat, food for fish and invertebrates, reef rugosity, shelter, and a seed bank for new coral recruits. With the loss of these species, the area is now more exposed to invasive species which are known to rapidly colonize open space.

Further surveys will be conducted to monitor for the establishment of invasive species. In cooperation with Cates Marine, ongoing debris surveys will periodically be conducted to ensure all debris from the *Pacific Paradise* was removed from the Waikīkī FMA and MLCD.

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Exhibit B

CORAL PENALTY MATRIX

	Encrusting	Solitary	Branching	Digiform	Plate-Like	Massive
0 – 5 cm	$10	$20	$25	$25	$25	$20
5 – 10 cm	$20	$40	$50	$50	$50	$40
10 – 20 cm	$50	$100	$100	$100	$100	$100
20 – 40 cm	$100	$200	$200	$200	$200	$200
40 – 80 cm	$200	n/a	$400	$400	$500	$500
80 – 160 cm	$500	n/a	$800	$800	$1000	$1000
+ 160 cm	$750	n/a	$1000	$1000	$1000	$1000

RARE CORAL PENALTY MATRIX

	Encrusting	Solitary	Branching	Digiform	Plate-Like	Massive
0 – 5 cm	$20	$40	$50	$50	$50	$40
5 – 10 cm	$40	$80	$100	$100	$100	$80
10 – 20 cm	$100	$200	$200	$200	$200	$200
20 – 40 cm	$200	$400	$400	$400	$400	$400
40 – 80 cm	$400	n/a	$800	$800	$1000	$1000
80 – 160 cm	$1000	n/a	$1000	$1000	$1000	$1000
+ 160 cm	$1000	n/a	$1000	$1000	$1000	$1000

FMA CORAL PENALTY MATRIX

	Encrusting	Solitary	Branching	Digiform	Plate-Like	Massive
0 – 5 cm	$15	$30	$35	$35	$35	$30
5 – 10 cm	$30	$60	$75	$75	$75	$60
10 – 20 cm	$75	$150	$150	$150	$150	$150
20 – 40 cm	$150	$300	$300	$300	$300	$300
40 – 80 cm	$300	n/a	$600	$600	$750	$750
80 – 160 cm	$750	n/a	$1000	$1000	$1000	$1000
+ 160 cm	$1000	n/a	$1000	$1000	$1000	$1000

MLCD CORAL PENALTY MATRIX

	Encrusting	Solitary	Branching	Digiform	Plate-Like	Massive
0 – 5 cm	$20	$40	$50	$50	$50	$40
5 – 10 cm	$40	$80	$100	$100	$100	$80
10 – 20 cm	$100	$200	$200	$200	$200	$200
20 – 40 cm	$200	$400	$400	$400	$400	$400
40 – 80 cm	$400	n/a	$800	$800	$1000	$1000
80 – 160 cm	$1000	n/a	$1000	$1000	$1000	$1000
+ 160 cm	$1000	n/a	$1000	$1000	$1000	$1000

RARE CORAL FMA PENALTY MATRIX

	Encrusting	Solitary	Branching	Digiform	Plate-Like	Massive
0 – 5 cm	$30	$60	$75	$75	$75	$60
5 – 10 cm	$60	$120	$150	$150	$150	$120
10 – 20 cm	$150	$300	$300	$300	$300	$300
20 – 40 cm	$300	$600	$600	$600	$600	$600
40 – 80 cm	$600	n/a	$1000	$1000	$1000	$1000
80 – 160 cm	$1000	n/a	$1000	$1000	$1000	$1000
+ 160 cm	$1000	n/a	$1000	$1000	$1000	$1000

RARE CORAL MLCD PENALTY MATRIX

	Encrusting	Solitary	Branching	Digiform	Plate-Like	Massive
0 – 5 cm	$40	$80	$100	$100	$100	$80
5 – 10 cm	$208	$160	$200	$200	$200	$160
10 – 20 cm	$200	$400	$300	$400	$400	$400
20 – 40 cm	$400	$800	$800	$800	$800	$800
40 – 80 cm	$800	n/a	$1000	$1000	$1000	$1000
80 – 160 cm	$1000	n/a	$1000	$1000	$1000	$1000
+ 160 cm	$1000	n/a	$1000	$1000	$1000	$1000

LIVE ROCK PENALTY MATRIX (m^2)

	Rubble	Pavement	Reef	Basalt	High Rugosity
Turf / Cyanobacteria	$10	$20	$40	$20	$40
Macroalgae	$20	$100	$200	$100	$200
CCA - Encrusting	$200	$400	$600	$400	$600
CCA - Rugose	$400	$800	$1000	$800	$1000
Sponge, Bryozoan, Other Sessile	$100	$150	$300	$150	$300
Soft Coral / Zoanthid	$80	$200	$400	$200	$400
High Biodiversity	$200	$400	$600	$400	$600

FMA LIVE ROCK PENALTY MATRIX (m^2)

	Rubble	Pavement	Reef	Basalt	High Rugosity
Turf / Cyanobacteria	$15	$30	$60	$30	$60
Macroalgae	$30	$150	$300	$150	$300
CCA - Encrusting	$300	$600	$800	$600	$900
CCA - Rugose	$600	$1000	$1000	$1000	$1000
Sponge, Bryozoan, Other Sessile	$150	$225	$450	$225	$450
Soft Coral / Zoanthid	$120	$300	$600	$300	$600
High Biodiversity	$300	$600	$800	$600	$900

MLCD LIVE ROCK PENALTY MATRIX (m^2)

	Rubble	Pavement	Reef	Basalt	High Rugosity
Turf / Cyanobacteria	$20	$40	$80	$40	$80
Macroalgae	$40	$200	$400	$200	$400
CCA - Encrusting	$400	$800	$1000	$800	$1000
CCA - Rugose	$800	$1000	$1000	$1000	$1000
Sponge, Bryozoan, Other Sessile	$200	$300	$600	$300	$600
Soft Coral / Zoanthid	$160	$400	$800	$400	$800
High Biodiversity	$400	$800	$1000	$800	$1000