U.S. Army Corps
of Engineers®
Honolulu District

Public Notice

Proposal for an "Umbrella" Coral Reef Mitigation Bank

Corps File No.	Date:
POH-2013-00221	**November 12, 2014**

Reply to:
U.S. Army Corps of Engineers
Honolulu District
Regulatory Office, CEPOH-RO
Building 230
Fort Shafter, Hawaii 96858-5440

Respond by:
December 15, 2014

Interested parties are hereby notified that the U.S. Army Corps of Engineers (Corps) is considering a proposal that would establish an umbrella coral reef mitigation bank that would incorporate multiple mitigation bank sites located in various service areas throughout the Main Hawaiian Islands (MHI).

BANK SPONSOR:

State of Hawaii, Department of Land and Natural Resources (DLNR)
1151 Punchbowl Street, #330
P.O. Box 621
Honolulu, Hawaii 96813
POC: Katherine Cullison, Mitigation Coordinator
(808) 587-2276
kate1@hawaii.edu

AGENT: Not applicable

LOCATION:

The location of the proposed umbrella mitigation bank encompasses the MHI and includes six service areas based on USGS 8-digit Hydrologic Unit Codes (HUC), namely: Hawaii (HUC 20010000), Maui (HUC 20020000), Molokai (HUC 20050000), Lanai (HUC 20040000), Oahu (HUC 20060000), and Kauai (HUC 20070000).

ACTIVITY/WORK:

As presented in its Prospectus, dated September 18, 2014, DLNR proposes to establish, use, and operate an "umbrella" compensatory mitigation bank for projects and activities that would result in unavoidable adverse impacts to coral reefs authorized by Department of the Army (DA) permits. This public notice is requesting comments on DLNR's Prospectus (attached).

ADDITIONAL INFORMATION:

Mitigation Banking Background—Mitigation banks provide an alternative to traditional Permittee-responsible compensatory mitigation projects. Mitigation banks offer an opportunity for bank sponsors to implement compensatory mitigation at a watershed or regional scale in advance of impacts to waters of the United States, thereby providing strategically located mitigation that optimizes ecological suitability based on watershed needs. Mitigation banks also offer the benefit of reducing temporal losses of aquatic resources because the mitigation work is completed in advance of the impacts occurring, meaning the anticipated loss of aquatic resource functions and/or services are replaced at the mitigation bank site prior to the loss occurring at the project impact site.

Mitigation banks establish "credits" through activities and measures that restore, create, enhance and/or preserve targeted aquatic resources, such as coral reefs or wetlands. These credits can then be sold by the mitigation bank sponsor to DA permit applicants who need to offset unavoidable adverse impacts to aquatic resources that would result from individual projects located within the approved "service area" of the mitigation bank. Upon the sale of available bank credits, the compensatory mitigation responsibility is transferred from the DA Permittee to the mitigation bank sponsor.

The document that addresses the mitigation bank process, including how it is established, used, and managed, is the Mitigation Banking Instrument (MBI). The MBI constitutes the Corps' regulatory approval for a mitigation bank to be used to provide compensatory mitigation for DA permits pursuant to 33 C.F.R. 332.8(a)(1).

The MBI is based on a Prospectus, which is a planning level document that is prepared by the mitigation bank sponsor and provides a summary of the information regarding the proposed mitigation bank, including, but not limited to: the objectives of the proposed mitigation bank; how the mitigation bank will be established and operated; the proposed service area(s); the general need for and technical feasibility of the proposed mitigation bank; the proposed ownership arrangements and long-term management strategy for the mitigation bank; the qualifications of the mitigation bank sponsor to successfully complete the type(s) of mitigation projects proposed; the ecological suitability of the site(s) to achieve the objectives of the proposed mitigation bank, including the physical, chemical, and biological characteristics of the bank site(s) and how the site(s) will support planned types of aquatic resources and functions; and when applicable, assurance of sufficient water rights to support the long-term sustainability of the mitigation bank.

Project Description and Objectives — According to DLNR's Prospectus, the proposed umbrella mitigation bank would provide high quality compensatory mitigation to offset the losses of coral reefs authorized by DA permits. The bank would have the potential to serve a variety of future DA permit applicants, including commercial and private entities as well as public agencies and other organizations proposing work in waters of the U.S. that would result in the unavoidable permanent loss of coral reefs.

More specifically, DLNR proposes to maintain or improve the quantity and condition of coral reefs at banks sites and provide high quality compensatory mitigation that yields ecologically successful and sustainable results. These objectives would be accomplished by:

- Identifying and prioritizing resources for strategic site selection
- Integrating bank efforts with other conservation activities, where practicable
- Monitoring bank sites and applying adaptive management, as needed
- Providing long-term stewardship of the resources

The Prospectus identifies two potential mitigation bank sites located within the Oahu service area, namely: Kaneohe Bay Patch Reefs on the east shore of the island and Waikiki Marine Life Conservation District (MLCD) located along the south shore of Oahu.

The Waikiki MLCD Mitigation Bank Site would be enhanced and/or restored through the transplanting of coral colonies onto suitable areas of reef structure, controlling invasive algae, and out-planting of native grazing sea urchins that would function as a natural bio-control. The goal of this site is to increase live coral cover that would provide additional habitat for reef-dwelling organisms, including fish.

The Kaneohe Bay Patch Reefs Mitigation Bank Site would entail similar mitigation activities as the Waikiki MLCD site that would also restore degraded patch reefs where invasive algae has taken over and resulted in partial or full mortality of live corals. According to DLNR, work activities at the proposed Kaneohe Bay Patch Reefs Mitigation Bank Site would continue to support invasive algae management efforts within the bay that are already in practice by DLNR and The Nature Conservancy. The initial Kaneohe Patch Reefs Mitigation Bank Site would be comprised of four patch reefs (Reefs #10, #14, #16 and #19), totaling 57,546 square meters. Reef restoration would be carried out in two phases. The first phase would involve the removal of the invasive algae by mechanical means via the "Supersucker" (i.e., an underwater vacuum system designed to remove and transport invasive algae off-site to uplands) and the second phase would entail the out-planting of sea urchins (bio-control agents) to the reefs to graze on any residual invasive algae and prevent its re-growth.

The overall intent of the DLNR coral reef umbrella mitigation bank is for the MBI to be modified or expanded as the need for new coral reef mitigation bank sites are identified and suitable sites are selected. In modifying the MBI, each new mitigation site that is proposed to be added to the umbrella mitigation bank would first necessitate the preparation and public review of a site-specific compensatory mitigation plan. If approved by the Corps and IRT, the mitigation plan would become a modification of the MBI and the new mitigation site would be operated and managed in accordance with the terms and conditions of the umbrella MBI.

Service Area — A "service area" for an approved mitigation bank is the geographic area within which impacts can be mitigated at a specific mitigation bank as designated in its MBI. The proposed service areas for the DLNR umbrella coral reef mitigation bank include six islands: Kauai, Oahu, Lanai, Molokai, Maui, and Hawaii. Each island is identified by an 8-digit HUC and constitutes an individual service area.

Evaluation Process — The Corps is soliciting comments from interested parties, including the general public; Federal, State, and local agencies; Native Hawaiian Organizations; and other interested parties to help inform the Corps and the Interagency Review Team (IRT) as to the overall merits of the proposal, the scope of the proposed umbrella mitigation bank, the delineation of the service areas, the ecological suitability of the sites to achieve coral reef restoration, and to identify project aspects that will need to be addressed during the development of a draft MBI, should the Corps, in consultation with the IRT, determine there is potential for the proposed umbrella mitigation bank to provide coral reef compensatory mitigation. Should the Corps' evaluation of the Prospectus result in an affirmative decision and should DLNR elect to move forward with the preparation of a draft MBI, the decision whether to approve the umbrella coral reef MBI will be based on the Corps' evaluation of: IRT input and comments; credit determination; the technical feasibility and ecological suitability of the proposal to successfully achieve compensatory mitigation of coral reefs; and fulfillment of applicable requirements prescribed in federal regulation at 33 C.F.R. 332.8.

Comment and Review Period — Conventional mail or electronic (e-mail) comments on this public notice will be accepted and made part of the official administrative record. In order to be accepted, e-mail comments must originate from the author's e-mail account and must include on the subject line of the e-mail message the Corps file number as indicated on the cover page of this public notice. Conventional mail comments must also include reference to the subject and Corps file number.

E-mail comments should be sent to:

susan.a.meyer@usace.army.mil
-or-
cepoh-ro@usace.army.mil.

Conventional mail comments should be sent to:

U.S. Army Corps of Engineers, Honolulu District
Regulatory Office (CEPOH-RO)
Attn: Susan A. Meyer
Building 230
Ft. Shafter, Hawaii 96848

All comments whether conventional mail or e-mail must reach this office no later than the expiration date of this public notice to ensure consideration. All comments received within the established review period will be meaningfully considered by the Corps and the IRT. Comments will be distributed to the IRT and the mitigation bank sponsor within 15 days of the close of the public comment period. The Honolulu District Engineer and the IRT will also have the opportunity to comment to the sponsor.

This public notice is issued by the Chief, Regulatory Office.

Attachment
(Prospectus entitled "*Hawaii Department of Land and Natural Resources, Aquatic Umbrella Mitigation Bank*", dated September 18, 2014)

Hawai`i Department of Land and Natural Resources
William Aila, Chairperson
1151 Punchbowl Street
Honolulu, HI 96813
(808) 587-0400

Hawai`i Department of Land and Natural Resources
Aquatic Umbrella Mitigation Bank
Prospectus

Prepared by Division of Aquatic Resources. (808)587-0100. 1151 Punchbowl St. #330. Honolulu, HI 96813

SUMMARY

This document is the Prospectus for the proposed Aquatic Umbrella Mitigation Bank sponsored by Hawai`i Department of Land and Natural Resources ("DLNR"). This prospectus provides an overview of the proposed statewide mitigation bank and is the basis for informed public and agency comments.

Infrastructure development and maintenance activities in or near aquatic environments can cause harmful impacts to aquatic habitats. These activities must be authorized by permits from the US Army Corps of Engineers ("Corps"), which has a programmatic goal of "no-net-loss" of aquatic resources. In pursuit of this goal, the Corps requires a permit applicant to first avoid and minimize adverse impacts, and finally to provide mitigation to compensate for unavoidable permanent losses of aquatic resources. A mitigation bank is a site where aquatic resources are restored, created, enhanced, or preserved for the purpose of providing compensatory mitigation in advance of authorized impacts to similar resources. An umbrella bank is a regional mitigation program with the potential for incorporating multiple mitigation bank sites.

There are currently no mitigation banks in Hawai`i. Permitees are responsible for mitigating their individual impacts, which results in smaller haphazardly placed projects that may or may not offset the loss of ecological functions at the permit site. It also results in significant permit processing delays, as the mitigation proposal for each permit action must be evaluated before the permit can be approved. The Corps has stated that it is preferable, both economically and ecologically, for aquatic resources that are used as mitigation offsets to be created and maintained by a third-party who has the scientific and management expertise to do so. In this case, the proposed third-party sponsor is the State of Hawai`i DLNR, the agency delegated to manage and conserve these public trust resources, and responsible for the success of the mitigation projects. The DLNR mitigation bank will provide a preferred mechanism for offsetting natural resource losses associated with authorized impacts

The benefits of mitigation banking include:

- Increased likelihood that the compensatory mitigation will be successful in offsetting project impacts
- Reduced permit processing times
- The use of extensive resources, planning, and scientific expertise not always available to permittee-responsible mitigation projects

The Corps evaluates the bank according to the ecological gain generated, and expresses that value in terms of credits. Credits are the standard unit of measurement that serve as the currency of the mitigation bank, and provide the economic compensation to the sponsor for restoring the degraded habitat.

This prospectus identifies the first two proposed bank sites: Kāne`ohe Bay and Waikīkī Marine Life Conservation District, both coral reef habitats. The restoration of these sites will utilize invasive species control and coral replenishment. DLNR anticipates incorporating additional sites statewide as they become necessary and feasible, and may add bank sites for other types of aquatic habitats.

The process of establishing a mitigation bank involves several phases and is reviewed throughout by regulatory agencies. This prospectus is made available with the goal of generating thoughtful feedback to aid in creating a draft mitigation banking instrument. DLNR looks forward to receiving comments and suggestions on the contents of this prospectus.

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TABLE OF ACRONYMS

DLNR	Hawai`i Department of Land and Natural Resources
Bank	Hawai`i DLNR Aquatic Umbrella Mitigation Bank
Corps	U.S. Army Corps of Engineers
CWA	Clean Water Act
DA	Department of the Army
MOA	Memorandum of Agreement
EPA	Environmental Protection Agency
Mitigation Rule	Compensatory Mitigation for Losses of Aquatic Resources. 33 CFR Part 325 and 332; 40 CFR 230
DE	Corps District Engineer
IRT	Interagency Review Team
NMFS	NOAA National Marine Fisheries Service
USFWS	U.S. Fish and Wildlife Service
MBI	Mitigation Banking Instrument
DOH	Hawai`i Department of Health
CZM	Hawai`i Office of Planning, Coastal Zone Management
HUC	Hydrologic Unit Code
Trust Fund	Aquatic Mitigation and Restoration Trust Fund
AFRC	Anuenue Fisheries Research Center
Waikīkī MLCD	Waikīkī Marine Life Conservation District
Bay	Kāne`ohe Bay, O`ahu
SNAP	Snapshot Survey

1 INTRODUCTION

1.1 BACKGROUND

1.1.1 MITIGATION REQUIREMENTS UNDER THE CLEAN WATER ACT

The primary objective of the Clean Water Act ("CWA") is to "restore and maintain the chemical, physical, and biological integrity of the nation's waters."[1] To achieve this objective, the U.S. Army Corps of Engineers ("Corps") requires a Department of the Army ("DA") permit pursuant to Section 404 of the CWA for any discharge of "dredged or fill" material into the waters of the U.S. For every authorized discharge, the permit applicant must mitigate the adverse impacts to the aquatic resources. The 1990 Memorandum of Agreement ("MOA") between the Environmental Protection Agency ("EPA") and the DA establishes a three-part process, known as the "mitigation sequence"[2] to help guide mitigation decisions and determine the type and level of mitigation required under CWA Section 404 regulations:

Step 1. Avoid – The permit applicant must first avoid adverse impacts to aquatic resource. The Corps will not permit a discharge if there is a practicable alternative with less adverse impact.[3]

Step 2. Minimize – If the permit applicant cannot avoid impacts, the applicant must take appropriate and practicable steps to minimize adverse impacts.

Step 3. Compensate – For unavoidable adverse impacts which remain after the applicant completes steps 1 and 2, the applicant may be required to replace the loss of the aquatic resources through compensatory mitigation. Compensatory mitigation is the restoration, establishment, enhancement, and/or preservation of aquatic resources for the purposes of offsetting unavoidable losses. The amount and quality of compensatory mitigation will not substitute for avoiding and minimizing impacts.

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[1] 33 U.S.C. § 1251.

[2] 1990 Memorandum Of Agreement (MOA) on The Determination of Mitigation under the Clean Water Act Section 404(b)(1) Guidelines, Feb. 6, 1990, The U.S. Department of the Army – The U.S. Environmental Protection Agency. (Portions of this MOA that concern the type and location of compensatory mitigation are superseded by the 2008 Compensatory Mitigation Rule, 33 C.F.R. Part 332.)

[3] According to 40 C.F.R. § 230.91(c)(2), practicable means "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes."

The Corps is responsible for determining the appropriate form and amount of compensatory mitigation. The Compensatory Mitigation Rule ("Mitigation Rule"), 33 C.F.R. Part 332, establishes a preference hierarchy for the types of compensatory mitigation. The Corps prefers mitigation banks over any other form of compensatory mitigation,[4] because banks enable faster permit approval time and increased likelihood of ecological success.

A mitigation bank is "a site, or suite of sites, where [aquatic] resources . . . are restored, established, enhanced, and/or preserved for the purpose of providing compensatory mitigation for impacts authorized by DA permits."[5] Where mitigation bank resources are restored, established, enhanced, and/or preserved, the bank sponsor and Corps quantify the value of the resource improvements into "credits." Applicants for Section 404 DA permits may then purchase these credits to satisfy their compensatory mitigation requirements. After the sale of the credits, the bank sponsor is responsible for maintaining the improved resources in perpetuity. An umbrella mitigation bank is simply a bank with the potential for multiple sites. Once a sponsor establishes an umbrella bank, it may add additional sites by following procedures prescribed by the Corps.[6]

1.1.2 DOCUMENTATION AND PROCESS TO ESTABLISH A MITIGATION BANK

The prospectus provides an overview of the proposed mitigation bank and triggers agency and public involvement.[7] According to the Mitigation Rule, prospectus must contain 8 elements:[8]

1. Objectives
2. How the Bank will be established and operated
3. Proposed service areas
4. Need and technical feasibility
5. Ownership arrangements
6. Qualifications

[4] 33 C.F.R. § 332.3. Mitigation banks are followed by in-lieu fee program credits; permittee-responsible mitigation under a watershed approach; permittee-responsible mitigation through on-site and in-kind mitigation: and lastly, permittee-responsible mitigation through off-site and/or out-of-kind mitigation.
[5] 33 C.F.R. § 332.2.
[6] Mitigation banking is common in the continental U.S. As of July 2014, the Regulatory In-lieu Fee and Bank Information Tracking System ("RIBITS") identified 1,262 approved mitigation banks in 42 out of 50 States. *Banks and ILF Sites,* Regulatory In-lieu Fee and Bank Information Tracking System, https://rsgisias.crrel.usace.army.mil/ribits/f?p=107:158:7718716999231::NO:RP:: (last visited July, 21, 2014).
[7] 33 C.F.R. § 332.8.
[8] 33 C.F.R § 332.8(d)(2).

7. Ecological suitability
8. Assurance of sufficient water rights

As a courtesy, DLNR has included the optional conceptual mitigation plans for both sites in this prospectus in order to solicit informed feedback during the comment period and review process.

Within 30 days of receipt of the prospectus, the Corps District Engineer ("DE") provides public notice of the proposed bank and opens a 30-day comment period (Figure 1). Within 15 days of the close of the public comment period, the Corps distributes copies of all received comments to the Interagency Review Team ("IRT") and the bank sponsor.[9] The IRT, established by the Corps, is comprised of federal, tribal, state, and/or local regulatory and resource agency representatives. Although the Corps is ultimately responsible for approving a mitigation bank, the IRT reviews the bank documentation and advises the Corps. Representatives of the U.S. Environmental Protection Agency ("EPA"), National Marine Fisheries Service ("NMFS"), and U.S. Fish and Wildlife Service ("USFWS"), and certain State departments are automatically included on the IRT if they choose to participate.[10] Beyond these participants, the Corps may determine the composition of the IRT. The Corps may invite other public agencies with a substantive interest in the establishment of a mitigation bank to join the IRT.

After receiving prospectus comments, the bank sponsor prepares a draft Mitigation Banking Instrument ("MBI"). The MBI "is the legal document for the establishment, operation, and use of a mitigation bank."[11] The draft MBI "must be based on the prospectus and must describe in detail the physical and legal characteristics of the mitigation bank . . . and how it will be established and operated."[12] The draft MBI contains 7 elements:

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[9] *Id.*

[10] In Hawai`i, the following state and federal resource agencies are potential participants on an IRT:

- U.S. Army Corps of Engineers ("Corps"), Chair
- Hawai`i Department of Land and Natural Resources ("DLNR")
- U.S. Environmental Protection Agency ("USEPA")
- U.S. Fish and Wildlife Service ("USFWS")
- NOAA National Marine Fisheries Service ("NMFS")
- Hawai`i Department of Health ("DOH")
- Hawai`i Office of Planning- Coastal Zone Management ("CZM")

Although DLNR is usually member of the IRT, DLNR cannot participate as a reviewer for this mitigation bank because it is the bank sponsor.

[11] 33 C.F.R. § 332.2.

[12] 33 C.F.R § 332.8(d)(6).

1. A description of the proposed geographic service area
2. Accounting procedures
3. A statement that legal responsibility over compensatory mitigation transfers to the sponsor once the permittee purchases credits
4. Default and closure provisions
5. Reporting protocols
6. Credit release schedule tied to specific milestones
7. Mitigation plans for each proposed bank site (mitigation plans contain additional key elements)

Upon receiving the draft MBI, the Corps distributes copies to the IRT for a 30-day comment period, followed by a 60-day discussion period. Within 90 days of distribution of the draft instrument to IRT members, the Corps notifies the sponsor of any changes that may be necessary in the final MBI.

The sponsor must submit to the Corps a final MBI that contains supporting documentation explaining how the final MBI addresses IRT comments. Within 30 days, the Corps will notify IRT members whether or not the MBI will be approved. If no IRT member objects within 45 days of receipt of the final MBI, the Corps informs the sponsor of the final decision and arrange for the appropriate parties to sign the MBI.

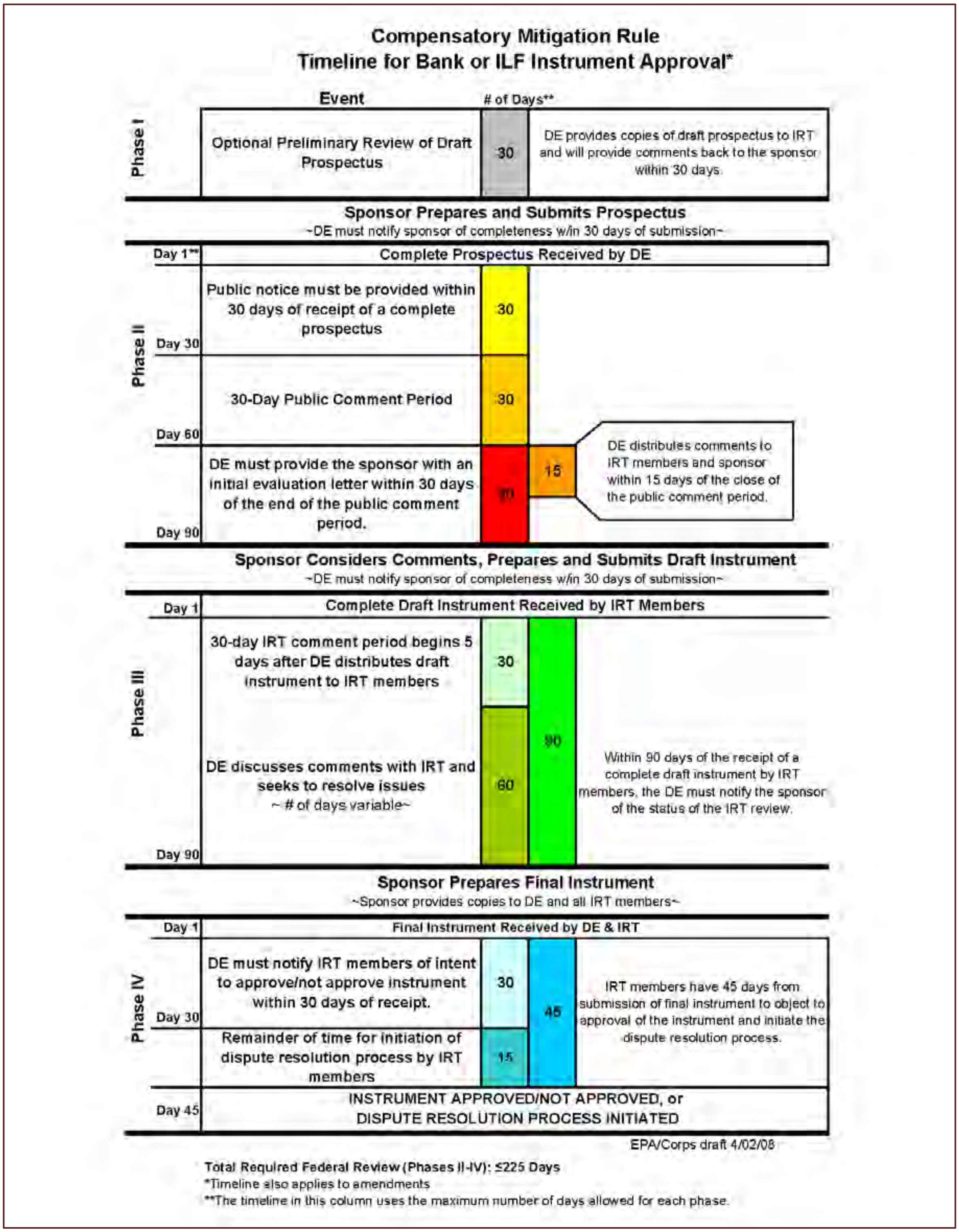

FIGURE 1. OFFICIAL TIMELINE FOR INTERAGENCY REVIEW OF MITIGATION BANK DOCUMENTS

1.2 PURPOSE

The Hawai`i Department of Land and Natural Resources ("DLNR") proposes to sponsor the Hawai`i DLNR Aquatic Umbrella Mitigation Bank ("Bank") to provide high quality mitigation for unavoidable impacts to aquatic resources authorized by DA permits. As the Sponsor, the DLNR will identify, fund, operate, maintain, and manage the Bank and all bank sites.

In Hawai`i, infrastructure development and harbor maintenance affect the quality and quantity of valuable aquatic habitats. Presently, there are no mitigation banks in the State. Therefore, when section 404 permit applicants reach the compensatory mitigation stage of the mitigation sequence, they must design and implement their own compensatory mitigation projects ("permittee-responsible compensatory mitigation"). Permittee-responsible compensatory mitigation is neither the most effective nor the most efficient form of compensatory mitigation. Permittee-responsible compensatory mitigation often delays permit approvals because the Corps must review and accept each permit applicant's mitigation plans. In addition, most permittee-responsible projects are small and do not yield the most optimal resource replacements. The Corps prefers mitigation banks as the alternative to permittee-responsible mitigation because the large size and long-term management of banks increases the likelihood of successful ecological benefit. The purpose of this Bank is to offset natural resource losses from DA permits with sustainable and high quality replacement habitats. The Bank's purpose is consistent with DLNR's responsibility to protect and conserve the State's natural resources for present and future generations.[13]

By issuing this prospectus, DLNR seeks comments from state and federal agencies and interested parties. DLNR will consider these comments when drafting the MBI. This prospectus contains an overview of the Bank objectives, general need for a mitigation bank, establishment and operation procedures, qualifications of DLNR as the Bank sponsor, and the proposal for two initial coral reef bank sites within the Waikīkī Marine Life Conservation District and Kāne`ohe Bay. In the future, the DLNR may add additional bank sites that contain a variety of state-owned aquatic habitats, such as wetlands, estuaries, coral reefs, seagrass beds, and anchialine ponds.

[13] See Section 4.1.

2 OBJECTIVES

The purpose of the Bank is to provide the highest quality of compensatory mitigation to offset losses of aquatic resources caused by DA permit actions. The Bank may serve a variety of DA permit applicants, including commercial entities and public and private agencies and organizations. The objectives of the Bank are to:

1. Maintain or improve the quantity and condition of aquatic resources at bank sites
2. Provide high quality compensatory mitigation that yields ecologically successful and sustainable results

The DLNR seeks to achieve these objectives by:

- Identifying and prioritizing resources for strategic site selection
- Integrating Bank efforts with other conservation activities, where practicable
- Monitoring bank sites and applying adaptive management as needed
- Providing long-term stewardship of the resources

These objectives are consistent with DLNR's mandate to preserve and enhance Hawai`i's aquatic resources and are compatible with Hawai`i's Constitution and environmental laws (see section 4.1).

The Bank objectives also align with the goals of the Coastal Zone Management program's 2013 Ocean Resources Management Plan ("ORMP"). The ORMP provides a framework and implementation strategy for state agencies managing ocean resources.[14] The objectives in this prospectus are compatible with the following management priority goals in the ORMP:

1. Promote protection and sustainable use of marine resources
2. Minimize the spread of aquatic invasive species from where there is coral or water quality degradation
3. Improve the health and productivity of coral reef ecosystems at priority sites identified by the Hawai`i Coral Reef Program
4. Implement place based projects that demonstrate effective stewardship practices that can be applied to other areas
5. Preserve cultural heritage of the ocean and protected Native Hawai`ian rights for access and gathering in ocean and on coastline, and protect ocean and coastal

[14] The ORMP is mandated by Haw. Rev. Stat. Chapters 205A and 225M.

resources upon which Native Hawai`ian cultural practices depend.
6. Partner with communities to better manage Hawai`i's marine resources

3 GENERAL NEED FOR AN AQUATIC MITIGATION BANK IN HAWAI`I

In Hawai`i, development pressures and harbor maintenance requirements affect important and valued public trust aquatic resources. Compensatory mitigation is a critical tool to help the federal government meet the national goal of "no net loss" of aquatic habitats and services. The inconsistent results of permittee-responsible projects demonstrate the need for a strategic and comprehensive approach to compensatory mitigation. The State's unique and fragile resources will benefit from an umbrella mitigation bank with multiple sites because the Bank can offer sites in a diverse range of habitat types to effectively compensate for unavoidable DA permit authorized impacts.

Currently, there are no approved third-party aquatic mitigation banks or in-lieu-fee programs within the Corps' Honolulu District. Consequently, the Corps requires permit applicants to develop and implement permittee-responsible compensatory mitigation projects. Resource agencies have concerns about the consistency, efficiency, and the ecological sufficiency of these mitigation projects. As a mitigation bank sponsor, DLNR will provide the requisite long-term commitment to ensure perpetual stewardship and success of restoration efforts at the bank sites.

In the future, DLNR anticipates that a number of new projects will require DA permits and trigger compensatory mitigation requirements for impacts to aquatic resources. In addition to projects proposed by private entities, two state agencies, the Department of Transportation- Harbors Division ("DOT-Harbors") and the DLNR-Division of Boating and Ocean Recreation ("DLNR-DOBOR"), have extensive projects planned in the near future which may require compensatory mitigation.

DOT-Harbors is responsible for administering and managing the State-owned facilities used by cargo, passenger and fishing operations. In 2008, the Governor signed SB 3227 (Act 200, SLH 2008) into law. This Act provides for the implementation of the statewide Harbors Modernization Plan and appropriates funds for harbor expansions, improvements, and upgrades for the following state commercial harbors:

- Kaua`i: Nāwiliwili Harbor
- O`ahu: Honolulu Harbor, Kalaeloa Harbor
- Maui: Hāna Harbor, Kahului Harbor
- Hawai`i: Hilo Harbor, Kawaihae Harbor

Non-commercial harbors in Hawai`i are managed by the DOBOR, which has plans for several projects within the next 1-5 years, including:

- Kaua`i — Port Allen SBH Pier Improvements
- Kaua`i — Nāwiliwili SBH New Floating Dock
- Kaua`i — Kīkīa Ola SBH Maintenance Dredging
- Kaua`i — Port Allen SBH Pier A Replacements
- O`ahu — Ala Wai SBH 500 Row Improvements
- O`ahu — Sand Island South Boat Ramp Improvements
- O`ahu — Wai`anae SBH Pier Impr. Phase V
- O`ahu — Ke`ehi SBH Pier 500 Reconstruction
- O`ahu — Ala Wai SBH 600 Row Reconstruction
- O`ahu — He`eia Kea SBH Loading Dock & Revetment
- O`ahu — Ke`ehi SBH Pier 200 Reconstruction
- Lana`i — Mānele SBH Ferry Pier Replacement
- Lana`i — Mānele SBH Wooden Finger Pier Replacement
- Moloka`i — Kaunakakai Maintenance Dredging
- Maui — Ke`ehi Lagoon Shipyard at Keehi SBH
- Maui — Mā`alaea SBH Ferry Pier Replacement
- Maui — Lahaina SBH Inner Marginal Wharf
- Maui — Lahaina SBH Offshore Moorings
- Hawai`i — Wailoa SBH Maintenance Dredging
- Hawai`i — Keauhou Off-shore Mooring Installations

A mitigation bank will support the economy of Hawai`i by minimizing permitting delays for these planned improvements to State facilities while also effectively protecting public trust natural resources.

4 ESTABLISHMENT AND OPERATION

As the Bank Sponsor, DLNR will identify, fund, operate, maintain, and manage all bank sites.

4.1 OWNERSHIP

All bank sites will be located on State lands where DLNR retains ownership and long-term management authority. DLNR also has the authority to protect the resources contained in the bank sites.[15] The State has fee simple title to the all of Hawai`i's submerged lands from "the upper reaches of the wash of the waves on shore"[16] to three geographical miles seaward[17] or the extent of the State's authority. In addition to a real property interest in bank sites, the State also has an ownership interest in its natural resources under the public trust doctrine. The public trust doctrine is the common law principle that certain natural resources are held by the State in trust for the public. The doctrine places a responsibility on states to manage and protect public trust resources in perpetuity for present and future generations. Hawai`i's public trust doctrine is reflected in article XI sections 1 and 7 of the Hawai`i Constitution. Public trust resources consist of "all natural resources, including land, water, air, minerals and energy sources," as well as the submerged lands and the aquatic natural resources found within the State's boundaries.[18]

DLNR has the responsibility to "manage, administer, and exercise control over public lands, the water resources, ocean waters, navigable streams, coastal areas (excluding commercial harbor areas), and minerals."[19] DLNR's existing responsibilities include the protection and regulation of activities on public and conservation lands, the establishment of marine protected areas, and the authority to require permittees and natural resource violators to pay for the costs required to restore lost habitat or other natural resources.[20] DLNR is headed by the Board of Land and Natural Resources ("BLNR"). In April 2014, BLNR amended the stony coral and live rock rules in Hawai`i Administrative Rules ("HAR") Chapter 13-95 to include new definitions, prohibitions, methods for calculating administrative penalties for violations of the chapter, and cumulative penalties.[21] The amended coral and live rock rules make it unlawful for any person to damage stony corals and live rock "by intentional or negligent activity causing

[15] Each bank site's mitigation plan will describe the State's ownership in further detail.

[16] Haw. Rev. Stat. §§ 187A-1.5, 190.5.

[17] Submerged Lands Act, 43 U.S.C. § 1311(a); 43 U.S.C. § 1312; Hawai`i Admission Act §5(i); Haw. Const. art. XI § 6.

[18] Haw. Const. art. XI §§ 1, 7; *In Re Water Use Permit Applications*, 94 Haw. 97, 9 P.3d 409 (2000) (applying the Public Trust Doctrine to all waters of the State, including ocean waters and resources); 43 U.S.C. § 1311(a).

[19] Haw. Rev. Stat. § 171-3.

[20] See Haw. Rev. Stat. secs. 171-1 et. seq., 183C-1 et. seq., 188-53, 190-1 et. seq.

[21] The rules now contain a broader definition of "damage" and the definitions of live rock and stony corals were amended to encompass more resources. The rule provides specific methods of calculating administrative penalties and violators of any section of HAR Chapter 13-95 may be subject to administrative or criminal penalties or both. These penalties are cumulative to each other and to other remedies or penalties under State law.

the introduction of sediment, biological contaminants, or pollution into state waters."[22]

DLNR has the primary management control and oversight of the State owned mitigation bank sites and the resources contained therein. The Bank will enable DLNR to better protect and conserve public trust resources because it will ensure that compensatory mitigation is conducted in a manner that improves the reliability of mitigation efforts.

4.2 SERVICE AREAS

A service area is "the geographic area within which impacts can be mitigated at a specific mitigation bank [site]."[23] The Mitigation Rule states that compensatory mitigation should occur in the same service area as the DA permitted impact. The Bank is divided into six service areas: Kaua`i, O`ahu, Lana`i, Moloka`i, Maui, and Hawai`i. At this time, both initial bank sites are located within the O`ahu service area. In the future, DLNR may add additional bank sites in the other services areas, when appropriate and practicable. Pursuant the Mitigation Rule, DLNR has identified USGS hydrologic unit codes ("HUC") for each service area (
Figure 2):

- Kaua`i: HUC 200700
- O`ahu: HUC 200600
- Lana`i: HUC 200400
- Moloka`i: HUC 200500
- Maui HUC: 200200
- Hawai`i: HUC 200100

These are large service areas, each encompassing a wide variety of aquatic habitat types. For service areas that have multiple bank sites, DLNR will propose the most appropriate areas and/or habitat types for which it can provide suitable replacement of functions and services.

To address potentially conflicting ecological and economic issues, DLNR will develop a consistent and documented process for evaluating compensatory mitigation within service areas. This determination is subject Corps approval and IRT review.

[22] HAR §§ 13-95-70, 71.
[23] 33 C.F.R. § 332.2.

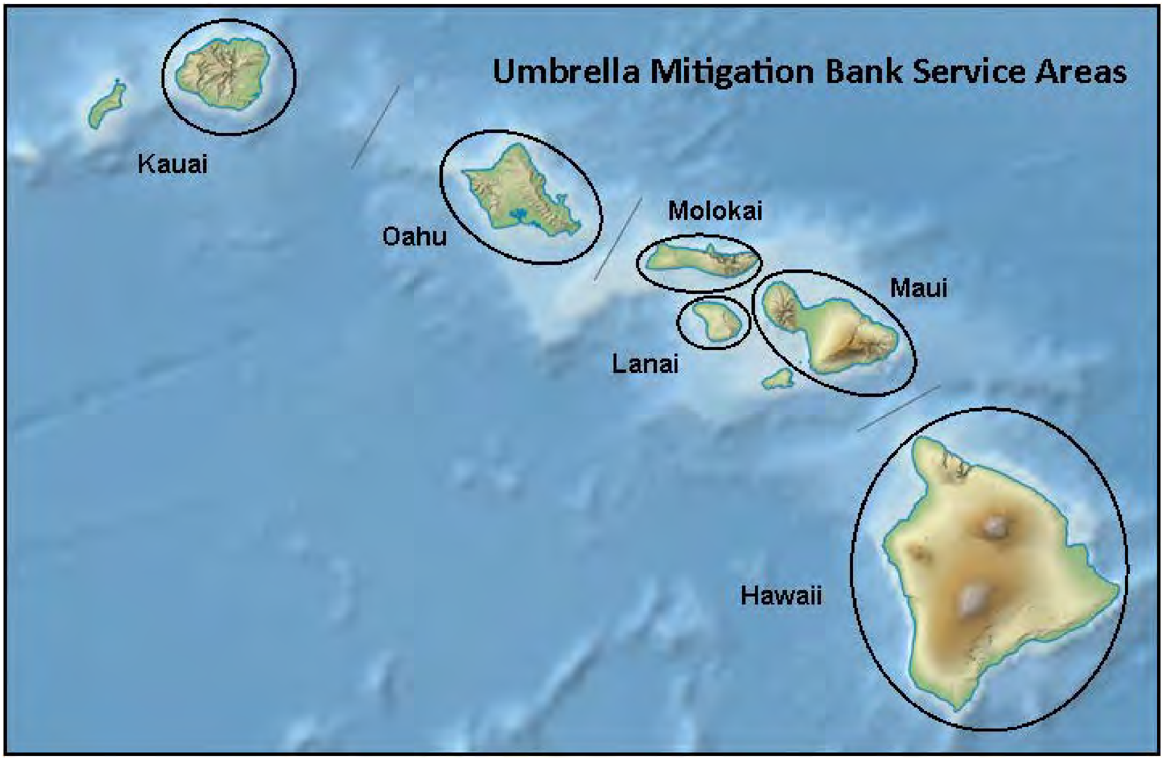

FIGURE 2. SERVICE AREAS OF THE BANK

4.3 BANK SITE SELECTION

DLNR selects bank sites based the potential to restore sustainable landscape-scale ecological processes. DLNR will consider many relevant factors including:

- Ecological values (habitat values, landscape values, adaptability) that affect likelihood of success
- Development trends
- Habitat status and trends (including climate change)
- Potential for functional lift
- Relative potential for land-based pollution of the aquatic resources
- Service area goals/objectives for the restoration of particular habitat types or functions
- Feasibility and cost-effectiveness

This prospectus describes two initial coral reef bank sites in the O'ahu service area: Waikīkī MLCD and Kāne`ohe Bay. Conceptual mitigation plans for each bank site are included in this prospectus. DLNR will include additional details specific to each bank site as part of the mitigation plans in the MBI.

4.3.1 MITIGATION PLANS

DLNR is responsible for selecting the bank sites and preparing the mitigation plan, which is included in the MBI. Once the Corps approves the MBI, DLNR may propose additional mitigation sites by submitting a comprehensive mitigation plan a modification to the MBI.

A mitigation plan includes:

1. Site description and selection criteria
2. Proposed service area
3. Objectives
4. Baseline information
5. Determination of type and amount of credits
6. Preliminary work-plan
7. Performance standards
8. Reporting and monitoring protocols
9. Maintenance plan
10. Long-term management plan
11. Adaptive management plan

4.4 MANAGEMENT

As sponsor of the Bank, DLNR is responsible for long-term management, monitoring, and maintenance, and adaptive management of each site. The MBI will contain the details of each component by site. See sections 6 and 7 for proposed bank sites.

4.4.1 LONG-TERM MANAGEMENT

The State will retain title to the bank sites (see section 4.1) and DLNR will be responsible for the Bank's management and long-term maintenance. DLNR will allocate funds for operation of each bank site as well as for the long-term management of the resource. DLNR has established an Aquatic Mitigation and Restoration Trust Fund ("Trust Fund") for mitigation and restoration projects. Each bank site will have a designated sub-account within the Trust Fund to ensure available funding for the life of the project.

4.4.2 MONITORING

To inform the long-term management of each bank site's biological resources, DLNR will conduct periodic monitoring based on performance standards. DLNR will adopt adaptive management measures as needed.

4.4.3 ADAPTIVE MANAGEMENT

Adaptive management is an approach to natural resource management that allows for course corrections throughout the life of the project to meet performance standards and to address the effects of climate change, flood, or other natural events. Adaptive management is informed by monitoring results and the best available science for aquatic resource management.

4.5 CREDITS

A credit is the unit of measure, often in area such as acres or hectares, that represents the aquatic functions and services associated with natural resource loss (at an impact site) or gain (at a mitigation site). The sponsor proposes to the Corps the number of potential credits available at each bank site based on the quantity and quality of the restored, established, enhanced, or preserved resources.

After the Corps evaluates the MBI and the proposed mitigation bank sites, the Corps determines the number of mitigation credits awarded to each bank site. The number of credits is based on the degree of expected improvement in ecological value resulting from the establishment and operation of the Bank. Many factors can affect the number of credits awarded, including the following:

- The extent to which target conditions can be achieved and maintained
- The quality and quantity of restoration, enhancement, preservation, or creation
- The extent to which the mitigation bank provides habitat for aquatic organisms, especially habitat for species listed or proposed for listing as threatened, endangered, or of special concern, or provides habitats that are unique for that mitigation service area
- The extent to which the bank site(s) are already protected by existing regulations or use restrictions

DLNR may request to modify the MBI to obtain additional bank site credits if monitoring indicates that the ecological improvements at the site exceed expectations.

4.5.1 CREDIT DETERMINATION

The Corps must approve the method for calculating credits. The purpose of any credit determination method is to provide a tool by which bank sponsors, managers, and regulators evaluate whether or not compensatory actions taken to mitigate impacts to natural resources will eventually replace the functions and values lost at permit sites.

The sponsor must use an appropriate assessment method or other suitable metric to assess and describe the aquatic resource type that will be restored established, enhanced and/or preserved by the mitigation bank. For each bank site, DLNR will propose to the Corps and IRT the number of credits available and brief rationale for this determination. For coral reef sites, DLNR has developed a Coral Assessment Tool to aid in calculating available credits. The number of credits assigned to each bank sites will reflect the difference between pre- and post-compensatory mitigation project site conditions.[24]

4.5.2 CREDIT ACCOUNTING

DLNR is responsible for establishing and maintaining an accounting system for credits that documents the activity for each mitigation bank site's credit account. DLNR will provide the ledger for each mitigation site to the Corps annually and each time credits are added or subtracted from the Bank.

5 QUALIFICATIONS AND FEASIBILITY

DLNR is uniquely qualified to establish and operate this umbrella bank because of its ownership authority, public trust responsibilities, and management experience over the aquatic resources of Hawai`i. A selection of the Department's aquatic management activities is listed below:

- Kawai Nui Marsh Wetland Restoration
  http://dlnr.hawaii.gov/wildlife/info/kawainui-marsh-wetland-restoration-and-habitat-enhancement-plan/
- Atlas of Hawaiian Watersheds and their Aquatic Resources
  http://www.hawaiiwatershedatlas.com/
- Long-term Monitoring of Coral Reefs in the Main Hawaiian Islands
  http://www.hawaiicoralreefstrategy.com/index.php/monitoring
- West Maui Ridge to Reef Initiative
  http://www.hawaiicoralreefstrategy.com/index.php/prioritysites/westmaui
- Kahekili Fisheries Management Area
  http://www.kahekilimarinereserve.com/
- Kāne`ohe Bay SuperSucker
  http://dlnr.hawaii.gov/ais/invasivealgae/supersucker/

[24] 33 C.F.R. 332.8(o)(3).

DLNR is confident that the bank site restoration methods meet technical feasibility requirements. DLNR has the infrastructure, equipment, and staff expertise to manage the Bank. DLNR currently operates active restoration projects throughout the state in a variety of aquatic habitats. DLNR manages the Anuenue Fisheries Research Center ("AFRC"), a comprehensive aquaculture facility on Sand Island that houses the urchin hatchery and the coral nursery. AFRC will support the aquaculture needs of the two initial sites in the O`ahu service area. DLNR has tested all of the restoration methods proposed at the bank sites. To meet the needs of each mitigation project, DLNR will use the best available science along with appropriate monitoring methods to evaluate the effectiveness of implementation strategies and to inform adaptive management. DLNR staff, relevant experts, and the IRT will review technical work plans to ensure the greatest chance of success for each bank site.

6 BANK SITE: WAIKĪKĪ MLCD

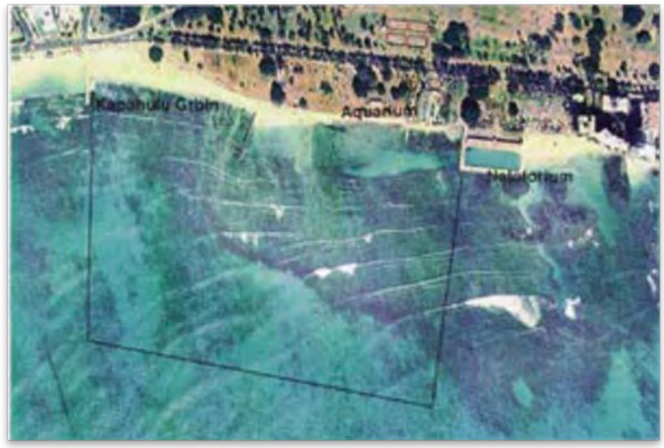

FIGURE 3. SHOWING LOCATION AND BOUNDARY OF WAIKĪKĪ MLCD ON THE ISLAND OF O`AHU

6.1 INTRODUCTION

The Waikīkī Marine Life Conservation District ("Waikīkī MLCD") is located at the east end (Diamond Head) end of Waikīkī Beach on the south shore of Oahu. The Waikīkī MLCD encompasses 76 acres (30.76 hectares) of near-shore habitat (Figure 3).[25] HAR Chapter 13-36 establishes Waikīkī MLCD as a "no take" protected area in which all forms of natural resource extraction are prohibited and recreational activities are limited. The State also regulates fishing and boating activities in the marine areas immediately adjacent to the MLCD.

DLNR proposes as a bank site a section of reef flat in the Waikīkī MLCD. This area once supported a healthy and diverse population of corals (see section 6.3.2 for more detail on site selection criteria). DLNR intends to restore coral reef habitat within the Waikīkī MLCD bank site and increase coral cover by outplanting healthy adult corals from the AFRC coral nursery. To supplement coral outplanting, DLNR may control invasive algae by outplanting collector urchins from the AFRC urchin hatchery when necessary.

[25] The Waikīkī MLCD extends along the shore from the groin at the end of Kapahulu Avenue to the western wall of the Waikīkī War Memorial Natatorium and extends seaward 500 yards (or the seaward edge of the fringing reef if it occurs beyond 500 yards).

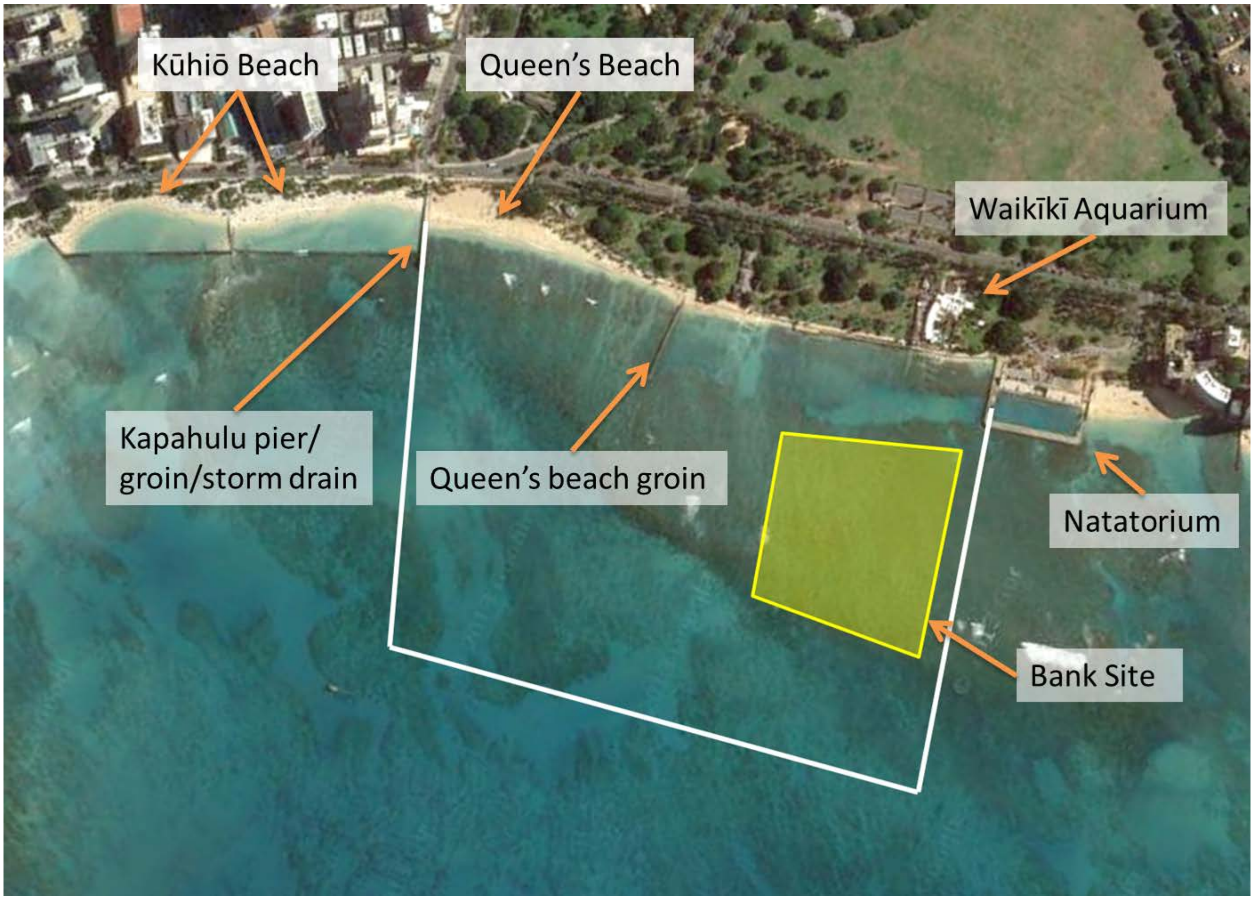

FIGURE 4. PROPOSED BANK SITE AND NEARBY LANDMARKS

6.2 SITE CHARACTERISTICS

6.2.1 HISTORY

Over a century ago, the Waikīkī shoreline area was composed of a narrow, thin ribbon of carbonate sand beach that lay seaward of wetlands, mudflats, duck ponds, and fishponds. However, development and other activities have significantly modified the shoreline and upland areas. Notable development affecting the shoreline in the past century includes:

- Waikīkī Aquarium (1904)
- Ala Wai Canal (1920-30)
- Natatorium on the shoreline and out 200-feet onto the reef (1927)
- Kapahulu storm drain (a groin and walking pier) (1950's)

- Queen's Beach storm drain/groin, extending 370 feet into the Waikīkī MLCD (1950's)
- Renovations to Waikīkī Aquarium (shown in Figure 4) (1955)
- Swimming channel (1955) (Figure 9)

In addition, a number of small channels, basins, and ponds were dredged close to the Waikīkī shoreline for a variety of purposes, including swimming and bathing; small boat and canoe access; and fill material for land-based projects.[26] Extensive seawalls were constructed along the shoreline both directly fronting the MLCD and on both adjacent sides. The seawalls changed the wave and current action, directly damaging the fringing reef and altering sand deposition. Furthermore, sand dredging and modification of the shoreline eroded the fringing reef area.

FIGURE 5. 1907 MAP OF WAIKĪKĪ, NOTE EXTENSIVE CORAL REEF DIAGRAMED IN LOCATION (IN YELLOW) OF THE CURRENT MLCD (CHAS. V.E. DOVE, FROM WIEGEL (2008).

In addition to shoreline modifications, experiments in the MLCD waters directly impacted the reef. In 1974, researchers introduced the invasive red algae *Gracilaria salicornia*, known locally as "gorilla ogo," to Waikīkī to examine its potential as an

[26] Wiegel RL (2005). Waikiki, Oahu, Hawaii-An Urban Beach. Chronology of Significant Events, 1805 – 2005. *Shore and Beach* 73(4): 30 – 32.

aquaculture crop. By 1995, it was the dominant seaweed in the area.[27] *Gracilaria salicornia*, which is relatively unpalatable to Hawaiian herbivorous fishes in the area,[28] can overgrow and kill coral and reduce the abundance and biodiversity of other coral reef organisms.

6.2.2 CURRENT USE

The Waikīkī MLCD is popular with both tourists and residents and hosts many uses (Figure 6), including:

- Surfing: The Waikīkī MLCD is bordered by four well-known surf sites immediately outside its boundaries, none of which will impact the bank site
- Non-motorized craft: Canoeing, kayaking, stand up paddling, and sailing are popular watersports in the area, but primarily occur outside the MLCD
- Beach Activities: Tourists and residents use the beach and shoreline of Queen's Surf Beach (the beach directly in front of the Waikīkī MLCD). Beachgoers swim and snorkel in the near-shore waters, although not to the heavy extent of adjacent beaches
- The Waikīkī Aquarium: The Aquarium obtains most of the seawater it uses from a seawater well that was drilled in the 1950s. The Aquarium also pulls in small amounts of seawater from an intake pipe located in the MLCD at a depth of 10 feet. Overflow from the saltwater exhibit tanks and pools, as well as treated seal pool water, are discharged through an outfall pipe in the MLCD. The discharge is limited and monitored according to Hawai`i Department of Health permit # HI 0020630

The following zoning exists for the areas within and adjacent to the Waikīkī MLCD:

- Waters are classified as Class AA under HAR § 11-54-3[29]
- Submerged Lands are classified as Conservation District under Haw. Rev. Stat. Ch. 205; HAR Ch. 13-5. Boating use is regulated under HAR §13-244-28, primarily to prevent user conflict

[27] Smith JE, Hunter CL, Conklin EJ, Most R, Sauvage T, Squair C, & Smith CM (2004) Ecology of the invasive red alga Gracilaria salicornia (Rhodophyta) on O'ahu, *Hawai'i. Pac Sci* 58:325–343.
[28] Williams ID, Walsh WJ, Miyasaka A, & Friedlander AM (2006). Effects of rotational closure on coral reef fishes in Waikiki-Diamond Head Fishery Management Area, Oahu, Hawaii. *Mar Ecol Prog Ser* 310: 139 – 149.
[29] "It is the objective of class AA waters that they remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from human-caused sources or actions." Haw. Rev. Stat. § 11-54-3(c)(1).

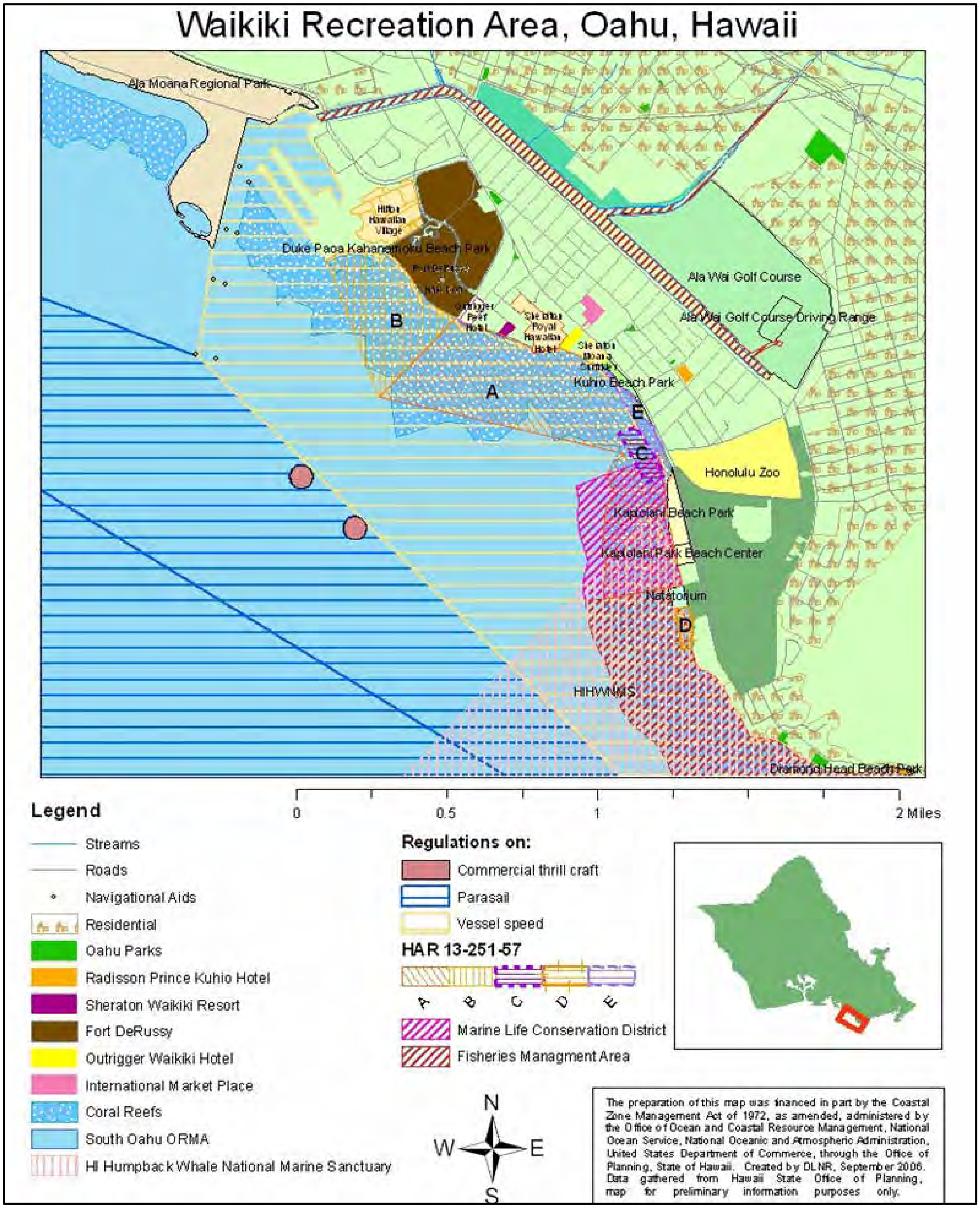

FIGURE 6. WAIKĪKĪ RECREATION AREA

6.2.3 WATERSHED

FIGURE 7. WAIKĪKĪ WITH HIGHLIGHTS FROM 1893, PRIOR TO DRAINAGE, SHOWING STREAMS (DARK BLUE), TARO/RICE LO'I (GREEN), PONDS (LIGHT BLUE). BY PETER T. YOUNG, HO'OKULEANA LLC.

The natural marshy wetland of Waikīkī was once quite vast, receiving water from Makiki, Mānoa, and Pālolo streams. However, over a century of urban development has devastated this watershed. In the 1920's, these streams were all diverted into the Ala Wai canal, drying the original Waikīkī marshland and permanently altering fresh water flow to the entire area. Figure 7 shows present-day Waikīkī overlaid with circa 1893 wetland areas, streams, and fishponds.

While the historic stream discharges have been mostly diverted to the Ala Wai Canal, the Kapahulu groin/ storm drain at the western end of the MLCD can potentially affect the near-shore water within the MLCD during storm events. However, prevailing currents generally take this discharge away from the MLCD.

6.2.4 BIOLOGICAL RESOURCES

While a century of shoreline development and modifications has significantly impacted the near-shore ecosystem, there is a lack of historic data that accurately quantifies the marine habitat losses. In particular, there is little information on the coral resources in the area until the late 1920's, when Dr. Charles Edmondson conducted the first documented surveys[30] of the immediate near-shore reef in front of what is now the Waikīkī Aquarium (Figure 8). Edmondson surveyed multiple transects on the shallow reefs that currently make up the proposed bank site and noted, amongst others, numerous live coral colonies of *Porites lobata*, *Pocillopora meandrina*, *Pocillopora damicornis,*[31] *Porites evermanni*, *Porites compressa*, *Montipora capitata*,[32] *Montipora patula*, *Montipora verrilli*, *Pavona varians*, *Pavona duerdeni*, *Fungia scutaria*, and *Cyphastraea ocellina*. Edmondson noted twenty-three species, varieties, and forms of corals in the shallow water reef environment immediately offshore of the Waikīkī area.[33]

In contrast to the abundant corals identified in Edmondson's surveys, today the Waikīkī MLCD contains very little coral. In 2006, Friedlander et al. [34] surveyed the Waikīkī MLCD and noted the following benthic composition:

67.2%	Turf algae
21.2%	Sand
10.6%	Macro-algae (*Acanthophora spicifera*, *Gracilaria salicornia*)
1%	Coral (*Porites lobata* and *Pocillopora meandrina)*

Friedlander et al. also noted the top ten fish species ranked by biomass:

Taxon name	Common name	Hawaiian name
Acanthurus nigrofuscus	Brown Surgeonfish	*Mai`i`i*
Naso unicornis	Bluespine Unicornfish	*kala*

[30] Edmondson CH (1928). The Ecology of an Hawaiian Coral Reef. Honolulu, HI. Bernice P. Bishop Museum Bulletin 45. 64 pp.
[31] Possibly misidentified as *Pocillopora ligulata.*
[32] Possibly misidentified as *Motipora verrucosa.*
[33] Edmondson CH (1928). The Ecology of an Hawaiian Coral Reef. Honolulu, HI. Bernice P. Bishop Museum Bulletin 45. 64 pp.
[34] Friedlander, A.M., Brown, E., Monaco, M.E., and Clark, A. 2006. Fish Habitat Utilization Patterns and Evaluation of the Efficacy of Marine Protected Areas in Hawaii: Integration of NOAA Digital Benthic Habitats Mapping and Coral Reef Ecological Studies. Silver Spring, MD.

Acanthurus leucopareius	Whitebar Surgeonfish	*maikoiko*
Thalassoma duperrey	Saddle Wrasse	*hinalea lauwili*
Acanthurus triostegus *Rhinecanthus rectangulus*	Convict Tang Reef Triggerfish	*manini humuhumunukunuk uapuaa*
Abudefduf abdominalis	Sargent Major	*mamo*
Stethojulis balteata	Belted Wrasse	*omaka*
Acanthurus blochii	Ringtail Surgeonfish	*pualu*
Naso lituratus	Orangespine Unicornfish	*umaumalei*

6.3 ECOLOGICAL SUITABILITY

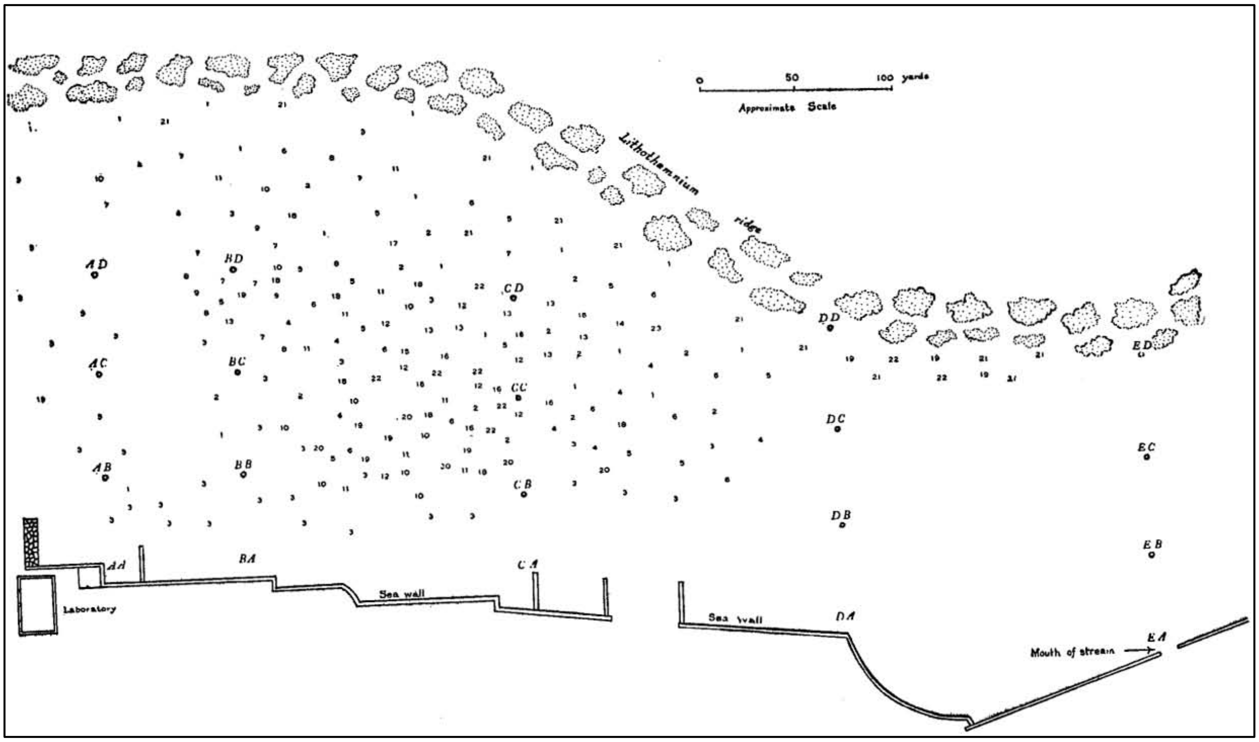

FIGURE 8. WAIKĪKĪ REEF FRONTING KAPI`OLANI PARK FROM EDMONDSON'S 1928 PAPER ON THE ECOLOGY OF A HAWAI`IAN CORAL REEF. THE AREA TO THE LEFT MARKED 'LABORATORY' IS THE APPROXIMATE LOCATION OF THE WAIKĪKĪ AQUARIUM, THE AREA TO THE RIGHT MARKED "MOUTH OF STREAM" CORRESPONDS TO THE KAPAHULU GROIN/DRAIN. THE REEF AREAS WHERE EDMONDSON CONDUCTED HIS CORAL TRANSECTS ARE WITHIN WHAT IS NOW THE WAIKĪKĪ MLCD

The Waikīkī MLCD bank site is ecologically suitable for restoration. DLNR selected the Waikīkī MLCD because it is fully-protected with regulated buffer zones to either side. In addition, it is adjacent to a park shoreline with urban controls and minimal point source drainages. The Waikīkī MLCD encompasses a large area of carbonate reef structure that historically supported significant coral resources and has the potential to host new coral colonies. The proposed bank site is a portion of the MCLD (Figures 4,9) selected for its size, supporting reef structure, accessibility, buffered distance from nearby sand wash, and documented historical presence of corals (Figure 8). To restore the coral ecosystem at the bank site, DLNR will outplant corals large enough to survive possible sand scour. Outplanted coral will provide additional habitat for fish and other reef-dwelling organisms. To increase survival of outplanted corals, DLNR will outplant adult (>20cm) corals, which are less likely to be affected by sand or sediments. The AFRC coral nursery will supply corals that are appropriate for outplanting at the bank site. The coral nursery operates under strict biosecurity procedures. Corals are quarantined, fragmented, and re-assembled to larger colony sizes. All corals are acclimated to the conditions of the receiver sites prior to outplanting, and will be free of invasive or parasitic animals or macro-algae.

When necessary, DLNR will support coral outplanting by manually removing invasive algae from the bank site and outplanting native collector urchins (*Tripneustes gratila*) as grazers.

6.4 CONCEPTUAL MITIGATION PLAN: WAIKĪKĪ MLCD

6.4.1 OBJECTIVES

DLNR proposes to restore the coral reef habitat within the bank site. Restoration will consist of outplanting coral colonies onto suitable areas of reef structure, controlling invasive algae, and outplanting native grazing sea urchins. The increase in live coral will provide additional habitat for reef-dwelling organisms, including fish.

DLNR has the following restoration objectives for the Waikīkī MLCD bank site:

1. Restore live coral within the bank site to the biodiversity levels documented by Edmonson in 1928
2. Increase the number of coral colonies per square meter to three times greater than the current baseline in the bank site
3. Double the baseline median size of live coral colonies (averaged across species) in the bank site

6.4.2 SITE SELECTION

The bank site is fully contained within the Waikīkī MLCD (Figures 4, 9). DLNR will conduct a thorough survey of the entire Waikīkī MLCD prior to determining the final boundaries of the bank site. When surveying the bank site, DLNR will map the existing reef structure, sedimentation, and algal abundance to determine the area where coral transplants are most likely to successfully establish. DLNR will also identify control/reference sites.

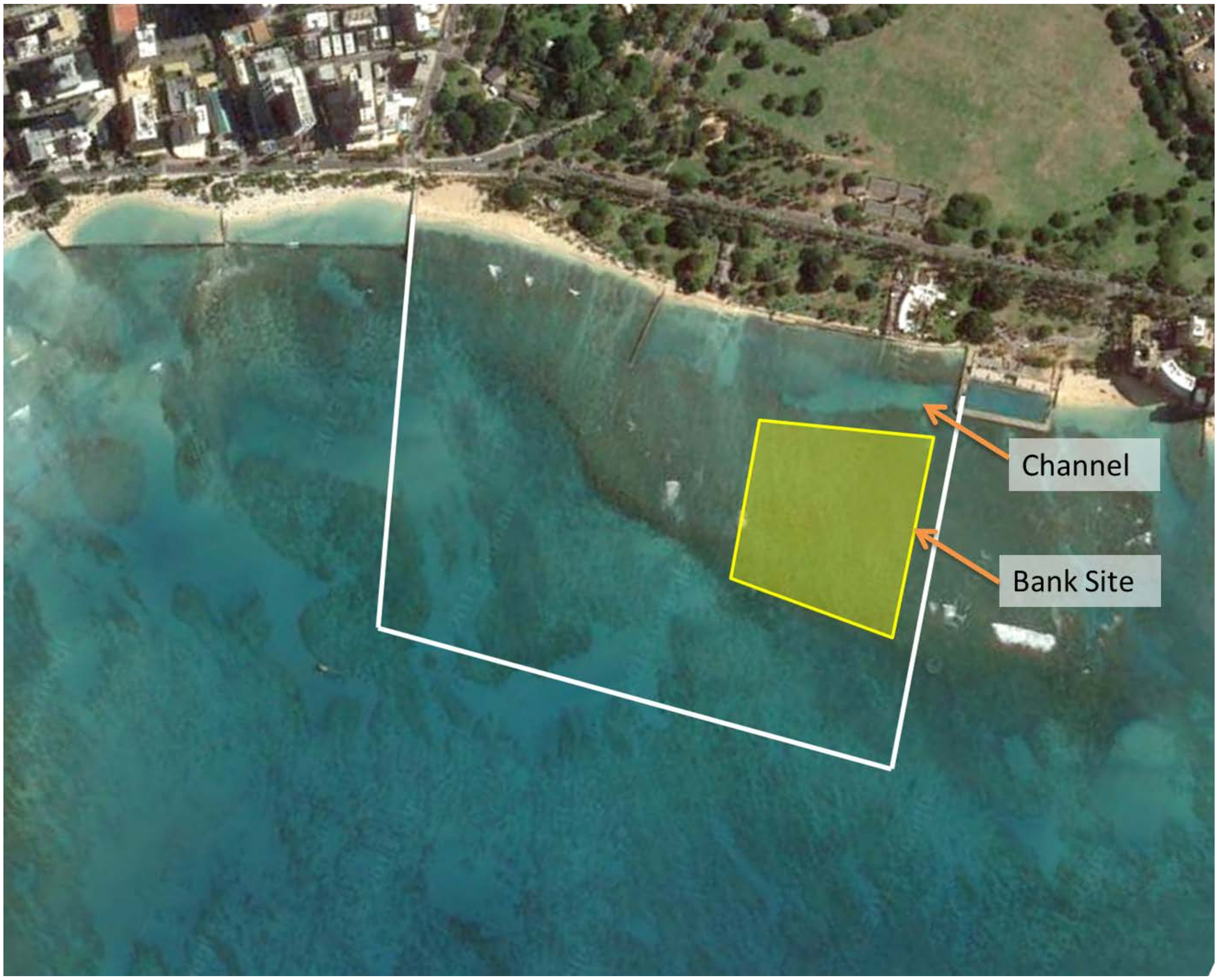

FIGURE 9. PROPOSED BANK SITE/TARGET CORAL RESTORATION AREA (YELLOW) WITHIN THE MLCD

6.4.3 BASELINE CONDITIONS

The majority of the reef flat within the Waikīkī MLCD is shallow (on average less than 2 m deep) with large amounts of uncolonized pavement. The reef flat primarily consists of hard substrate overgrown by macro-algae.[35] The reef flat has little bottom relief

[35] Williams ID, Walsh WJ, Miyasaka A, & Friedlander AM (2006). Effects of rotational closure on coral reef fishes in Waikiki-Diamond Head Fishery Management Area, Oahu, Hawaii. *Mar Ecol Prog Ser* 310: 139 – 149.

and fish are more concentrated in areas where three-dimensional structure increases. Most fish in the bank site are found along the dredged swim channel's sides (which have a number of small caves) and along the Natatorium wall. The channel itself is about 8 feet deep, while depths above the reef flat are generally less than 3 to 4 feet. At the outer edge of the reef, the bottom sharply drops off to about 15 to 20 feet. There are a number of arches, crevices and other features at the outer reef edge.

DLNR will conduct a thorough baseline survey of the entire Waikīkī MLCD prior to submitting the MBI. The MBI will describe in detail baseline ecological resources and the proposed transplant and control sites.

6.4.4 WORK PLAN

DLNR will include a complete work plan in the MBI. DLNR's proposed work plan is as follows:

1. Initial rapid survey of the Waikīkī MLCD. This survey is a rapid assessment to collect detailed information on the bank site and surrounding areas. DLNR proposes the bank site on the reef flat to ensure that the outplanted corals are distanced from most of the human disturbance occurring closer to shore. Furthermore, this site is historically known from Edmonson's surveys to support the species of coral DLNR proposes to restore
2. Detailed baseline mapping. DLNR will generate a detailed map of the Waikīkī MLCD bank site, noting potential outplanting locations and sub-habitat types, including:
   - Reef flat substrates
   - Reef holes and depressions larger than 0.5 m in diameter and with a deepest depth of between 20 cm to 1 m
   - Shallow reef channel edges and non-live coral protuberances within the channel
   - Reef crest
3. Outplanting preparation. Prior to introducing new coral, DLNR will manually clear each area of both *Gracilaria salicornia* and *Acanthophora spicifer*a. If necessary, DLNR will use collector urchins (*Tripneustes gratila*) cultured at the AFRC urchin hatchery to provide additional algae control
4. Transplantation of corals. DLNR will outplant corals at size classes large enough to improve resilience to predation and small-scale disturbance events. For most species, outplanted corals will be larger than 20 cm. DLNR will place corals in water depths and atop substrate in a manner that will maximize their survival

relative to light exposure and water motion while minimizing concerns related to inter or intra-specific competition

5. Documentation. DLNR will record coral transplantation with photos, measurements of transplants, and documentation of health status
6. Monitoring. The coral monitoring parameters may include relative coral survivorship; health state and growth; algae abundance within 10m; and urchin presence

6.4.5 MAINTENANCE PLAN

DLNR will include a site maintenance plan in the MBI. Site maintenance will likely include invasive species control and possible additional outplanting of corals. DLNR will perform maintenance in conjunction with regular monitoring according to the monitoring schedule proposed in section 6.4.7.

6.4.6 PERFORMANCE STANDARDS

Performance standards are observable or ecological criteria, based on measurable attributes, which are used to evaluate a mitigation project to determine if it is providing the expected resources and functions. DLNR will propose performance standards in the MBI.

DLNR will monitor coral and algae as the measurable attributes in the Waikīkī MLCD bank site. Coral indicators will include species richness, size, and colonies per square meter. For coral, target outcomes are the following: 1) achieve comparable diversity to the Edmonson survey, 2) triple the current baseline for number of colonies, and 3) double the current baseline for median size. DLNR may propose a target for algae reduction following analysis of the baseline survey. Algae will be noted by species and canopy height.

6.4.7 MONITORING

DLNR will submit a monitoring plan in the MBI. The plan will describe the coral and algae parameters, the monitoring protocol, the frequency of monitoring, and the length of the monitoring period. DLNR proposes to monitor the Waikīkī MLCD bank site according to the following monitoring schedule:

- Year 0-1: Within one month of transplantation
- Year 1–5: Seasonally (i.e. 2x per year, Winter and Summer)
- Year 6-8: Annually
- Year 9-20: Bi-annually (Once every two years)
- Year 20+: Every 5 years

6.4.8 ADAPTIVE MANAGEMENT

The Waikīkī MLCD mitigation plan will include an adaptive management plan. Adaptive management is an approach to natural resource management that allows for course corrections throughout the life of the project to meet performance standards and to address the effects of climate change, flood, or other natural events. The adaptive management plan will include potential corrective measures, such as revisions to maintenance and monitoring requirements, should mitigation fail to meet performance standards. Performance standards may be modified in accordance with adaptive management to account for measures taken to address deficiencies in the project. DLNR will request Corps approval for any modification of performance standards.

7 BANK SITE: KĀNE`OHE BAY PATCH REEFS

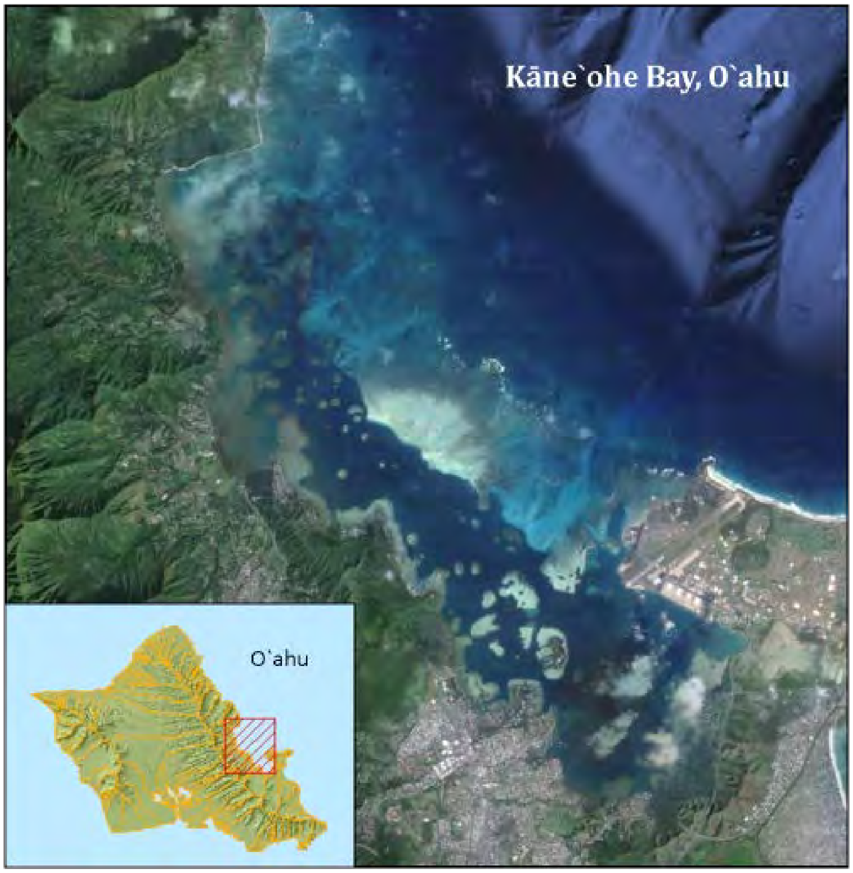

FIGURE 10. KĀNE`OHE BAY, O`AHU

7.1 INTRODUCTION

Kāne`ohe Bay (Bay) is the largest embayment in the Hawaiian Islands and contains a diverse array of marine ecosystems including open water, sand flat, barrier reef, patch reefs, and fringing reef (Figure 10). The large (~2.5 mile) barrier reef shelters the bay from tradewind swell and creates ideal conditions for coral growth. The Bay is extremely unique in that it contains numerous patch reefs, which are distinct island-like reef features providing an abundance of coral and marine life.

Coral reef habitats of Kāne`ohe Bay have become increasingly dominated by invasive algae since botanists introduced several algae species in the 1970's. Invasive algae overgrow reefs and eventually kill coral colonies and severely alter the coral reef ecosystems. Given these destructive effects, since 2007 DLNR has carried out invasive algae control efforts in the Bay using a combination of mechanical algae removal and biocontrol. The combination of these techniques has shown positive results at removing invasive algae and minimizing regrowth and spread. Given the vast distribution of invasive algae throughout the Bay, control efforts are expected to take a considerable effort to treat all of the affected areas. The initial bank site in the Bay is comprised of four patch reefs (Figures 11,16,17). The total area of all four patch reefs is 57, 546 square meters (5.75 Hectares). DLNR will restore/ rehabilitate the site by controlling invasive algae.

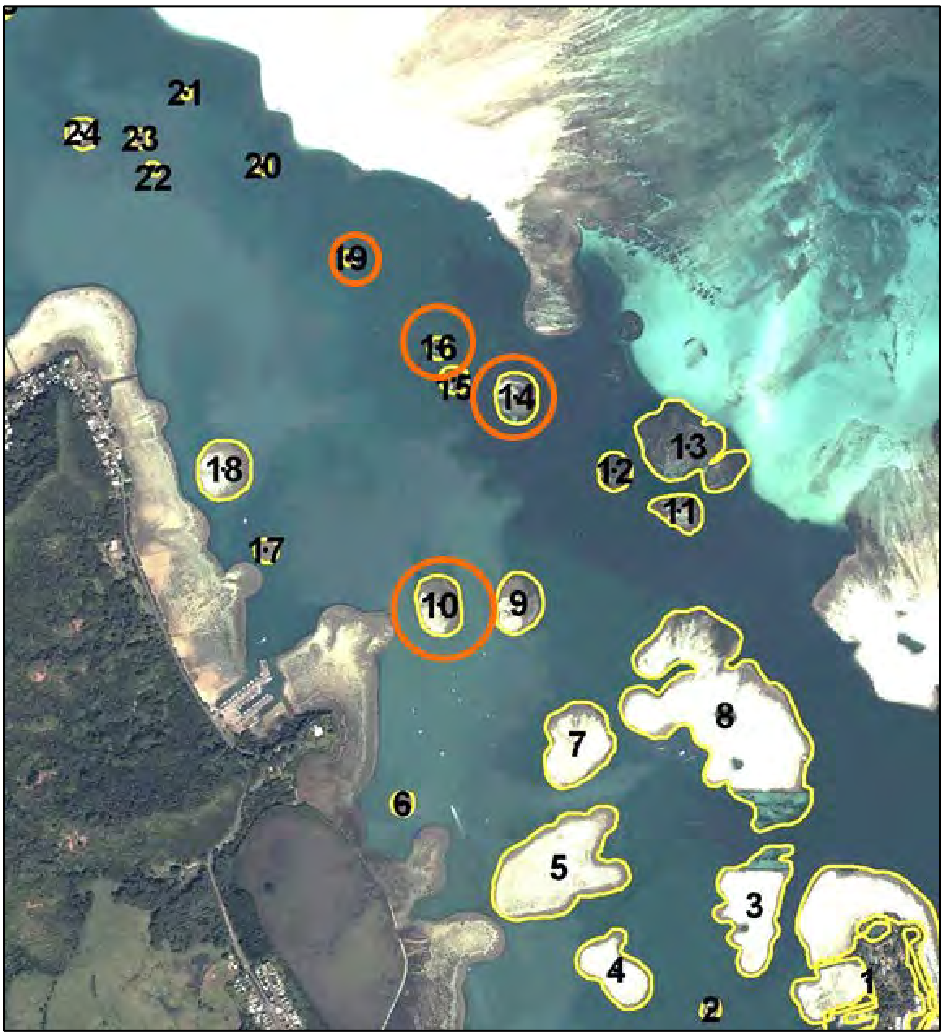

FIGURE 11. BANK REEFS, #10,14,16,19

7.1.1 BACKGROUND

FIGURE 12. SUPERSUCKER BARGE WORKING IN KĀNE`OHE BAY

The proposed mitigation bank site will continue invasive algae management efforts already in practice in the Bay: 1) mechanical remove of invasive algae and 2) outplanting biocontrol agents (native sea-urchins) to the reef. Kāne`ohe Bay is an ecologically suitable restoration site because there is an identifiable threat of invasive algae to coral reefs and there are established methodologies for restoring these areas. Removing invasive algae allows corals to regrow where partial mortality has occurred and recolonizes previously occupied habitats (Figure 13). Although coral colonization may take several years to occur, other native macro-algae or crustose coralline algae (a pre-cursor to coral growth) may colonize these areas in the interim.

Reef restoration is carried out in two phases; first the invasive algae are removed mechanically and secondly the biocontrol agents (native sea-urchins) are outplanted to the reef. The "SuperSucker," (Figure 12) designed by the University of Hawai`i and the Nature Conservancy, mechanically removes the algae from patch reefs in the Bay. The SuperSucker is an underwater vacuum system designed to remove and transport invasive algae from the reef (see Appendix H). Divers remove the algae from the reef by hand and feed it into a vacuum hose. The hose moves the algae from the reef to the barge. Once the algae reaches the barge it is sorted and bagged and then given to local farmers in the watershed for compost.

FIGURE 13. PHOTOS OF A REEF BEFORE AND AFTER CLEARING WITH THE SUPERSUCKER, ARROWS SHOW POINTS OF REFERENCE

DLNR's early projects in the Bay revealed that the SuperSucker efforts alone cannot restore the reefs in the Bay. A single reef can require 2-3 months to clear, and the removed algae grows back within 4-6 months. DLNR determined that grazing animals can be an effective natural bio-control, particularly the native collector urchin *Tripneustes gratila*. This short-spined species is found throughout the Hawaiian archipelago, can be reared via aquaculture, and is an effective grazer of *Kappaphycus/Eucheuma spp.* Once outplanted, the urchins remain on the desired reefs because urchins do not like to traverse the sand channels between patch reefs. In 2008, DLNR began a project on small patch reef #16 to test a combination of mechanical removal of algae with the outplanting of native grazing sea urchins (See Appendix B for a full description). The success of this project prompted DLNR to research, design, and build the state's only aquaculture facility for native urchins in order to supply the anticipated numbers needed for landscape scale algae control. Subsequently, DLNR conducted a larger multi-year restoration project on three additional reefs (see Appendix C).

After the SuperSucker mechanically removes the bulk of the invasive algae, DLNR will outplant hatchery raised urchins to the reef. The urchins graze on the remaining invasive algae and prevent it from growing back over time. DLNR will continue these combined restoration methods at the proposed bank site.

7.2 SITE CHARACTERISTICS

7.2.1 HISTORY

Kāne`ohe Bay, the largest embayment in Hawai`i, is traditionally a highly productive ecosystem containing both estuaries and coral reefs.[36] The Bay has been altered from its natural state by human-induced changes, including physical modifications, water quality degradation, and the introduction of invasive species.

Human activities began with ancient Hawaiians building over 30 walled fishponds along the shoreline. These ponds, which were strategically located around streams, caused negligible disturbance to the near-shore marine environment and may actually have served to buffer the Bay from the impacts of large discharges of storm water.[37] In contrast, over the past century human disturbances have extensively altered both the shoreline and the reef ecosystems of the Bay. Many of the fishponds were filled, often using material excavated from the adjacent reefs. Seawalls, piers, jetties, channels, and boat harbors were built along the shore, especially in the southern end of the Bay. Dredging activities removed, cleaved, and/or topped 11-15 million cubic yards of coral reef.[38]

The water quality in the Bay, especially the southern end, has been impacted by both land-based run-off (discussed further in section 7.2.3) and sewage. Major rainfall events discharge large amounts of sediments and nutrients into the Bay. In addition, extreme rainfall events send immense volumes of freshwater into the Bay, killing coral colonies. Large rainfall events followed by freshwater kills of coral were documented in 1965 and 1987.[39]

Before 1978, the Kāne`ohe Marine Corps Air Station and the Kāne`ohe Sewage

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[36] Holthus, P. (1986). Structural reefs of Kaneohe Bay, Hawaii: an overview. *Coral reef population biology. Hawaii Institute of Marine Biology Technical Report*, (37), 1-18.

[37] Banner, A. H. (1974). Kaneohe Bay, Hawaii, Urban pollution and a coral reef ecosystem. In *Proceedings of the Second International Symposium on Coral Reefs.* (Vol. 2); Devaney, D. M., Kelly, M., Lee, P. J., & Motteler, L. S. (1982). edition. Kaneohe: A History of Change. BP Bishop Museum. *US Army Corps of Engineers.. The Bess Press. Honolulu, Hi*.

[38] Holthus, P. (1986). Structural reefs of Kaneohe Bay, Hawaii: an overview. *Coral reef population biology. Hawaii Institute of Marine Biology Technical Report*, (37), 1-18.

[39] Jokiel, P. L., Hunter, C. L., Taguchi, S., & Watarai, L. (1993). Ecological impact of a fresh-water "reef kill" in Kaneohe Bay, Oahu, Hawaii. *Coral Reefs*, *12*(3-4), 177-184.; Wilkinson, C., & Brodie, J. (2011). *Catchment Management and Coral Reef Conservation: a practical guide for coastal resource managers to reduce damage from catchment areas based on best practice case studies* (p. 120). Global Coral Reef Monitoring Network.

Treatment Plant discharged sewage directly into the Bay's southern basin. The resulting nutrification of Bay water encouraged phytoplankton blooms and macro-algae overgrowth, which led to dramatically reduced coral populations. A 1970 survey noted that the southern sector was "virtually devoid of living coral," the reefs in the middle of the Bay were degrading and succumbing to algal overgrowth, and only the northern portion of the Bay had coral in good condition.[40] In 1978, both of the large sewage plants diverted discharge to a deep ocean outfall, with the smaller Ahuimanu plant diverted in 1986. When the sewage outfalls were diverted to deeper water, the turbidity, nutrient levels, and phytoplankton abundance all decreased in the Bay. Coral increased in the first few years after the sewage diversion. However, from 1983-1990, coral gains slowed.[41]

The introduction of non-native species to the Bay poses an ongoing threat to the coral reefs. In the early 1970's, marine botanists at the Hawai`i Institute of Marine Biology intentionally introduced non-native algae (*Gracilaria salicornia, Kappaphycus spp. Eucheuma spp.*) to Kāne`ohe Bay for aquaculture experiments.[42] The sheltered Bay provided suitable habitat conducive to the growth of these species. After the experiments ended, the invasive algae began to spread throughout the Bay, smothering and killing coral. These invasive algae are currently prevalent throughout the Bay on both patch and fringing reefs.

While invasive algae is an obvious threat, the other current factors contributing to the condition of Kāne`ohe Bay reefs are more complex and subtle than the direct impacts of the past. The dynamics of Kāne`ohe Bay are the subject of ongoing research, yet much remains to be learned about the effect that environmental and human factors have on the Bay and it's native ecosystem.

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[40] Banner, A. H., & Bailey, J. H. (1970). The effects of urban pollution upon a coral reef system: A preliminary report.

[41] Hunter, C. L., & Evans, C. W. (1995). Coral reefs in Kaneohe Bay, Hawaii: two centuries of western influence and two decades of data. *Bulletin of Marine Science*, *57*(2), 501-515.

[42] Smith, J. E., Hunter, C. L., & Smith, C. M. (2002). Distribution and reproductive characteristics of nonindigenous and invasive marine algae in the Hawaiian Islands. *Pacific Science*, *56*(3), 299-315.

7.2.2 CURRENT USE

Kāne`ohe Bay accommodates a variety of activities and uses including commercial tourism, fishing, recreation, and subsistence harvest. The following is a sampling of activities and uses in the Bay:

- Tourism: Several commercial operators engage in a number of activities in the Bay, including snorkeling tours, boat tours, personal watercraft rentals, and SCUBA diving
- Commercial fishing and aquarium collection: Commercial fishers use lay nets, hook and line, and gear for aquarium collection
- Sport/Subsistence fishing: Sport and subsistence fishers spearfish and also use hook and line
- Recreational activities: Kāne`ohe Bay is a popular recreational area for boating and snorkeling. Ahu o Laka (the "sand bar") barrier reef is a popular destination for boaters. Figure 14 displays the boating recreational zones
- Fish ponds: Fishponds are an important cultural site in the Bay and a rich Hawaiian tradition. There are several fish ponds in the Bay in various stages of development and use
- Military: The Marine Corps Air Station is located on Mōkapu Peninsula. The military uses portions of the Bay and Mōkapu Peninsula for military training and research activities. The military also has a 500-yard buffer zone around the peninsula that restricts public use

The Bay is located within the Conservation District.[43] Land designation in the watershed ranges from urban in the south to agriculture and conservation in the north.

[43] Haw. Rev. Stat. Ch. 205; HAR 13-5.

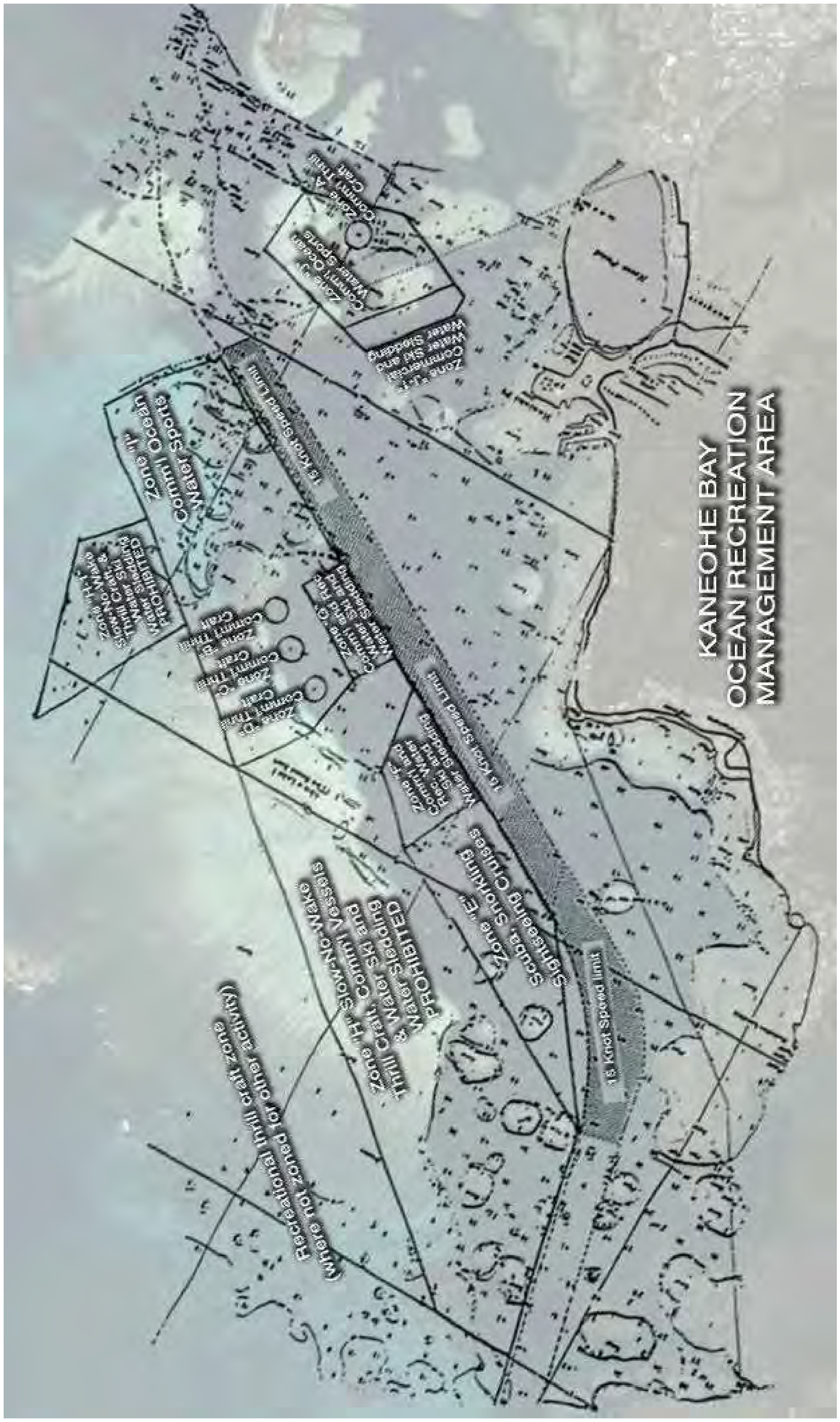

FIGURE 14 OCEAN RECREATION MANAGMENT AREA FOR KĀNE`OHE BAY

7.2.3 WATERSHED

FIGURE 15. KĀNE`OHE BAY WATERSHED

The waters of Kāne`ohe Bay are designated by the State of Hawai`i as class "AA," which requires that the water must remain as close as possible to its natural pristine state.[44] Nevertheless, many human-induced changes have affected the water quality and drainage into the Bay. Around the turn of the century, land use in Kāne`ohe transitioned from native vegetation and taro lo`i towards the cultivation of pineapple, rice, and sugarcane. These farming changes, as well as the introduction of hoofed animals and the effects of their grazing, led to an increase in erosion and sedimentation into the Bay. Most of the individual watersheds that drain into the Bay have rolling or flat lowland sections and steep mountainous headwaters. During intense rainfall events, these watersheds can experience flash floodrun-off. With the urbanization of Kāne`ohe, impervious surfaces and stream channelization increased, amplifying the volume of discharged runoff water in the Bay. Urbanization also dramatically decreased sediment retention in the watershed, causing land-based sediments, pollutants, and nutrients to flush into the Bay.

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[44] HAR § 11-54-3.

The 2012 Ko`olau Poko Watershed Management Plan's key findings for Kāne`ohe Bay noted that the Bay is susceptible to near-shore water pollution because of poor water circulation within the Bay and degradation of local stream water. In addition, inadequate riparian buffer zones provide limited filtration of surface water runoff into the streams.

7.2.4 BIOLOGICAL RESOURCES

The Bay shelters significant biological resources. At one time, the reefs throughout the Bay were noted for significant coral growth and described as "coral gardens,"[45] where "nearly all the reef-forming genera in the Hawaiian waters are represented… and grow luxuriantly".[46] Corals common in the Bay include *Montipora capitata*, *Porites compressa*, *Pocillopora damicornis*, and *Fungia scutaria*. In addition to coral reefs, the Bay has a diverse assemblage of plankton, pelagic fish, endangered green sea turtles, endangered monk seals, Pacific bottlenose dolphins, reef fish, and invertebrates.[47] The Bay is also an important scalloped hammerhead shark pupping area.[48] Appendix D provides a list of species noted in recent DLNR surveys of patch reefs in the Bay.

7.3 ECOLOGICAL SUITABILITY

Since 2007, DLNR has prioritized restoration in Kāne`ohe. DLNR has invested considerable effort into testing and refining the restoration methods proposed at the bank site, which include invasive algae removal, bio-control using native grazing urchins, and outplanting native corals.

Ongoing threats to the Bay include land-based sources of pollution, boating impacts, recreational and commercial use, and invasive species. At this time, DLNR proposes to address the threat of invasive algae at the bank site. The target alien algae is the *Kappaphycus/Eucheuma* species complex, which have heavily invaded many patch reefs in the Bay and resulted in coral decline through overgrowth and smothering.

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[45] MacKaye, A. L. (1915). Coral of Kaneohe Bay. Pages 135-139 in T. Thrum, editor. Hawaiian Almanac and Annual for 1916. Thrum, Honolulu.
[46] Edmondson, C. H. (1928). *The ecology of an Hawaiian coral reef* (Vol. 45). Bernice P. Bishop Museum.
[47] Jokiel, P. L. (1991). Jokiel's illustrated scientific guide to Kaneohe Bay, Oahu.
[48] Clarke, T. A. (1971). The Ecology of the Scalloped Hammerhead Shark, Sphyrna lewini, in Hawaii. *Pacific Science, 25*(2), 135-144.

DLNR will combine mechanical removal and urchin outplanting to control the algae, and will supplement these activities with coral outplanting where appropriate. Before submitting the MBI, DLNR will discuss with the IRT the criteria for determining the coral species and timing of outplanting. Each patch reef in the bank site has coral populations that will improve once that algae is removed. The restored state is expected to be sustainable with minimal effort and will provide improvement for many components of the reef ecosystem.

7.4 CONCEPTUAL MITIGATION PLAN: KĀNE`OHE BAY

7.4.1 OBJECTIVES

DLNR intends to rehabilitate 57,546 square meters of reef habitat distributed among four select patch reefs. DLNR will accomplish rehabilitation through the following activities:

- Removing invasive alien algae
- Outplanting native grazing sea urchins for algae control
- Outplanting species-appropriate coral colonies

7.4.2 SITE SELECTION

DLNR selected Kāne`ohe Bay for restoration efforts because of the Bay's unique patch reef ecosystems and abundant ecological resources. To select the individual patch reefs that make up the bank site, DLNR conducted a multi-step evaluation that quantified the benthic composition of 53 distinct patch reefs in the Bay. Using satellite imagery and past survey data, reefs that were composed of sand, low coral cover, and no invasive algae cover were designated as "low priority" and removed from management consideration. The remaining patch reefs were then identified for a bay-wide rapid-assessment survey (a snapshot, or "SNAP" survey) to map coral and invasive algae (*Eucheuma spp.* and *Kappaphycus spp.*) density and distribution in the Bay. DLNR surveyed forty-one patch reefs from February to April 2014 and established a Kāne`ohe Bay coral and invasive algae distribution dataset. The resulting data was displayed using ArcGIS software, which showed the variable distribution of both invasive algae and coral throughout the Bay's patch reefs. Reefs were ranked for management priority based on a high co-occurrence of both live coral and invasive algae. DLNR believes the four reefs included in the bank site have the highest value for restoration. DLNR also used the snap-assessment results to select control and reference monitoring sites. The full report of the SNAP survey is included as Appendix F.

Bank Site Restoration (Treatment) Reefs: For the bank site, DLNR selected four patch reefs (Reefs 10, 14, 16, 19) as "restoration reefs" (also referred to as treatment reefs). Combined, these reefs make up 57,546 square meters of patch reef habitat. DLNR will restore these restoration reefs by controlling invasive algae.

Control Reefs: DLNR designated three reefs within the Bay as "control reefs" (Reefs 9, 15, 23). The control reefs are in the same geographic area as the restoration reefs and have similar reef area and coral and invasive algae cover. The control reefs will demonstrate the condition of the resources over time without restoration efforts, and can be used as a baseline for calculating the restoration credit gain of the project. Any potential modifications to the bank sites credit earnings may be based on regular comparisons between restoration reefs and control reefs.

Reference Reefs: DLNR designated three reefs as "reference reefs" (Reefs 12, 17, 22). The reference reefs have high coral cover and virtually no invasive algae. Reference reefs represent the optimal restoration target condition and will be useful for determining performance standards for the bank site.

REEF	% Coral	% Ed/Ks	AREA (m2)	Designation
19	75.00	21.02	1,023	Restoration
16	41.02	10.17	4,303	Restoration
10	45.48	14.41	30,098	Restoration
14	21.78	11.40	22,122	Restoration
15	42.32	12.70	7,732	Control
9	43.44	11.54	28,343	Control
23	47.29	4.36	3,119	Control
12	64.78	0.02	11,854	Reference
22	70.75	0.00	1,016	Reference
17	32.70	0.00	6,881	Reference

FIGURE 16. REEFS SELECTED FOR RESTORATION (TREATMENT), CONTROL, REFERENCE.

CORAL & ALGAE NOTES AS % ENCOUNTERED

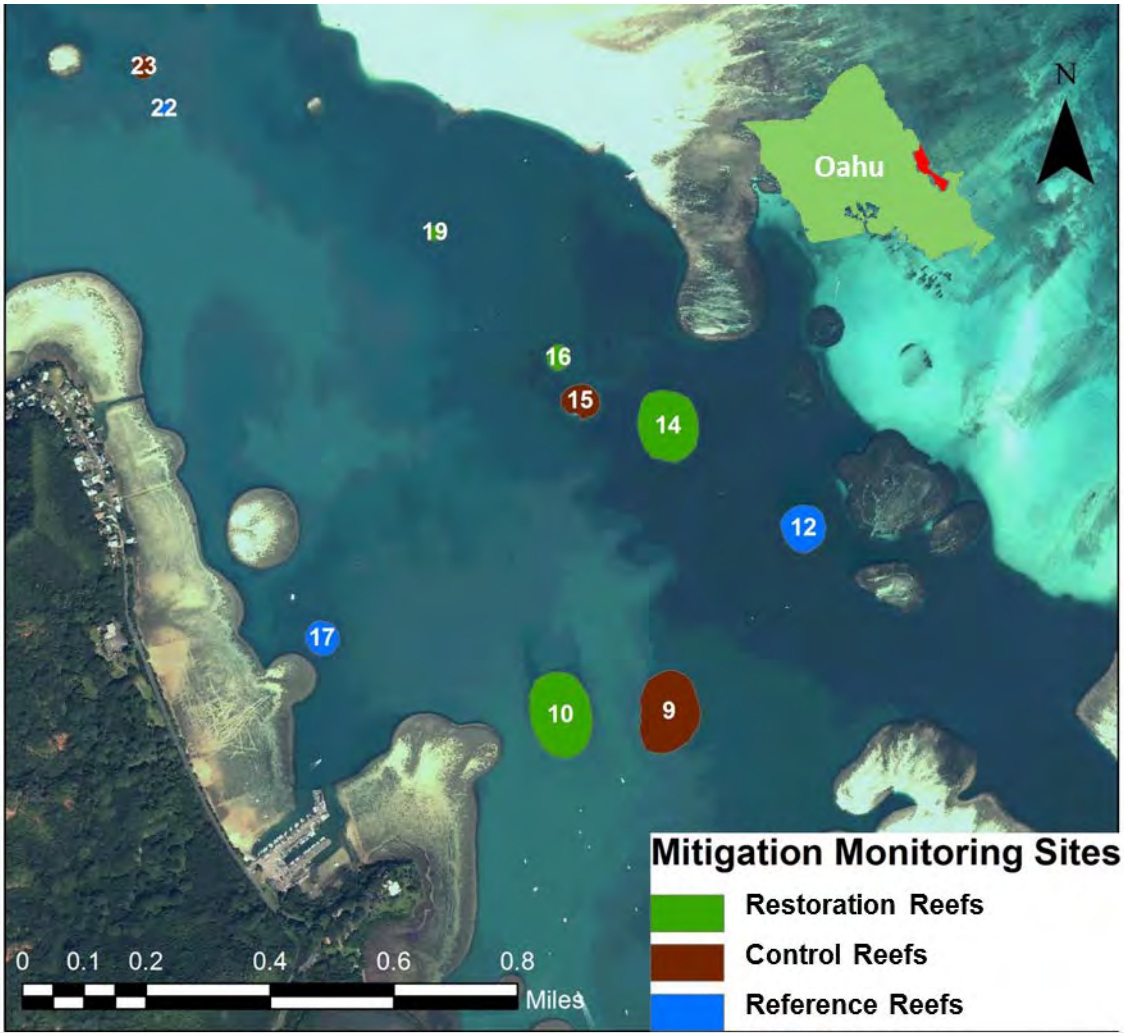


FIGURE 17. BANK REEFS: RESTORATION/TREATMENT (GREEN), CONTROL (RED), REFERENCE (BLUE)

7.4.3 BASELINE CONDITIONS

DLNR will conduct a detailed baseline survey of the restoration, control and reference reefs. The MBI will include a comprehensive report on the baseline surveys, including monitoring methods and results.

To identify long-term trends in baseline conditions and the potential for sustainable restoration, DLNR has monitored four discrete coral reef areas in Kāne`ohe Bay, (Patch Reefs 26, 27, 44 and Marker 12 Fringe Reef) over several years. Patch Reefs 26 and 27 were restored with algal removal and urchin outplanting and resulted in sustained algae reduction. Marker 12 Fringe Reef and Patch Reef 44 were not treated in any manner and displayed increases in algal distribution and density. Further information on these surveys can be found in Appendices G and C.

7.4.4 WORK PLAN

After using the SuperSucker to remove algae, DLNR will outplant urchins from the AFRC urchin hatchery. The hatchery cultures the urchins from initial spawning and larval settlement to a minimum of 15 mm in size. DLNR will treat the restoration reefs with urchins based on their availability from the hatchery. The target outplanting density of urchins is 3 per square meter. In year 1, DLNR anticipates that staff biologists can clear and outplant urchins to reefs 16, 19, and 14 (a combined area of 27,448 square meters). DLNR will treat reef 10 (30,098 square meters) in year two, or as soon as urchins are available.

DLNR may outplant coral from the AFRC coral nursery or from the salvaged coral scheduled for removal from the He`eia Kea small boat harbor. DLNR will only outplant healthy coral species appropriate to Kāne`ohe Bay.

The rehabilitation of the bank site will involve four distinct activities:

1. Detailed baseline surveys. DLNR will conduct comprehensive baseline surveys of all 10 reefs (4 restoration, 3 control, 3 reference) prior to any rehabilitation activities. The MBI will contain the baseline survey results
2. Algae removal using the Super Sucker. DLNR will conduct additional surveys for each reef following algae removal and determine the need for coral outplanting
3. Outplanting cultured native sea-urchins for natural algae control. DLNR will place urchins on each reef at a density of 3 per square meter
4. Outplanting coral colonies to restore the coral coverage and composition of the reefs. For reefs that receive outplanted coral, DLNR will select coral species as appropriate for the location of the reef, wave exposure, and depth of the individual receiving sites

7.4.5 MAINTENANCE PLAN

Site maintenance will likely include algae control, replacement or additional outplanting of urchins, and possible coral outplanting. DLNR will perform maintenance in conjunction with regular monitoring per the schedule outlined in 7.4.7. DLNR will include a site maintenance plan in the MBI.

7.4.6 PERFORMANCE STANDARDS

Performance standards are observable or ecological criteria based on measurable attributes that are used to evaluate a mitigation project to determine if it is providing the anticipated resources and functions. Performance standards will take into account the variability by exhibited reference sites.

For this site, the monitored attributes are coral, algae, and crustose coralline algae (CCA). Coral indicators will include percent cover. Algae will be noted by species, percent cover, and canopy height.

DLNR will propose performance standards for each patch reef in the site that are tied to the established baseline for that reef. DLNR will likely propose the following milestones:

1. Baseline survey
2. Reduce and maintain invasive algae coverage to less than 3%
3. Increase in benthic habitat available for invertebrate recruitment
4. Increase in coral

The MBI will contain the final proposed performance standards.

7.4.7 MONITORING

The monitoring plan in the MBI will describe the monitored ecological parameters, the monitoring protocol, frequency of monitoring, and length of the monitoring period.

DLNR will conduct a detailed baseline survey prior to the start of any treatment on the bank site patch reefs. DLNR will subsequently survey restoration, control, and reference reefs twice a year; winter (January/February) and summer (July/August) seasons, for 2 years after the last reef is fully treated. Reefs surveys will continue annually in the summers thereafter within the same 14-day timeframe each year (weather permitting).

7.4.8 ADAPTIVE MANAGEMENT

The Kāne`ohe Bay mitigation plan will include an adaptive management plan. Adaptive management is an approach to natural resource management that allows for course corrections throughout the life of the project to meet performance standards and to address the effects of climate change, flood, or other natural events. The adaptive management plan will include potential corrective measures, such as revisions to maintenance and monitoring requirements, should mitigation fail to meet performance standards. Performance standards may be modified in accordance with adaptive management to account for measures taken to address deficiencies in the project. DLNR will request Corps approval for any modification of performance standards.

APPENDIX A

CHRONOLOGY OF SIGNIFICANT COASTAL EVENTS AT WAIKĪKĪ AFFECTING THE MLCD AND ADJACENT AREAS, 1825-2007

Source: Wiegel RL (2008). Waikīkī Beach, Oahu, Hawaii: History of its transformation from a natural to an urban shore. *Shore and Beach* 76(2): 3 – 30.

1868	Tsunami. Reef bared at Waikīkī
1877	Kapi`olani Park opened; Waikīkī Road
1880, circa	Bridge/causeway built across from Ku'ekaunaki Stream mouth at the entrance to Kapi`olani Park; at edge of ocean
1890, circa	Pier built at Queen Lili`uokalani's beach property
1897	First map of Waikīkī, M.D. Monsarrat
1898	Sans Souci Hotel opened. Built partly on piles over water
1899	James B. Castle home built, partly on piles; seawall
1900 (prior to)	867-foot long highway retaining wall (seawall) built along Waikīkī Road (renamed Kalākaua Avenue in 1905)
1902	Trans-Pacific communications cable brought to shore along Kapua Entrance (channel)
1916	Seawall 210 feet long built in front of what is now (2002) the Elks Club
1916	Seawall 208 feet long built in front of what is now (2002) the New Otani Kaimana Beach Hotel
1919(prior to)	Several seawalls built along most (all?) of Kapi`olani Park
1920	Several seawalls built along most (all?) of Kapi`olani Park
1921-1924	Ala Wai Canal draining, wetland reclamation and mosquito control projects
1924, circa	Streams no longer flow into the ocean at Waikīkī
1927	Natatorium built, 375 feet long, extending 200 feet onto reef
1928	Ala Wai Canal draining, wetland reclamation and mosquito control projects
1937	Severe wave action; beach eroded, seawalls overtopped
1938	Kūhiō Beach. 700-foot-long shore- parallel breakwater (crest at about MLLW) constructed; known as the "crib wall"

1938	Kūhiō Beach. Coral patches cleared by dragline excavator shoreward of breakwater
1938	Kūhiō Beach. 7,000 cubic yards of sand placed on shore, in conjunction with the new breakwater. Sand brought from other part of Oahu
1939	Kūhiō Beach. Sandbag groin built at western end of sand fill
1946, 1 April	Tsunami (source, Aleutian Islands) caused reef to be "bared" during wave drawdowns; seawalls overtopped during run-ups
1951	110,000 cubic yards of sand imported and placed along shore between the Breakers (about 1,000 feet southeasterly of the Kapahulu storm drain/groin) and the "crib wall" northwesterly of Ohua Avenue
1951	Seawall ("terrace wall") built southeasterly from Kapahulu storm drain/groin, 425 feet long
1951-1957	Waikīkī Beach Development Project. A 1965 report to U.S. Congress states that 159,000 cubic yards of sand were placed in the area. This must include the 110,000 cubic yards of sand placed in 1951 (see above)
1952-1953	Kūhiō Beach. 730-foot long shore-parallel extension built to the southeast of the "crib wall" breakwater; crest about +3 feet above MLLW. Swimming area dredged inside the seawall. Sand brought from other parts of Oahu and placed on beach
1955	Present aquarium built
1956-1957	Queen's Surf Beach groin/ storm drain built, 360 feet long
1957	Kapi`olani Park Beach. Between 32,000 and 35,000 cubic yards of sand placed on coral base
1957	Kapi`olani Park Beach. Shore-parallel swimming basin dredged in reef and covered with sandy bottom, just northwesterly of the Natatorium.
1959	Kūhiō Beach. 18,757 cubic yards of sand fill placed in the area
1959	Hurricane Dot
1960, 23 May	Tsunami (source, Chile) caused reef to be "bared" during wave drawdowns; seawalls overtopped during run-ups
1963	Outrigger Canoe Club (new - at Sans Souci/Kaimana Beach), 1,660 cubic yards of coral fill and 6,000 cubic yards of sand from foundation excavation placed on beach
1963	Connecting channel 41⁄2 feet deep dredged in reef, new Outrigger Canoe Club

1963	190-feet long groin built west of the new Outrigger Canoe Club
1963	Bagged concrete groin at northwest end of Kūhiō Beach extended
1968	Kūhiō Beach. Sand bag groin at western end of beach extended
1969-1972	Groin built in front of Elks Club
1972	Kūhiō Beach and Queen's Surf Beach sand fill of 82,500 cubic yards (quantity not certain)
1972	Highway retaining seawall (Kalākaua Avenue) removed
1972	Beachwalk park begun, a "linear park" between Kalākaua Avenue and Kūhiō and Queen's Surf Beaches
1975	Kūhiō Beach. 9,500 cubic yards of sand placed in the area
1982	Hurricane Iwa
1982	Sans Souci pier destroyed as a result of Hurricane Iwa
1991	Queen's Surf Beach. Sidewalk improvements made following alignment near the 1952 beach backshore line, reducing beach area
2000	Kūhiō Beach. 1,400 cubic yards of sand dredged from thin pocket in reef offshore and pumped through a pipeline to the beach
2000	SHOALS bathymetry survey of Waikīkī, and other shallow water coastal regions of Hawaii, made jointly by the U.S. Army Corps of Engineers and U.S. Navy
2002	Sand moved by front-end loader in Feb. from west end of Kaimana Beach (where it accumulated) to east end (from where it had eroded)

2006, 4 December-5 January 2007 Kūhiō Beach Nourishment Project; sand pumping to re-nourish beach and demonstrate the effects of offshore sand retrieved from the reef flat. 8,155 cubic yards of sand dredged and pumped to beach; grading completed

APPENDIX B: REEF 16 PILOT PROJECT

In 2008, DLNR-DAR began a pilot project to test the efficacy of invasive algae control using the SuperSucker and using native grazing sea urchins (*Tripneustes gratila*). Reef # 16 was chosen to for algae removal, while the nearby reef #14 was chosen as a control. DAR chose patch reefs 16 and 14 because of their relatively small sizes, their proximity to the harbor access, their moderately complex coral structure, and heavy concentrations of *Kappaphycus/Eucheuma*.

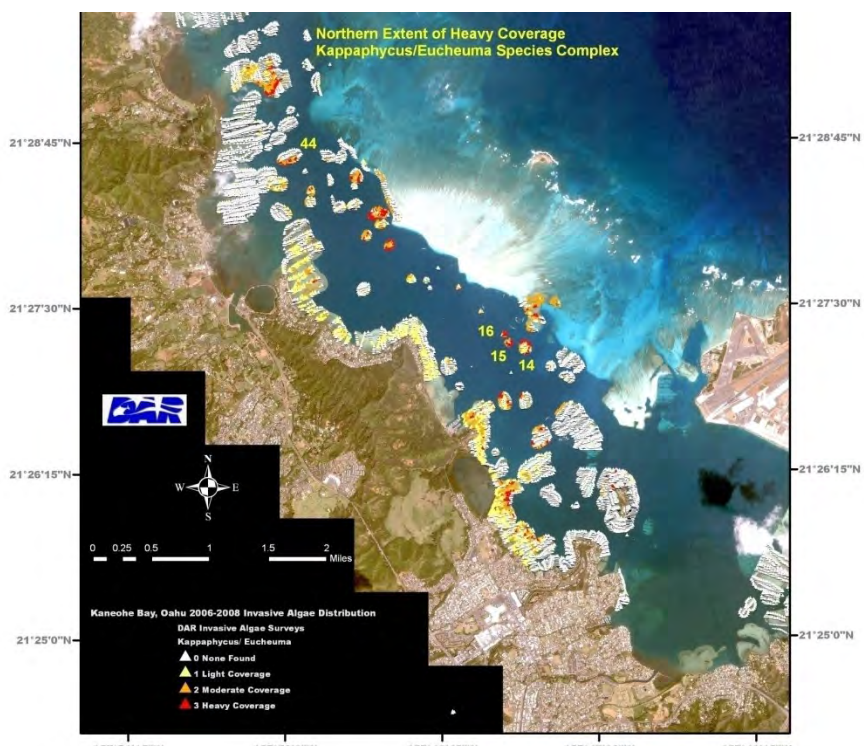
Reef 16: Test Reef

- Ideal size for patch reef in terms of removing algae efficiently.
- Proximity to larger patch reefs with algal coverage which may be used for control or replicate plots.
- Moderate composition of live coral, fish and invertebrates.

Reef 14: Control Reef

- Although much larger in size, Reef 14 has similar eco-tones that can be used as replicate control plots
- Good composition of live coral, fish and invertebrates: Reef 14 has a relatively "pristine" area, approximately 23 meters of the Leeward 100m edge zone transect that has mostly live coral and a good population of larger and more diverse fish. This illustrates the differences between areas that are "pristine" and more common areas that are inundated by *Kappaphycus* coverage and composed of a half rubble coral/half live coral substratum.

KĀNE`OHE BAY MAP SHOWING REEFS 14-16, AND BAY DISTRIBUTION OF *KAPPAHYCUS/EUCHEUMA*



Year 1 (2008-2009): First algae removal using SuperSucker only.

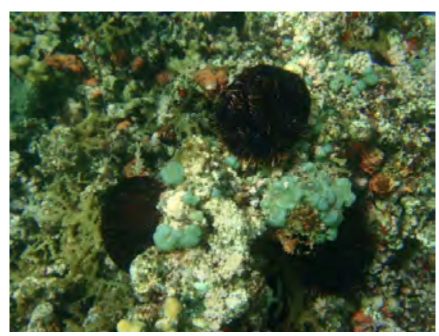
Year 2 (2009-2010): 2nd algae removal using SuperSucker, plus the addition of transplanted urchins to half of the reef (windward side).

The results of the pilot project showed that the SuperSucker alone did not yield sustainable algae reduction, and the algae grew back in about four months. When the experiment was repeated with the addition of urchins, the algae reduction was maintained at well below 5% cover for the duration of the monitoring period (11 months).

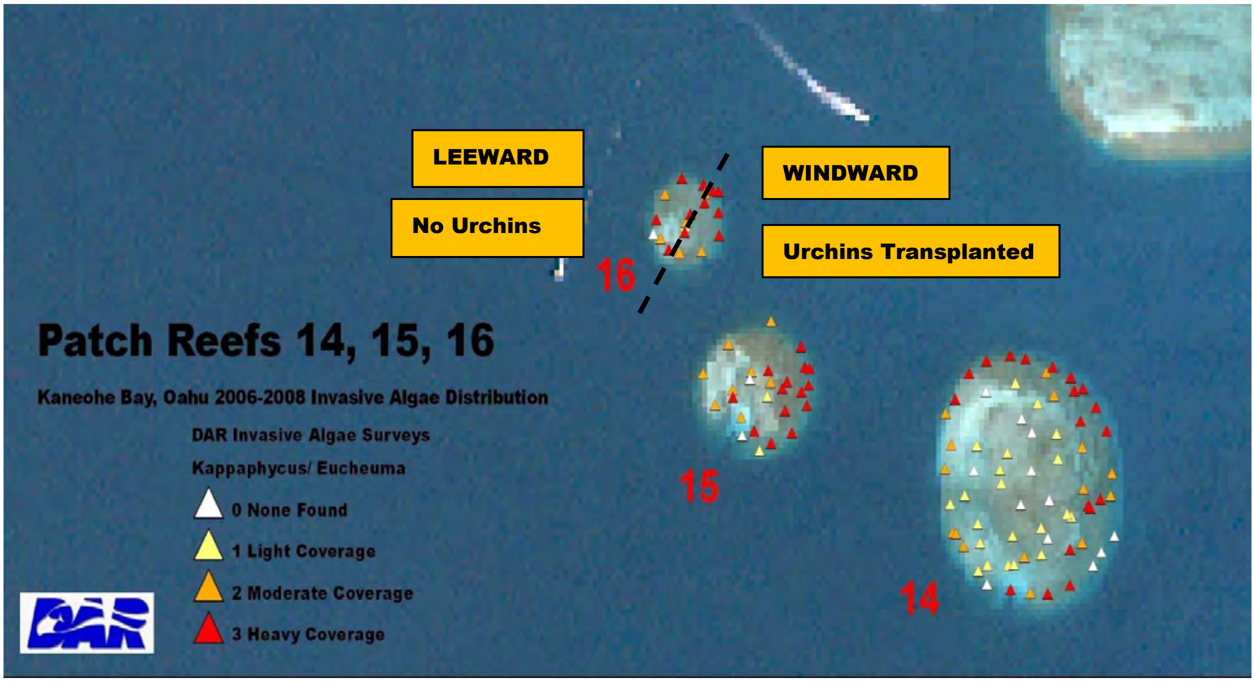
Reef 16: ≈ 3000m^2 area and ≈ 10,450 lbs. algae removed by SuperSucker.

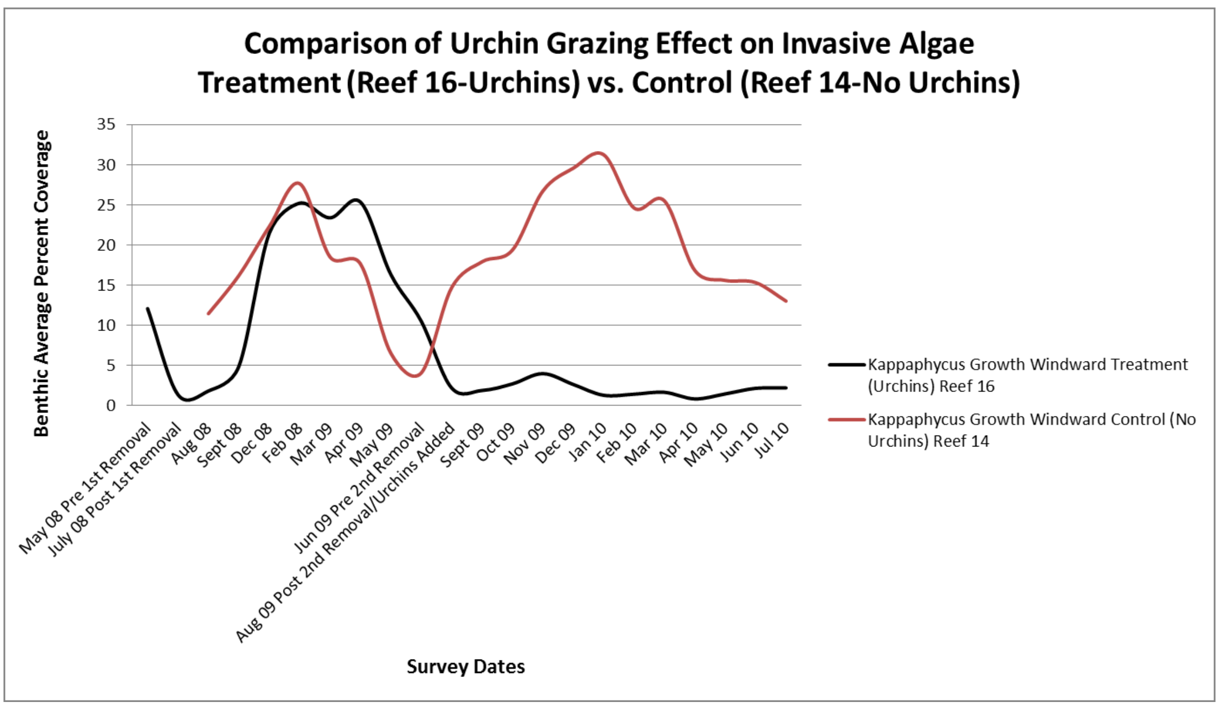
***Kappaphycus/ Eucheuma* spp. coverage on Reef 16.**

Removing algae from Reef 16, utilizing Super Sucker underwater vacuum hose.



Divers hand-transplanted collector urchins directly to areas of Windward side of Reef 16 with residual *Kappaphycus/ Eucheuma* spp. fragments.





GRAPH DISPLAYING MONTHLY AVERAGE BENTHIC PERCENT COVER OF KAPPAPHYCUS SPP. COMPLEX ON REEF 16 (TREATMENT) VS. REEF 14 (CONTROL) 2008-2011. COURTESY OF DAR 2014.

The results of the pilot project showed that the SuperSucker alone did not yield sustainable algae reduction, and the algae grew back in about four months. When the experiment was repeated with the addition of urchins, the algae reduction was maintained at well below 5% cover for the duration of the monitoring period (11 months).

APPENDIX C

RESTORATION PROJECT REEFS 26-29 KANEOHE BAY, OAHU

For more information or questions about this report, please contact
Brian Neilson, Division of Aquatic Resources, (808) 587-0101

The aquatic invasive species team's first full-scale invasive algae restoration project took place In Kaneohe Bay, patch reef's 26, 27, and 29 (see map on page C-1). This project, primarily funded by Hawai`i Invasive Species Council and a NOAA Estuary Restoration Grant and was carried out from November 2011 through February 2014. Reefs were cleared using a combination of mechanical removal (The Super Sucker) and sea-urchin biocontrol (described in the "Background" section). Reefs 26 and 27 were cleared and stocked with sea urchins and this effort was successful in terms of maintaining low (<1%) invasive algae coverage more than two years after the initial mechanical removal. Restoration efforts on Reef 29 were limited by the hatcheries urchin production. Although the reef was successfully cleared by the Super Sucker, a large amount of algae grew back since urchins were not outplanted to control invasive algae regrowth. Consequently, Reef 29 was re-cleared in 2013 when more urchins were available for outplanting. Currently invasive algae density remains low on Reef 29. Reef size, removal dates, pounds of algae removed, urchin outplanting reef habitat, and monitoring data is summarized in for each reef.


Mokolii
OAHU
0 8 km
Kapapa
Barrier Reef
Ahuolaka
Kekepa
KAHALUU
K.M.C.A.S.
Moku o Loe Island
KANEOHE

Reef 26

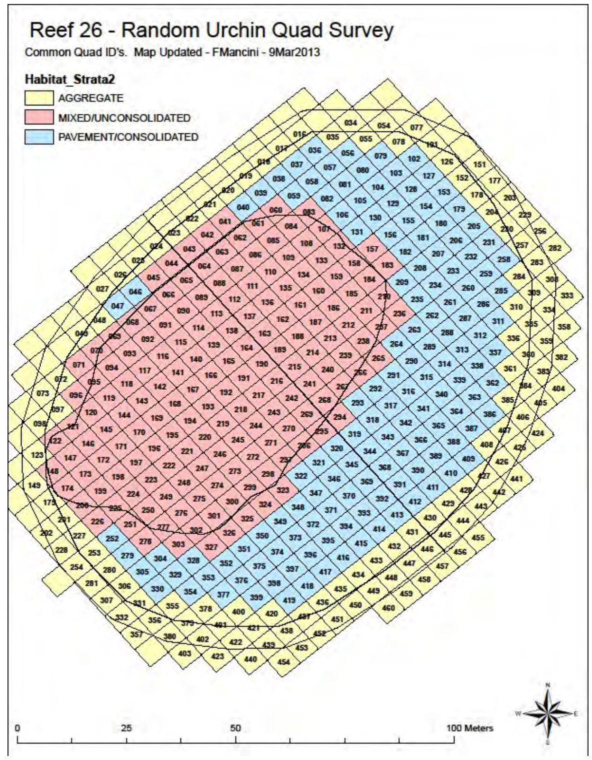
Size: 12,500 square meters

Algae removal: 11/2011-3/2012
11,053 lbs. total

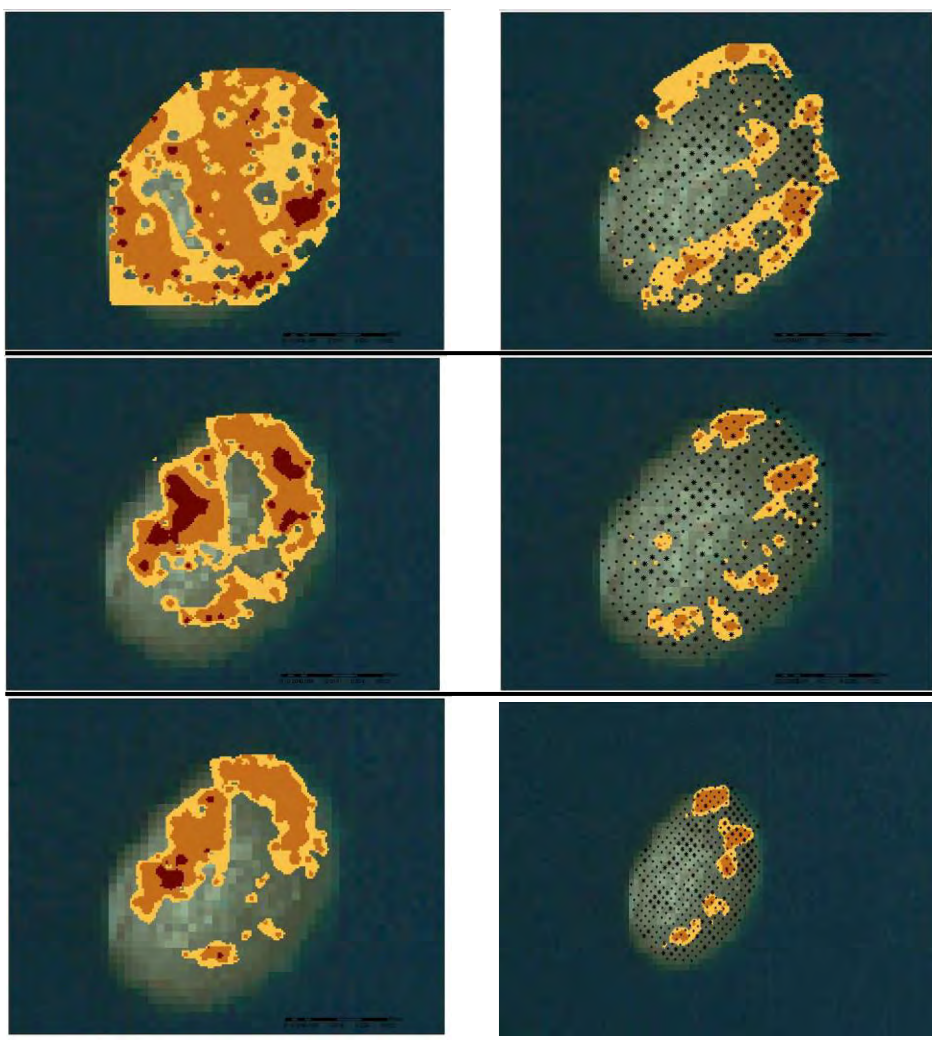
Urchin outplanting: 12/2011-5/2012,
12/2013, 6/25/2014
46,913 urchins

Right: Habitat Map

Below: Algae coverage maps by species, before and after algae removal



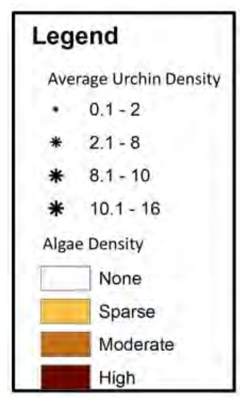
June, 2011 **December, 2013**



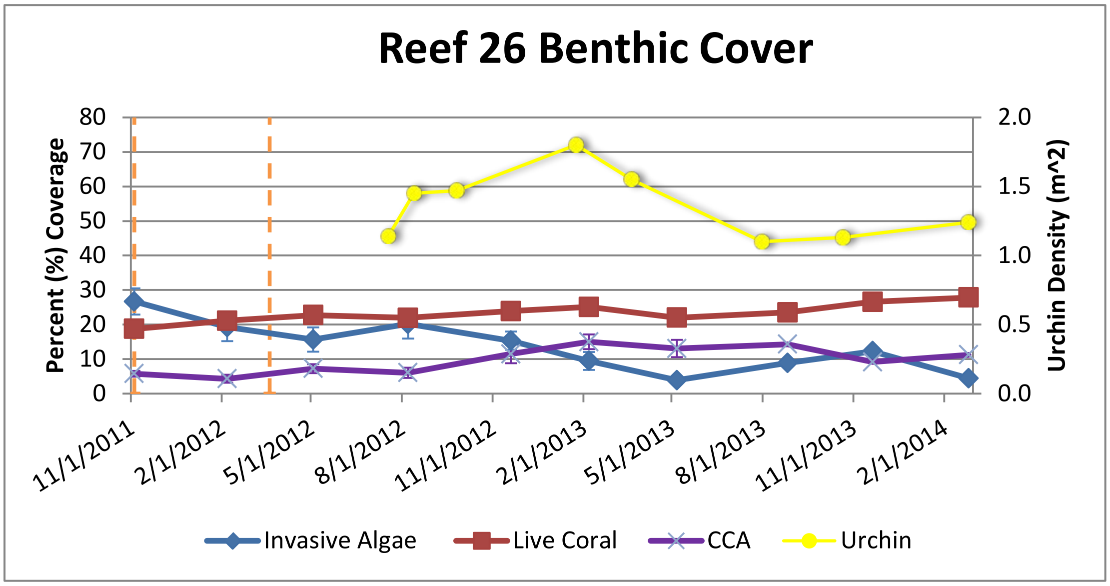
Kappaphycus/Eucheuma

Gracilaria salicornia

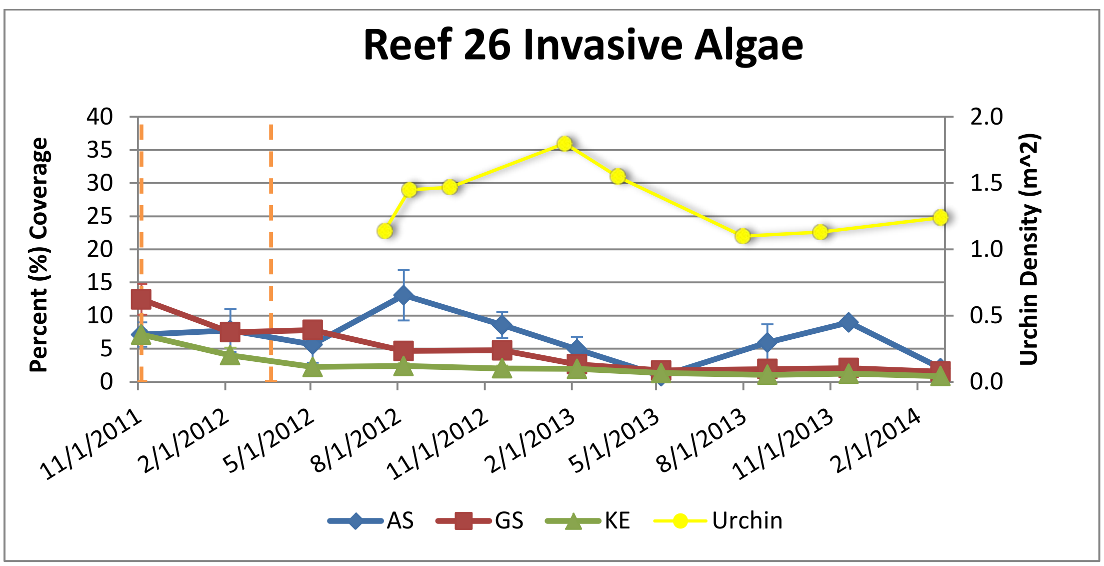
Acanthophora spicifera



Monitoring Preliminary Analysis



Reef 26. Percent cover of invasive algae and live coral coverage calculated using line point intercept (LPI) over 14-25m transects. Urchin density calculated using quadrat sampling. Dashed vertical line represents date of final mechanical removal event. This reef has been stocked with urchins for the longest period.



Reef 26 data showing individual alien invasive species (AS- *Acanthophora specifera,* GS- *Gracilaria salicornia,* KE- *Kappaphycus/Eucheuma spp.)*; time of mechanical removal (dashed lines); and urchin density numbers per square meter. Spike in AS believed to be due to seasonal growth. Super Sucker mainly targets KE, because GS and AS are too labor intensive to remove. However, these species are reduced through addition of urchins.

Reef 27

Size: 12,500 square meters

Algae removal: 03/2012-8/2012

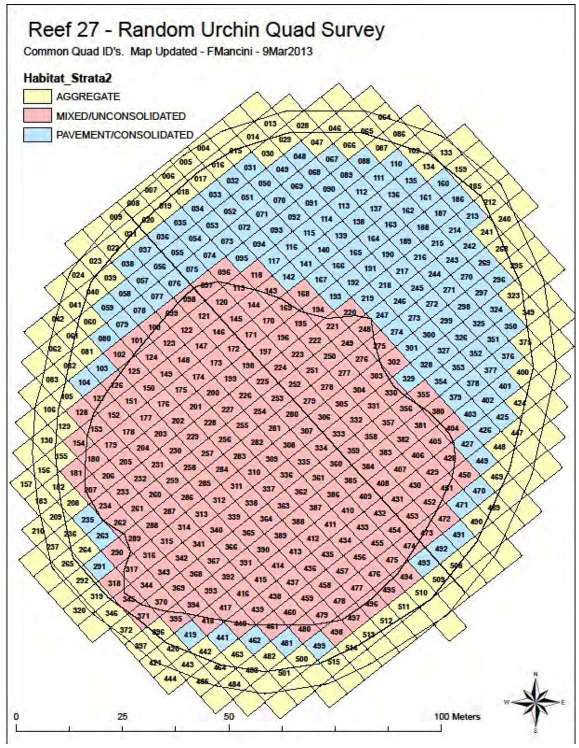
15,642 lbs. total

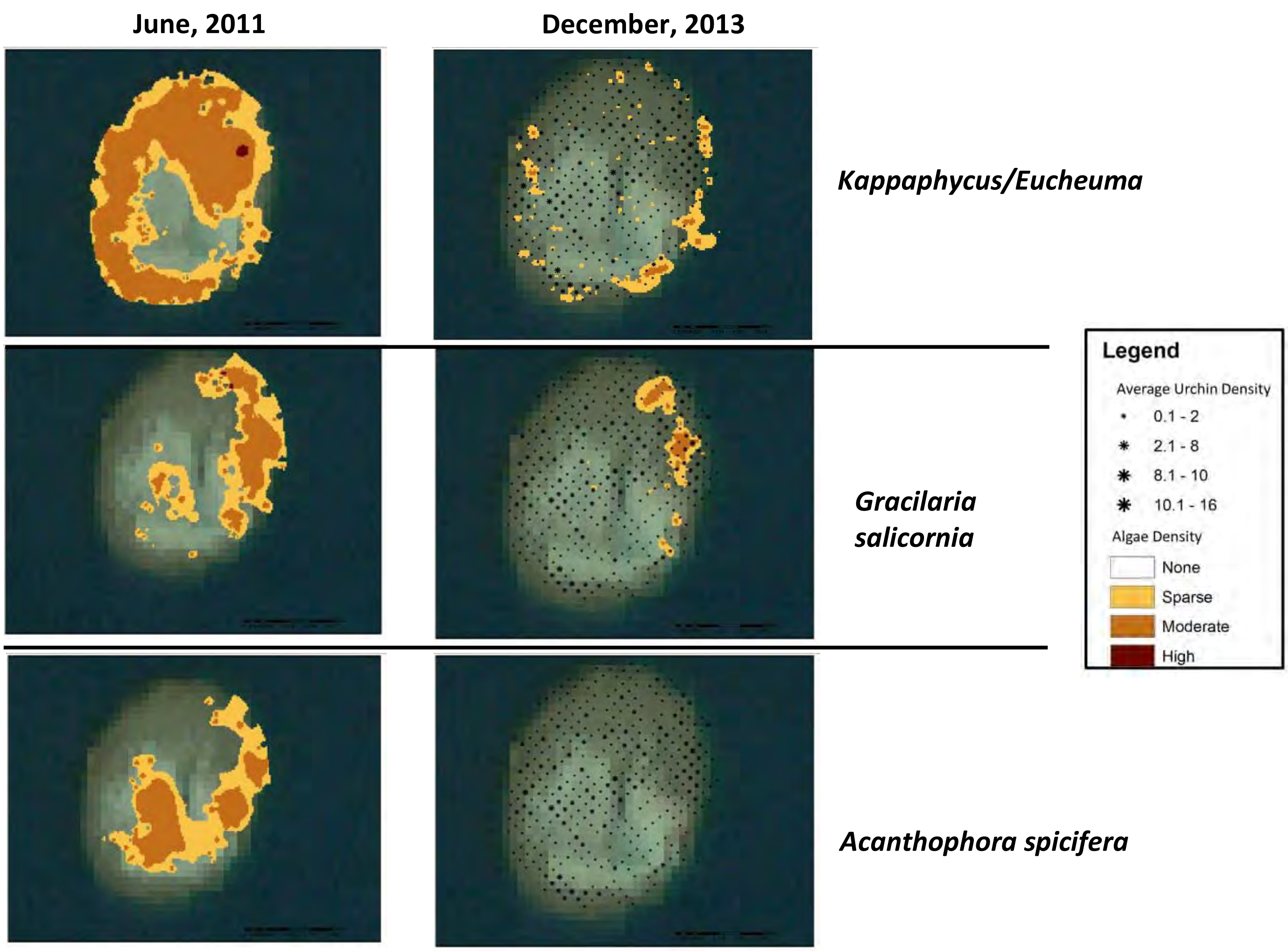
Urchin outplanting: 08/2012-12/2013

52,153 urchins total

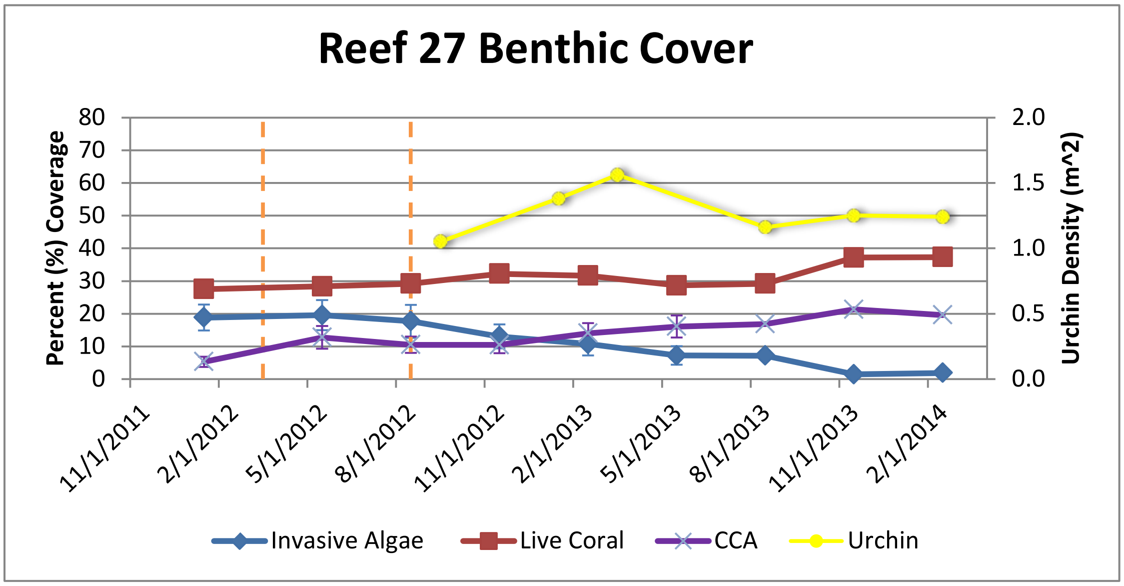
Right: Habitat Map

Below: Algae coverage maps by species, before and after algae removal

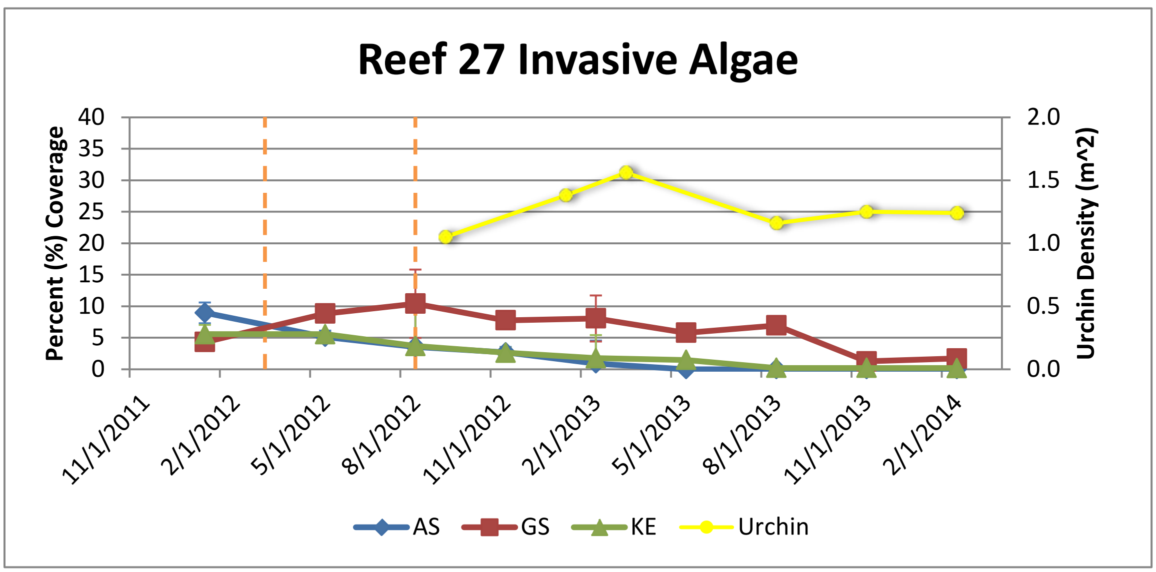




Monitoring Preliminary Analysis



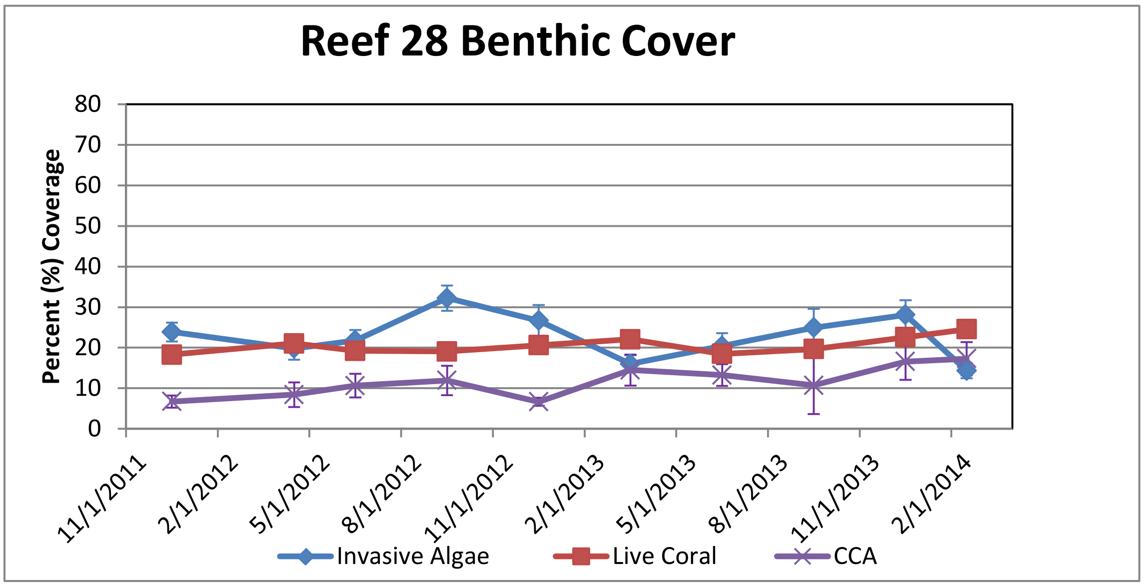
Reef 27. Pecent cover of invasive algae and live coral coverage calculated using database of line point intercept (LPI) over 13-25m transects. Urchin density calculated using reef wide non-randomized sampling. Dashed vertical line represents date of final mechanical removal event.



Reef 27 data showing individual alien invasive species (AS- *Acanthophora specifera*, GS- *Gracilaria salicornia*, KE- *Kappaphycus/Eucheuma spp.)*; time of mechanical removal (dashed lines); and urchin density numbers per square meter. Super Sucker mainly targets KE, because GS and AS are too labor intensive to remove. However, these species are reduced through addition of urchins.

Reef 28

Reef 28 is used as the control reef for Reefs 26, 27, and 29; therefore, no mechanical removal or urchin outplanting has ever occurred on this reef. It is similar in size of Reefs 26/27 being approximately 13,000m^2 and was selected as a control based on its location and size. At the time of selection, the coverage of KE was not as high as the treated reefs, but it has seen a recent increase since June, 2013.*G.salicornia* varies from 12-21% and doesn't seem to have any seasonal characteristics, while *Acanthophora spicifera* does have a possible seasonal growth beginning in the summer and then coming to a peak in the winter.



Reef 28. Invasive Algae and Live Coral coverage calculated using database of Line Point Intercept (LPI) over 18-25m transects. Reef 28 set as control, no manipulation has occurred.

Reef 29

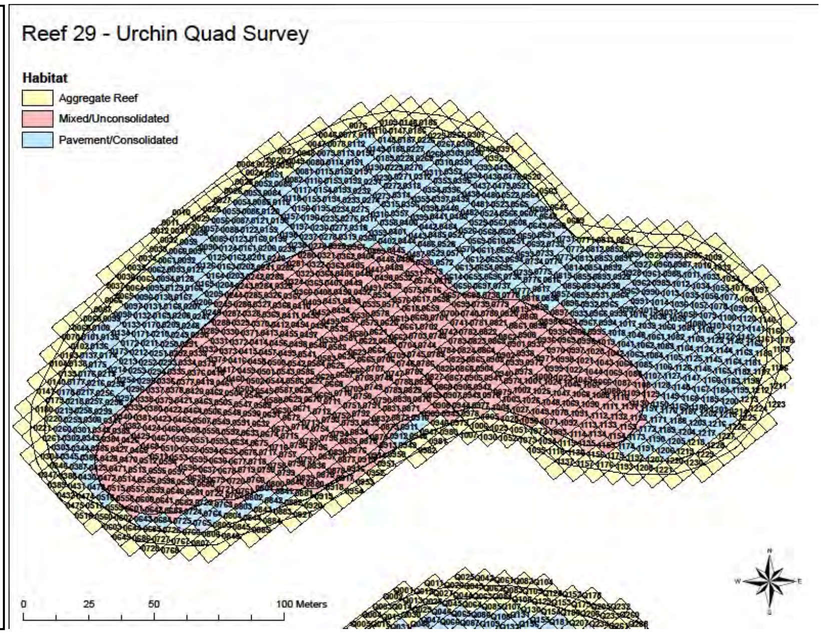
1st Algae removal: 03/2012-1/2013
11,438 lbs. total

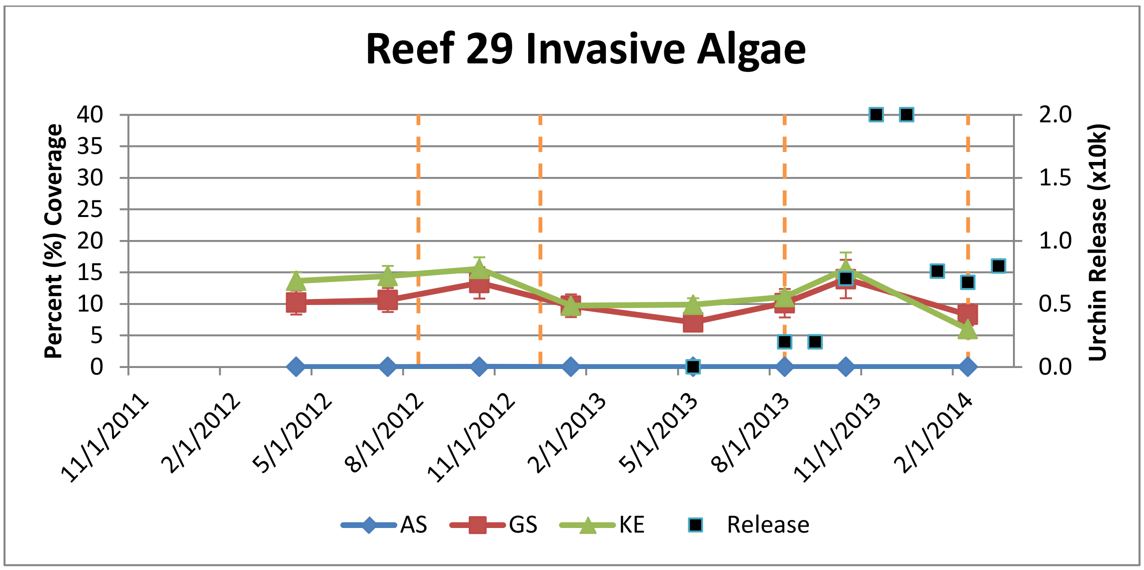
2nd Algae removal: 8/2013-2/2014

Urchin outplanting: 08/2013- 3/2014
93,000 urchins as of 3/2014

Right: Habitat Map (F. Mancini)

Below: Monitoring results





Reef 29 data showing individual alien invasive species (AS- *Acanthophora specifera,* GS- *Gracilaria salicornia,* KE- *Kappaphycus/Eucheuma spp.)* and time of mechanical removal (dashed lines), including second removal effort and number of urchins released. Note the reduction in both GS and KE with the continued removal and addition of urchins.

APPENDIX D

BIOLOGICAL RESOURCES IN KĀNE`OHE BAY

Fish observed by DLNR-DAR staff during surveys 2010-2013

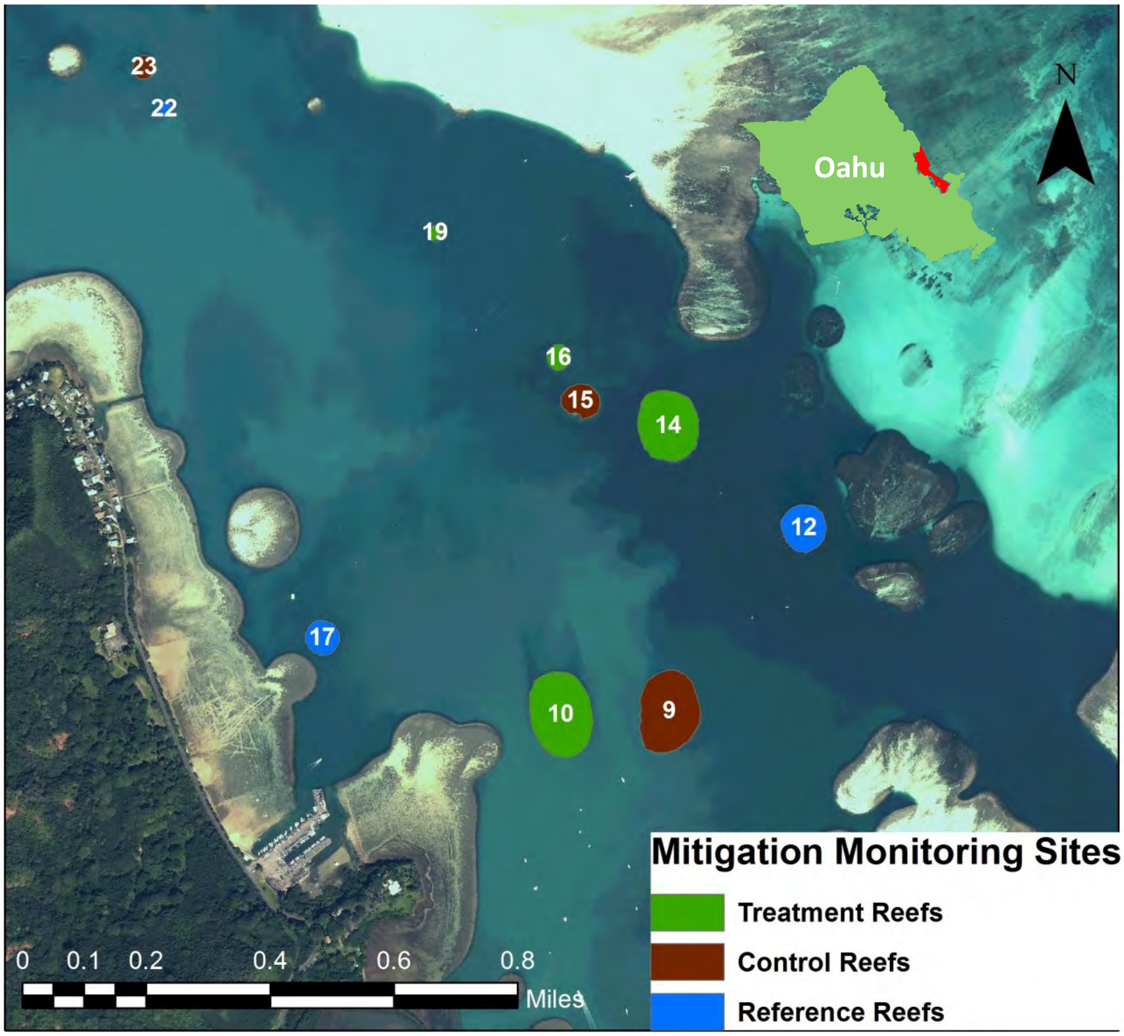
Scientific Name	Common Name	Hawaiian Name
Abudefduf abdominalis	Hawaiian Sergeant	mamo
Abudefduf vaigiensis	Indo-Pacific Sergeant	mamo
Acanthurus triostegus	Convict Surgeonfish (Convict Tang)	manini
Acanthurus blochii	Ringtail Surgeonfish	pualu
Acanthurus nigroris	Bluelined Surgeonfish	
Acanthurus nigrofuscus	Brown Surgeonfish	
Arothron hispidus	Stripebelly Puffer (White-spotted Puffer)	o'opu hue
Asterropteryx semipunctata	Half-Spotted Goby	o'opu
Aulostomus chinensis	Trumpetfish	nūnū
Bodianus bilunulatus	Hawaiian Hogfish (Tarry Hogfish)	'a'awa
Bothus mancus	Flowery Flounder	pāki'i
Canthigaster jactator	Hawaiian Whitespotted Toby	
Chaetodon auriga	Threadfin Butterflyfish	kikākapu
Chaetodon miliaris	Milletseed Butterflyfish	lau wiliwili
Chaetodon lunula	Raccoon Butterflyfish	kikākapu
Chaetodon ornatissimus	Ornate Butterflyfish	kikākapu
Chaetodon unimaculatus	Tear Drop Butterfly	kikakapu
Chaetodon lunulatus	Oval Butterflyfish	kapuhili
Chaetodon multicinctus	Pebbled Butterfly (Multiband Butterflyfish)	kikakapu
Cheilio inermis	Cigar wrasse	kupou
Chlorurus sordidus	Bullethead Parrotfish (Daisy Parrotfish)	uhu
Chromis ovalis	Oval Chromis	
Chromis hanui	Chocolate-Dip Chromis (Hawaiian Bicolor Chromis)	
Ctenochaetus strigosus	Goldring Surgeonfish (Spotted Surgeonfish)	kole
Dascyllus albisella	Domino Damselfish (Hawaiian Dascyllus)	'alo'ilo'i

Scientific Name	Common Name	Hawaiian Name
Diodon hystrix	Giant Porcupinefish (Spotfin Porcupinefish)	
Fistularia commersonii	Cornetfish (Bluespotted Cornetfish)	nūnū peke
Gnatholepis anjerensis	Eye-bar Goby	o'opu
Gnatholepis cauerensis	Hawaiian Shoulder-Spot Goby	o'opu
Gomphosus varius	Bird Wrasse	hinalea 'aki-lolo or hinalea 'i'iwi
Gymnothorax meleagris	Whitemouth Moray (Turkey Moray)	puhi 'ōni'o
Gymnothorax flavimarginatus	Yellowmargin Moray (Yellow-Edged Moray)	puhi paka
Labroides phthirophagus	Hawaiian Cleaner Wrasse	
Lutjanus fulvus	Blacktailed Snapper	to'au
Mulloidichthys flavolineatus	White Goatfish (Yellowfin Goatfish)	weke'a
Mulloidichthys vanicolensis	Yellowfin Goatfish	weke-'ula
Naso lituratus	Orangespine Unicornfish	umauma-lei
Naso brevirostris	Paletail Unicornfish	kala lolo
Ostracion meleagris	White Spotted Boxfish	moa
Parupeneus multifasciatus	Manybar Goatfish	moano
Parupeneus pleurostigma	Sidespot Goatfish	moano
Plectroglyphidodon johnstonianus	Blue-Eyed Damsel	
Psilogobius mainlandi	Hawaiian Shrimp Goby	o'opu
Stegastes marginatus	Hawaiian Gregory	
Stethojulis balteata	Belted Wrasse	omaka
Thalassoma duperrey	Saddle Back Wrasse	hinalea lau-wili
Thalassoma trilobatum	Christmas Wrasse	awela
Zanclus cornutus	Moorish Idol	kihikihi
Zebrasoma flavescens	Yellow Tang	lau-i-pala
Zebrasoma velifer	Sailfin Tang	mane'one'o

Benthic organisms observed by DLNR-DAR staff during surveys 2010-2013

Scientific name	Benthic Group
Anotrichium tenue	Algae - Native
Caulerpa racemosa	Algae - Native
Codium arabicum	Algae - Native
Dictyosphaeria cavernosa	Algae - Native
Dictyosphaeria verslusii	Algae - Native
Dictyosphaeria cavernosa	Algae - Native
Dictyosphaeria verslusii	Algae - Native
Dictyota sandvicensis	Algae - Native
Galaxaura rugosa	Algae - Native
Gelidiella acerosa	Algae - Native
Padina spp	Algae - Native
Predaea spp	Algae - Native
Turbinaria ornata	Algae - Native
Acanthophora spicifera	Algae - Non Native
Eucheuma denticulatum	Algae - Non Native
Gracilaria salicornia	Algae - Non Native
Kappaphycus spp.	Algae - Non Native
Kappaphycus/Euchema complex	Algae - Non Native
Fungia scutaria	Coral
Montipora patula	Coral
Montipora capitata	Coral
Pavona varians	Coral
Pocillopora damicornis	Coral
Pocillopora meandrina	Coral
Porites compressa	Coral
Leptolyngbya crosbyana	Cyanobacteria
Sabellastarte spectabilis	Invertebrate
Mycale grandis	Sponge
Palythoa caesia	Zoanthid

APPENDIX E
DESCRIPTION OF KĀNE`OHE BAY BANK REEFS



This appendix provides basic descriptions of the four reefs (#10, 14, 16, 19) that together comprise the Kāne`ohe Bay Mitigation Bank Site. Additional information from the complete baseline surveys will be provided in the MBI.

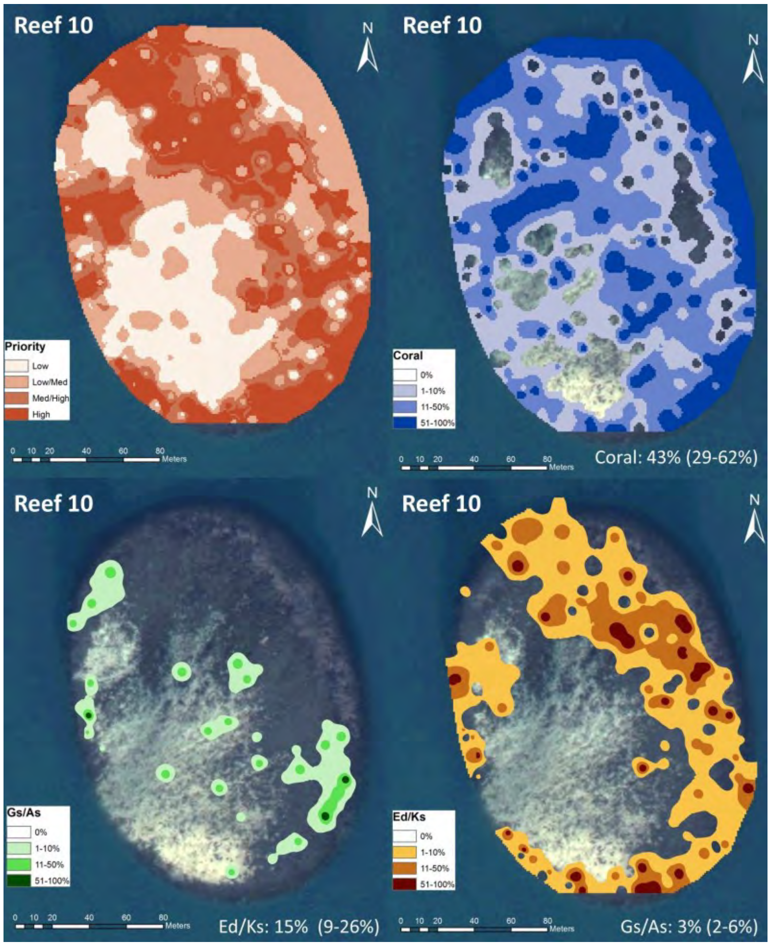
Reef 10: Longitude 21 26'45" N and Latitude 157 48'15" W

REEF	Priority RANK	% Priority	% Ed/Ks	%GS	AREA (m2)	Priority	Justification	Designation
10	4	59.73	14.41	3.09	30,098	High	High Coral/High Algae	Treatment

Benthic Structure: Aggregate live coral, mixed unconsolidated live coral, rubble, sand and pavement with native and invasive macro-algae cover. The edges of the reef are comprised of aggregate live coral, mix unconsolidated live coral, pavement, sand and native and invasive macro-algae cover. The center of the reef is comprised of mix unconsolidated live coral, sand, rubble and native and invasive macro-algae cover.

Coral: Primarily comprised of *Porites compressa* and *Montipora capitata*, but also includes species such as *Pocillopora damicornis and Fungia scutaria* among others.

Invasive algal cover is comprised of moderate amounts of *Eucheuma denticulatum* and *Kappaphycus Clade B* with low occurrence of *Gracilaria salicornia* and *Acanthophora spicifera*. In general, *Eucheuma denticulatum* and *Kappaphycus* Clade B are distributed on the north and windward reef tops and edges.



Reef 14: Longitude 21 27’10” N and Latitude 157 48’5” W

REEF	Priority RANK	% Priority	% Ed/Ks	%GS	AREA (m2)	Priority	Justification	Designation
14	6	43.51	11.40	3.43	22,122	High	High Coral/High Algae/Historical Data	Control

Benthic structure: Aggregate live coral, mixed unconsolidated live coral, pavement and sand. The edges of the reef are comprised of aggregate live coral, mix unconsolidated live coral, pavement and native and invasive macro-algae cover. The center of the reef is comprised of small amounts of mix unconsolidated live coral, pavement and sand with native and invasive macro-algae cover.

Coral: Primarily comprised of *Porites compressa* and *Montipora capitata*, but also includes species such as *Pocillopora damicornis, Pocillopora meandrina, Pavona varians* and *Fungia scutaria* among others. The leeward edge and edge top is comprised of considerably higher coverage of aggregate live coral whereas the windward edge and edge top is comprised primarily of mixed unconsolidated live coral and pavement.

Native algal cover is comprised of *Sargassum spp., Dictyota spp., Codium arabicum, Coelothrix irregularis*, *Dictyosphaeria spp., and Martensia fragilis* among others.

Invasive algal cover is comprised of *Gracilaria salicornia, Acanthophora spicifera, Hypnea musciformis*, *Eucheuma denticulatum* and *Kappaphycus Clade B*. In general, *Eucheuma denticulatum* and *Kappaphycus Clade B* are more prevalent on the edges and edge tops of Reef 14. The benthic percent cover of *Eucheuma denticulatum* and *Kappaphycus Clade B* was higher on the windward edge and edge top compared to the leeward edge and edge top.

Reef 16: Longitude 21 27'17" N and Latitude 157 48'14" W

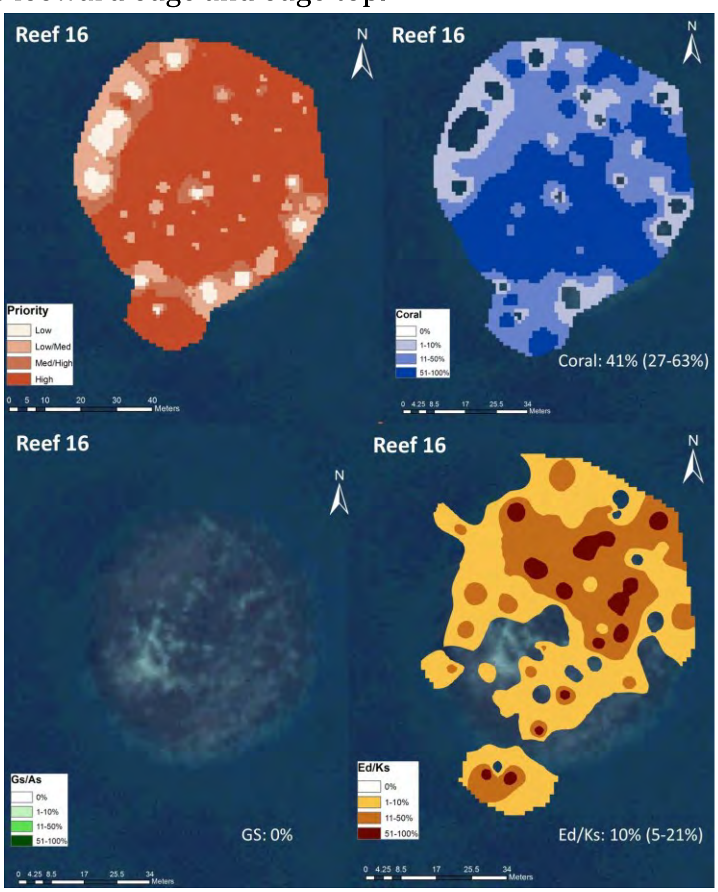
REEF	Priority RANK	% Priority	% Ed/Ks	%GS	AREA (m2)	Priority	Justification	Designation
16	3	71.51	10.17	0.00	4,303	High	High Coral/High Algae	Treatment

Benthic Structure: Aggregate live coral, mixed unconsolidated live coral, rubble, sand and pavement with native and invasive macro-algae cover. In general, the edges and center of the reef are relatively uniformly comprised of aggregate live coral and mix unconsolidated live coral, with sand patches interspersed. However, the leeward edge and edge top was comprised of higher coverage of aggregate live coral whereas the windward edge and edge top is comprised primarily of mixed unconsolidated live coral and pavement.

Coral: Primarily comprised of *Porites compressa* and *Montipora capitata*, but also includes species such as *Pocillopora damicornis, Pocillopora meandrina, Pavona varians, Montipora patula* and *Fungia scutaria* among others.

Native algal cover includes *Anotrichium tenue, Dictyosphaeria spp., Dictyota spp., Kallymenia spp*., among others.

Invasive algal cover is comprised of *Eucheuma denticulatum* and *Kappaphycus Clade B* and minimal amounts of *Gracilaria salicornia and Acanthophora spicifera*. The benthic percent cover of *Kappaphycus spp*. was higher on the windward edge and edge top compared to the leeward edge and edge top.



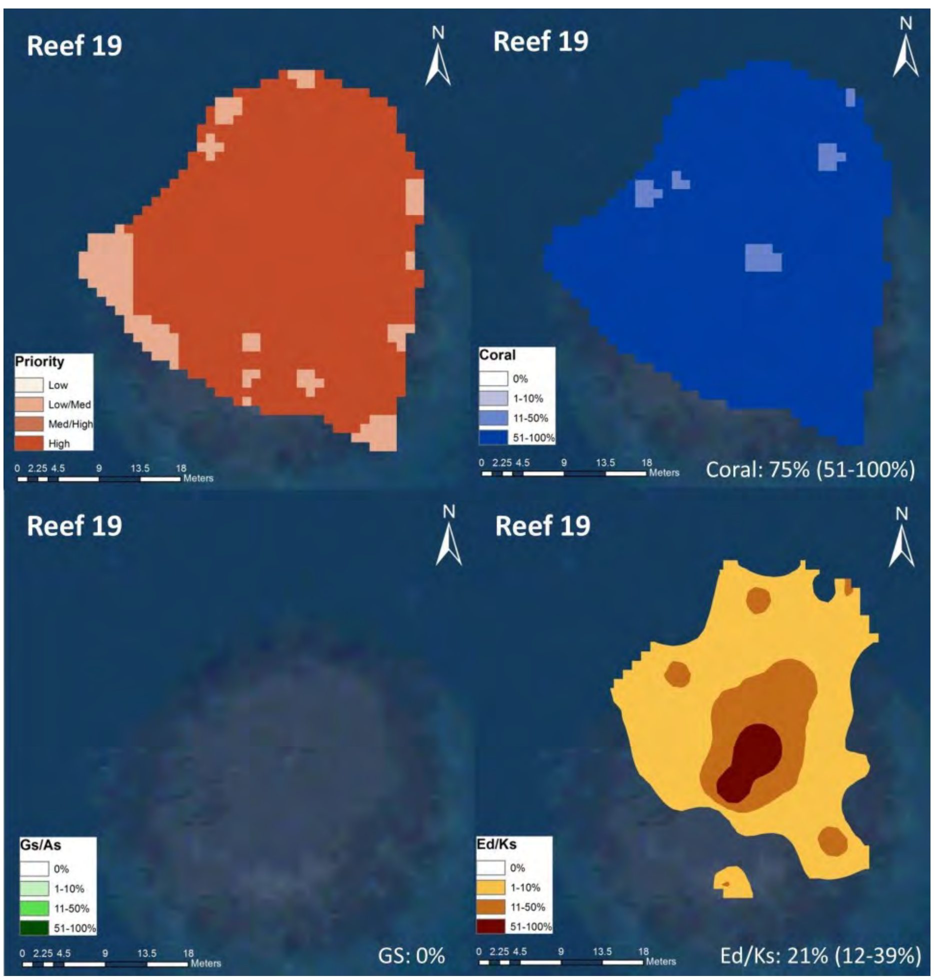
Reef 19: Longitude 21 27'27" N and Latitude 157 48'25" W

REEF	Priority RANK	% Priority	% Ed/Ks	%GS	AREA (m2)	Priority	Justification	Designation
19	1	100.00	21.02	0.00	1,023	High	High Coral/High Algae	Treatment

Benthic Structure: Aggregate live coral and mixed unconsolidated live coral. The edges of the reef are comprised of aggregate live coral, mix unconsolidated live coral, and native and invasive macro-algae cover. The center of the reef is comprised of aggregate live coral reef, mix unconsolidated live coral and native and invasive macro-algae cover.

Coral: Primarily comprised of *Porites compressa* and *Montipora capitata*, but also includes *Pocillopora damicornis and Fungia scutaria* among other species.

Invasive algal cover is comprised of moderate amounts of *Eucheuma denticulatum* and *Kappaphycus Clade B* and minimal to possible zero occurrence of *Gracilaria salicornia* and *Acanthophora spicifera*. In general, *Eucheuma denticulatum* and *Kappaphycus* Clade B are evenly distributed across the reef.



APPENDIX F

Kāne`ohe Bay, Oahu Snap-Assessment Report

Prepared by:

**Brian Neilson, Jono Blodgett, Cathy Gewecke,
Brad Stubbs, Kendall Tejchma**

May 2014

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Executive Summary

The proliferation of introduced invasive algae throughout Kāne`ohe Bay poses a major threat to coral reef ecosystems. As a result, extensive invasive algal management has been carried out over the past decade. Given the bay-wide distribution of invasive algae, it is essential that management also be conducted on a bay-wide scale. This allows managers to prioritize control efforts and invest resources to areas that have the greatest ecological gain. In order to implement a bay-wide management approach, current coral and invasive algae data are needed to make informed decisions.

A bay-wide snap-assessment survey was carried out to map coral and invasive algae cover of patch reefs in the bay. The primary objectives of this project were to:

1) Provide essential data to inform bay-wide management decisions aimed at controlling the spread of *Eucheuma spp*. and *Kappaphycus spp*. and to conserve or restore coral reef ecosystems in Kāne`ohe Bay.

2) Select patch reefs for inclusion in the State of Hawaii's proposed mitigation bank prospectus.

3) Provide baseline data to monitor coral and invasive algal trends in Kāne`ohe Bay overtime.

Forty-one patch reefs were surveyed from February to April 2014 and a Kāne`ohe Bay coral and invasive algae distribution dataset was established. Results showed that invasive algae were distributed throughout the bay at variable densities. Coral distribution was also variable, with high coral densities found on patch reefs throughout the bay. Mitigation reefs were selected by use of a prioritization ranking structure that weighted reefs with a high co-occurrence of live coral and invasive algae (*Eucheuma spp.* and *Kappaphycus spp.*). These reefs were believed to have the highest potential for invasive algae restoration. This prioritized ranking was used to select four treatment reefs for immediate removal efforts and inclusion into the mitigation bank prospectus. The snap-assessment results were also used to select control and reference monitoring sites. The survey methodology was found to provide accurate and repeatable coral and invasive algal cover estimates and will provide a valuable data set for tracking changes in coral and algal distribution over time.

It is recommended that the snap-assessment survey, in combination with prioritization models, is used to construct a bay-wide invasive algae action-plan that incorporates a variety of management strategies and objectives. It is also recommended that the snap-assessment surveys are repeated annually or bi-annually to track coral and invasive algae trends in the bay over time.

Introduction

Coral reef habitats of Kāne`ohe Bay, Oahu have become increasingly dominated by alien algae since introduction in the 1970's (Russel 1983, Smith et al. 2002, Conklin and Smith 2005). Several species of alien algae, particularly *Eucheuma spp., Kappaphycus spp., and Gracilaria salicornia*, are a major threat. These species dominate reef habitats, out-compete native species, reduce photosynthesis of native organisms, alter water chemistry, and kill corals (Russell 1983, Conklin and Smith 2005, Chandrasekaran et al. 2008, Martinez et al. 2011).   In addition, these species are able spread and proliferate if left unchecked (Rodgers and Cox 1999, Conklin and Smith 2005). Given these destructive effects and since *Eucheuma spp.* and *Kappaphycus spp.* currently have not dispersed widely outside of Kāne`ohe Bay, there is a strong incentive to actively control their spread.

Therefore, the State of Hawaii's, Department of Land and Natural Resources, Division of Aquatic Resources and its partners, The Nature Conservancy, University of Hawaii, and National Oceanic and Atmospheric Administration have carried out extensive control efforts through mechanical removal by use of the supersucker and biocontrol by outplanting the native sea urchin *Tripneustes gratilla*.

Currently, invasive algae have colonized a large portion of the patch reefs and fringing reefs in the bay to various levels of coverage (Smith et al. 2002, Conklin and Smith 2005). Given the expansive distribution of invasive algae, a bay-wide approach is essential to prioritize management efforts. Current invasive algae and coral distribution data is important to implement an action plan. Therefore, a bay-wide assessment was carried out by the University of Hawaii with funding from the Division of Aquatic Resources and help from The Nature Conservancy of Hawaii.

A snapshot ("snap") assessment rapidly assesses important reef characteristics. Data is compiled into a single database where reef attributes can easily be compared, sorted, prioritized, ranked, and decision support tools can be deployed to guide future management efforts. The primary objectives of this project were to:

- Provide essential coral and invasive algae data to inform bay-wide decision making in order to preserve and restore native coral reef ecosystems in Kāne`ohe Bay and control the spread of *Eucheuma spp*. and *Kappaphycus spp*.
- Select patch reefs for inclusion in the proposed State of Hawaii proposed mitigation bank prospectus.
- Provide baseline data that could be used to monitor coral and invasive algae trends in Kāne`ohe Bay overtime.

Methods

Site Description

Kāne`ohe Bay is a 60 km^2 embayment, located on the east-shore of Oahu, Hawaii and has a barrier reef, fringing reef, and numerous patch reef habitats (Figure 1).

Site Selection

All patch reefs across the bay were evaluated for coral and invasive algal coverage as possible inclusion in the snap-assessment (Figure 1). Survey reefs were selected using satellite imagery and past survey data. Reefs included in the snap-assessment had high to moderate coral cover or a known presence of *Eucheuma/Kappaphycus*. Patch reefs excluded from the survey were primarily composed of sand habitats or no known presence of *Eucheuma/Kappaphycus*. Barrier and fringing reefs were excluded from the survey because current management techniques are not yet suited to treat expansive reef areas. Several patch reefs with no known presence of *Eucheuma/Kappaphycus* presence, but with high potential coral reef habitat were surveyed for baseline data of unaffected reefs. Forty-one patch reefs were surveyed to estimate coral and invasive algae cover.

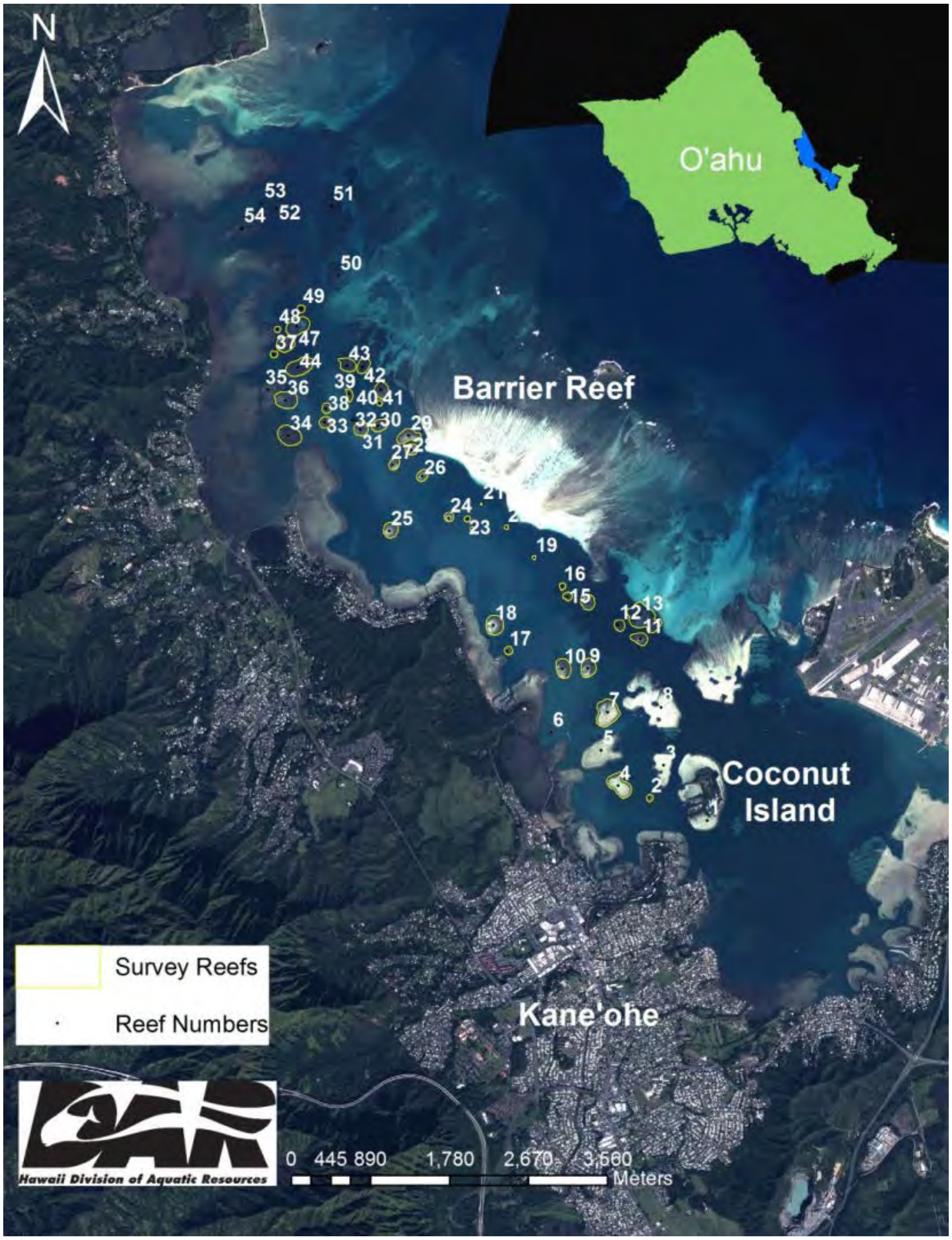


Figure 1. Kāne`ohe Bay, Oahu. Reefs outlined in yellow were surveyed as part of the snap-assessment.

Survey Methods

Surveyors, spaced approximately 5-10 m apart, swam transects across the reef and randomly placed a 0.5 m measuring stick every 5-10 m (Figure 2). Surveyors swam multiple passes across the reef to sample the reef's flat, crest and slope to depths of ≤ 3 m. Surveyors made every attempt to avoid bias by haphazardly selecting survey points by placing the stick at regular intervals and not looking at the reef bottom when placing the survey stick on a point.

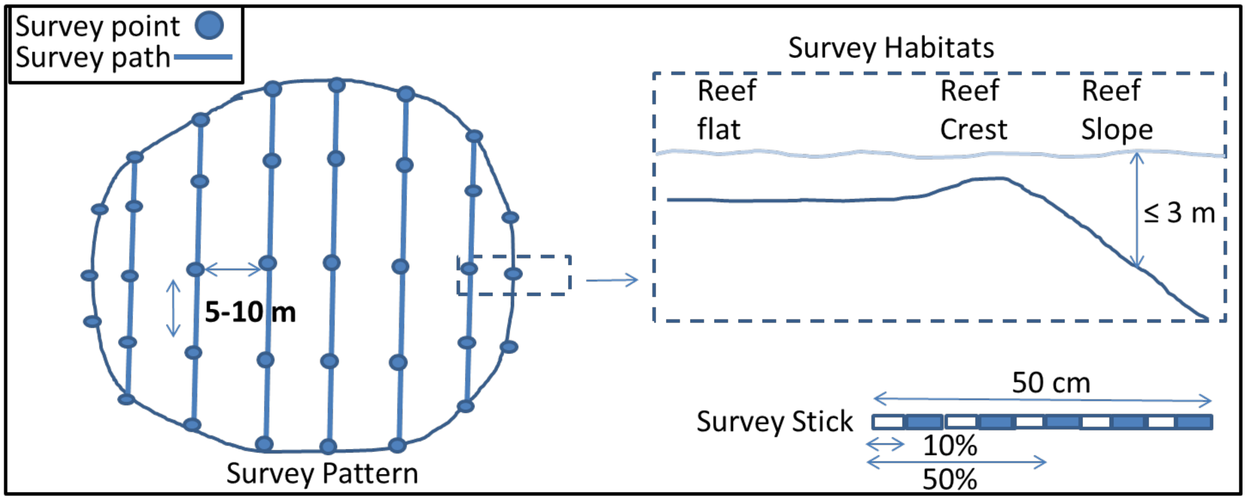


Figure 2. Snap assessment survey pattern, survey point, survey path, survey habitats, and survey stick.

At each survey point, a waypoint was taken using a GPS, the habitat (slope, crest, and flat) and percent cover (live coral, *Eucheuma/Kappaphycus, and Gracilaria/Acanthophora*) were estimated based on the benthic composition below the measuring stick. Invasive algae were grouped into two categories: 1) *Eucheuma* and *Kappaphycus* and 2) *Gracilaria* and *Acanthophora* (composed of *Gracilaria salicornia* and *Acanthophora spicifera*).

The measuring stick was partitioned into ten, 5 cm increments. Coral and algae data was categorized into four separate cover classes accumulated across the stick (Table 1). If live coral was visible beneath the algae, it was recorded. Therefore, it was possible to have greater than 100% accumulative cover of benthic types. In addition, the presence of large coral heads (coral colony > 160 cm) was noted (yes/no) if the stick lay above one.

Table 1. Cover classification for the snap-assessment survey. Cover was accumulated across the 50 cm survey stick for each cover category. Cover code was recorded on the datasheet for each associated percent cover class.

Percent cover	Length	Cover Code
0%	0 cm	0
1-10%	0.1-5 cm	1
11-50%	5-25 cm	2
51-100%	25-50 cm	3

Ease of mechanical removal of *Eucheuma/Kappaphycus* was also estimated ("1" easy, "2" moderate, "3" difficult). This measurement was a qualitative assessment of the area visible around the surveyor and not limited to the survey stick. Ease of removal could also be used as a presence/absence survey for *Eucheuma* and *Kappaphycus*. "3" was defined as a site with multiple algae attachment points, algae growing within rubble, or growing within coral branches. "1" was defined as a site with few attachment points, growing on solid dead coral substrate and dislodges easily. "2" would have qualities in between easy and difficult. Surveyors also recorded the presence of coral species uncommon in Kāne`ohe Bay and took photographs of each patch reef to document the various reef characteristics and habitat features.

Reef flat depth was estimated by taking an average of 20 depth measurements across the reef flat. Depth measurements were averaged for each reef and then standardized to mean lower low water (MLLW) using NOAA historical tide charts.

Data Management and Mapping

GPS latitude and longitude locations were downloaded and associated survey data entered. The resulting dataset was, checked for errors, compiled in an MS Access database, and exported to an ArcGIS geodatabase. Coral, *Eucheuma/Kappaphycus*, *Gracilaria/Acanthophora*, ease of removal, and habitat type were mapped using ArcGIS software for each reef. Interpolated raster coverage maps of the reef were created using the ArcGIS inverse distance weighting (IDW) tool, which averages each 1 m^2 pixel based on the 12 closest surrounding survey data points. Refer to Appendix A for individual reef coverage maps.

Data Summaries

Reef coverage was used to estimate percent cover and area of coral and invasive algae for each patch reef surveyed. Percent cover was estimated by multiplying the area estimated by the IDW interpolation of each cover class (0%, 1%, 1-10%, 11-50%, 51-100%) times the low (1, 11, 51%), median (5, 20, 75%), and high (10, 50, 100%) coral cover class and then dividing by the total reef area. In addition, algal removal planning information was estimated including reef area, supersucker algal removal time, and urchin stocking levels. Reef area was estimated based on the survey area.

Management Prioritization

An ArcGIS based decision-support tool, Weighted Overlay Tool, was used to prioritize reefs in order to select patch reefs with a high co-occurrence of coral and *Eucheuma/Kappaphycus*. Interpolated coverage maps were added into the model as equal influence factors. Percent cover categories are summarized in Table 2. Every square meter of patch reef was assigned a priority value based on the co-occurrence of coral and *Eucheuma/Kappaphycus* influence factors.

Table 2. Influence factors inputted into the Weighted Overlay Model.

Influence Factor	Percent Cover
low priority	0%
low/medium priority	1-10%
medium/high priority	11-50%
high priority	51-100%

Prioritization of reefs was carried out by comparing the relative proportion of medium/high and high priority area of each reef and ranking the reefs accordingly, from high to low priority. Maps were examined with coral and *Eucheuma/Kappaphycus* maps to evaluate the accuracy of the Weighted Overlay Tool prioritization model.

Survey Error Determination /Map Coverage Overlay Analysis

Three reefs (Reefs 19, 23, 26) were randomly selected to re-survey within two-weeks of the initial survey in order to evaluate the repeatability of the survey and ground truth the ArcGIS interpolated coverage maps. Estimates of percent coral and algae coverage were compared between survey 1 and survey 2 to estimate survey error. Map coverage errors were assessed by overlaying interpolated map coverages for each reef and species coverage. The raster calculator was used to evaluate how well the coverage maps between survey 1 and 2 matched.

Results

Coral Cover

Forty-one patch reefs were surveyed from February-April 2014 and over 14,000 data points were collected. Coral cover was variable throughout the bay and ranged from 75% to 12 % (Table 3, Figure 3, Appendix A). Reefs 19 and 21 had the highest proportion of coral cover. The total estimated coral area was 263,069 m^2 (range: 170,877 to 397,720 m^2) of patch reefs surveyed.

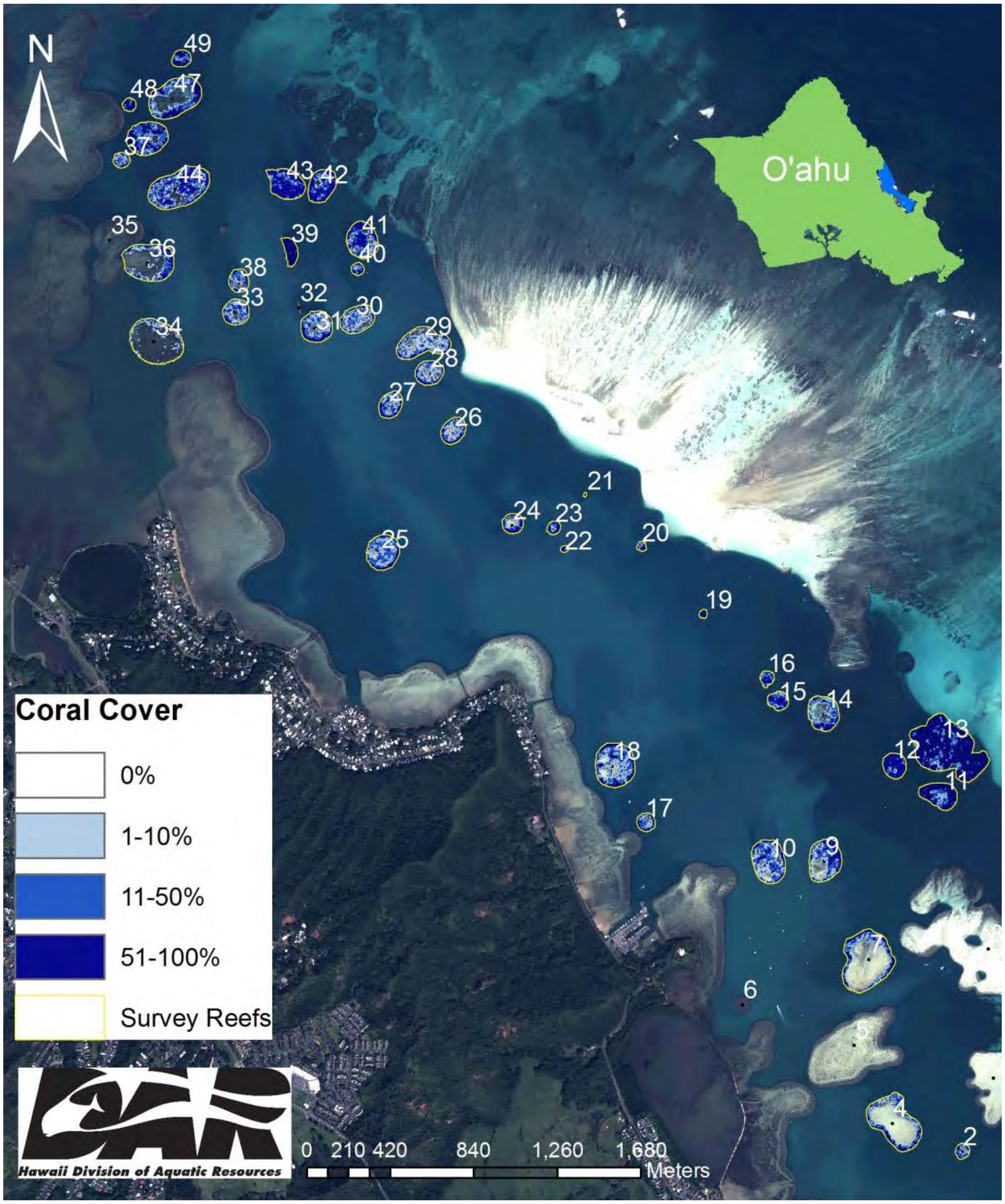


Figure 3. Kāne`ohe Bay coral cover distribution of surveyed reefs. Reefs outlined in yellow were surveyed as part of the snap assessment. Refer to Appendix A for higher resolution, individual reef coverage maps.

Table 3. Coral cover, *Eucheuma/Kappaphycus* (Ed/Ks), *Gracilaria/Acanthophora* (Gs/As), Percent of reef classified as high priority, prioritization rank, and mitigation bank designation of surveyed patch reefs in Kāne`ohe , Oahu. Percent cover is reported as median

REEF	AREA (m^2)	Coral Cover	Ed/Ks Cover	Gs/As Cover	% High Priority	Rank
2	4,472	27.5% (range: 17.11 to 47.64%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31
4	48,488	12.69% (range: 7.87 to 21.62%)	0.41% (range: 0.23 to 0.78%)	0.27% (range: 0.09 to 0.55%)	0.00	31
7	60,940	12.07% (range: 7.61 to 19.4%)	0.74% (range: 0.33 to 1.53%)	4.99% (range: 2.56 to 9.59%)	1.88	23
9	28,343	43.43% (range: 28.81 to 62.42%)	11.54% (range: 6.93 to 20.08%)	3.48% (range: 1.88 to 6.63%)	55.70	5
10	30,098	45.48% (range: 29.82 to 68%)	14.41% (range: 8.64 to 25.84%)	3.08% (range: 1.57 to 6.13%)	59.73	4
11	19,170	56.24% (range: 37.53 to 79.62%)	0.05% (range: 0.02 to 0.11%)	0% (range: 0 to 0%)	0.55	27
12	11,854	64.77% (range: 43.65 to 89.19%)	0.02% (range: 0 to 0.04%)	0% (range: 0 to 0%)	1.85	24
13	79,618	63.56% (range: 42.79 to 87.88%)	0.18% (range: 0.08 to 0.36%)	0% (range: 0 to 0%)	0.02	31
14	22,122	21.77% (range: 13.68 to 35.23%)	11.4% (range: 6.74 to 21.2%)	3.42% (range: 1.55 to 7.35%)	43.51	6
15	7,732	42.31% (range: 27.6 to 64.27%)	12.7% (range: 6.97 to 25.81%)	0.01% (range: 0 to 0.02%)	72.05	2
16	4,303	41.02% (range: 26.62 to 63.24%)	10.16% (range: 5.34 to 20.66%)	0% (range: 0 to 0%)	71.51	3
17	6,881	32.67% (range: 20.81 to 51.7%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31
18	36,495	25.26% (range: 15.76 to 41.43%)	0.58% (range: 0.23 to 1.21%)	1.98% (range: 1.06 to 3.8%)	1.66	25
19	1,023	75% (range: 51 to 100%)	21.02% (range: 12.44 to 38.74%)	0% (range: 0 to 0%)	100.00	1
20	1,855	45.98% (range: 30.48 to 66.22%)	1.9% (range: 0.77 to 4.09%)	0.01% (range: 0 to 0.02%)	32.02	10
21	271	74.59% (range: 50.7 to 99.63%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31
22	1,016	70.74% (range: 47.95 to 95.44%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31
23	3,119	47.28% (range: 31.11 to 70.03%)	4.35% (range: 2.27 to 8.22%)	0% (range: 0 to 0%)	41.30	7
24	8,258	35.35% (range: 23.27 to 51.55%)	0.59% (range: 0.26 to 1.19%)	0.44% (range: 0.17 to 0.95%)	10.39	16
25	23,331	24.07% (range: 14.54 to 43.33%)	0% (range: 0 to 0.01%)	0.02% (range: 0 to 0.04%)	0.00	31
26	12,338	24.93% (range: 15.56 to 40.35%)	0.19% (range: 0.06 to 0.42%)	1.04% (range: 0.53 to 2.02%)	3.78	20
27	12,345	31.26% (range: 19.75 to 50.54%)	0.14% (range: 0.04 to 0.3%)	0.03% (range: 0.01 to 0.08%)	4.03	19
28	13,974	24.89% (range: 15.49 to 40.24%)	0.56% (range: 0.2 to 1.18%)	3.3% (range: 1.56 to 7.32%)	10.61	15
29	29,773	16.87% (range: 9.9 to 29.59%)	1.78% (range: 0.73 to 3.73%)	1.13% (range: 0.49 to 2.36%)	8.25	17
30	18,949	18.21% (range: 10.91 to 31.31%)	7.48% (range: 3.85 to 15.13%)	0% (range: 0 to 0%)	29.60	11
31	20,742	28.26% (range: 17.89 to 44.56%)	0.39% (range: 0.14 to 0.82%)	0.04% (range: 0.01 to 0.1%)	5.18	18
33	14,051	23.31% (range: 14.26 to 40.02%)	0.07% (range: 0.02 to 0.16%)	0.28% (range: 0.09 to 0.61%)	0.54	28
34	49,872	5.53% (range: 3.26 to 9.55%)	0.03% (range: 0.01 to 0.07%)	15.67% (range: 9.4 to 27.46%)	0.10	30
36	40,612	15.55% (range: 9.79 to 25.09%)	0.03% (range: 0.01 to 0.06%)	3.02% (range: 1.41 to 6.33%)	0.47	29
37	5,193	28% (range: 17.42 to 46.32%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31
38	8,658	27.85% (range: 17.55 to 45.51%)	6% (range: 2.92 to 12.62%)	0.97% (range: 0.4 to 2.14%)	38.83	8
39	7,848	72.4% (range: 49.12 to 97.41%)	0.23% (range: 0.06 to 0.49%)	0% (range: 0 to 0%)	3.30	21
40	3,228	44.43% (range: 29.06 to 66.45%)	2.67% (range: 1.1 to 5.96%)	0% (range: 0 to 0%)	23.14	12
41	23,100	38.87% (range: 25.33 to 58.29%)	7.13% (range: 3.79 to 14.27%)	0.15% (range: 0.05 to 0.34%)	37.64	9
42	17,693	49.12% (range: 32.51 to 71.36%)	0.08% (range: 0.02 to 0.19%)	0% (range: 0 to 0%)	1.31	26
43	21,852	57.41% (range: 38.35 to 81.43%)	0.41% (range: 0.11 to 0.87%)	0% (range: 0 to 0%)	13.58	14
44	47,068	33.02% (range: 21.2 to 51.44%)	2.22% (range: 1.04 to 4.63%)	0.02% (range: 0.01 to 0.04%)	13.95	13
46	27,388	38.75% (range: 25.05 to 60.88%)	0% (range: 0 to 0%)	1.69% (range: 0.78 to 3.54%)	0.00	31
47	40,381	23.19% (range: 14.82 to 36.56%)	0% (range: 0 to 0%)	0.3% (range: 0.11 to 0.63%)	0.00	31
48	3,593	59.17% (range: 39.56 to 84.06%)	0% (range: 0 to 0%)	0% (range: 0 to 0%)	0.00	31
49	6,480	53.42% (range: 35.43 to 77.58%)	0.19% (range: 0.06 to 0.42%)	0% (range: 0 to 0%)	2.50	22

***Eucheuma/Kappaphycus* Cover**

Eucheuma/Kappaphycus was distributed throughout patch reefs of varying covers ranging from 21 to 0% (Table 3, Figure 4, Appendix A). Reefs 19 and 10 had the highest proportion of *Eucheuma/Kappaphycus* cover. Eucheuma/Kappaphycus was estimated to cover 18,616 m^2 (range: 10,239 to 35,470 m^2) of patch reef habitat in the bay.

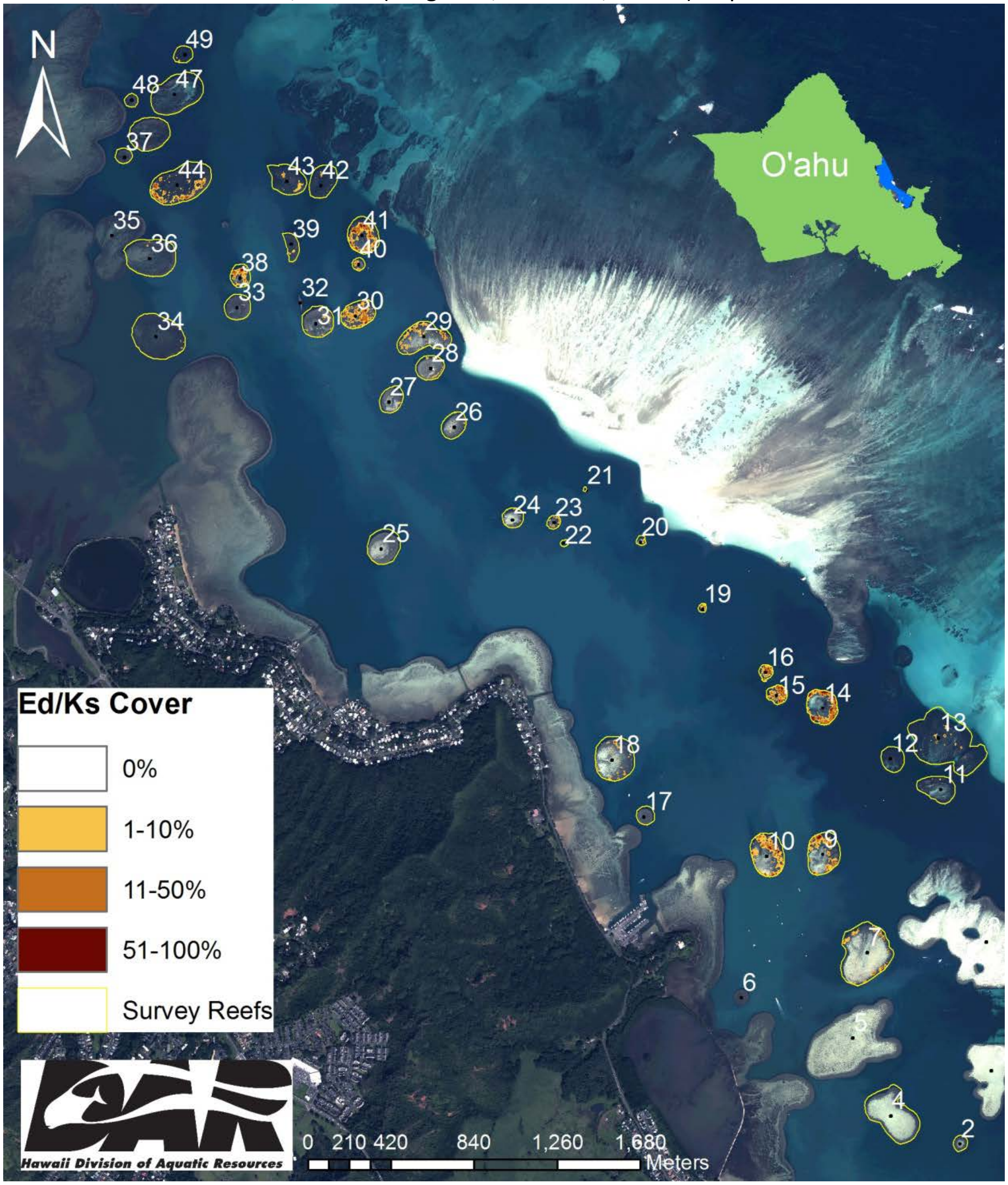


Figure 4. Kāne`ohe Bay Eucheuma/Kappaphycus cover distribution of surveyed reefs. Reefs outlined in yellow were surveyed as part of the snap assessment. Refer to Appendix A for higher resolution, individual reef coverage maps.

Gracilaria/Acanthophora Cover

Gracilaria/Acanthophora cover was distributed throughout the bay and ranged from 15.7 to 0% on patch reefs surveyed (Table 3, Figure 5, Appendix A). Reef 34 had the greatest *Gracilaria/Acanthophora* cover of patch reefs surveyed. *Gracilaria/*Acanthophora was estimated to cover 17,227 m2 (range: 9,368 to 32,800 m2) of patch reef habitats surveyed.

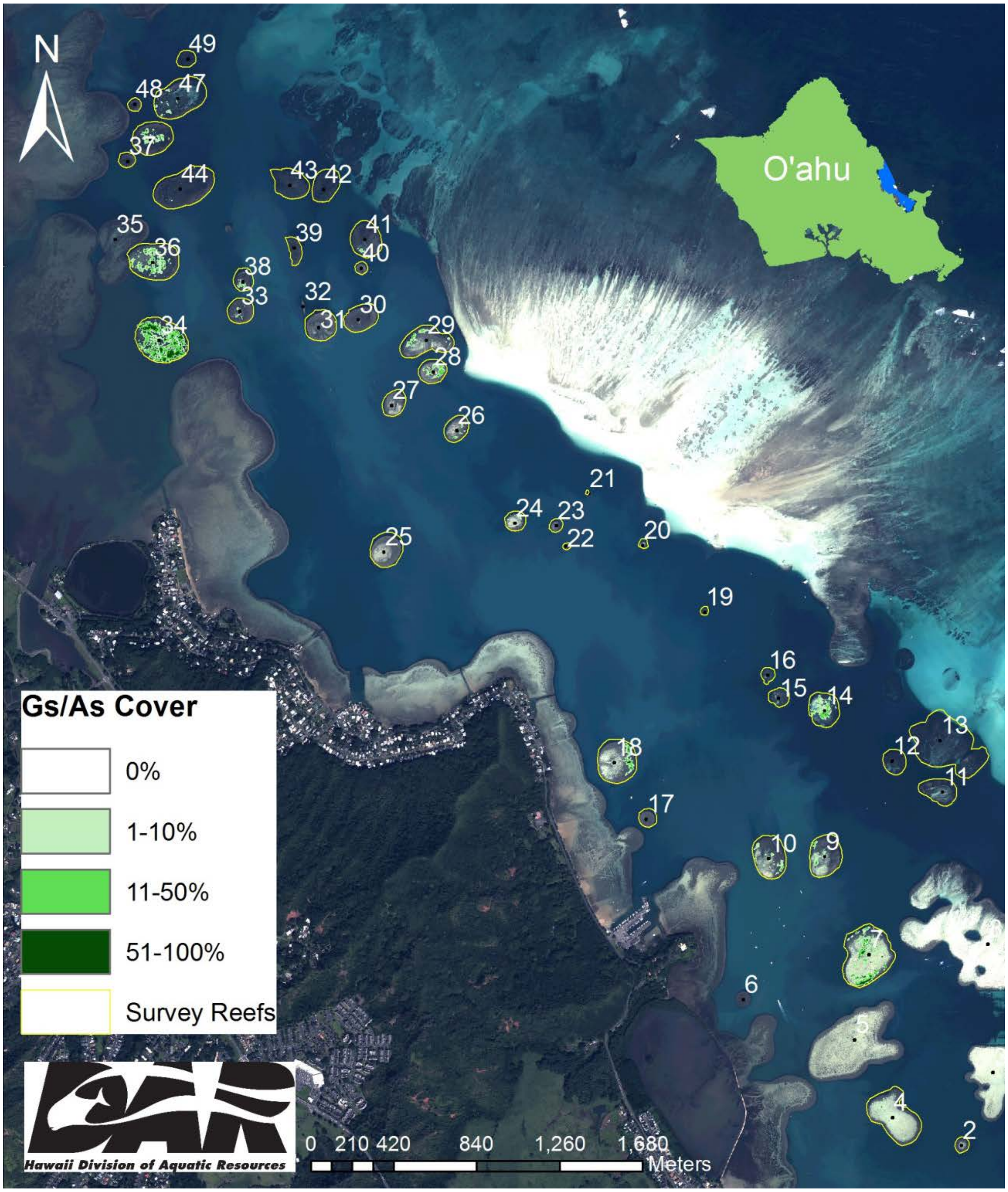


Figure 5. Kāne`ohe Bay *Gracilaria/Acanthophora* cover distribution of surveyed reefs. Reefs outlined in yellow were surveyed as part of the snap assessment. Refer to Appendix A for higher resolution, individual reef coverage maps.

Management Prioritization

Forty-one patch reefs were prioritized and ranked based on management need with the objective to target reefs with a high co-occurrence of coral and algae (Table 3, Figure 6, Appendix A). Prioritization was based on the proportion of co-occurrence of coral and *Eucheuma/Kappaphycus* (Figure 7). Patch reefs with high coral and high algae cover (Figure 7: left side of x-axis) were prioritized accordingly.

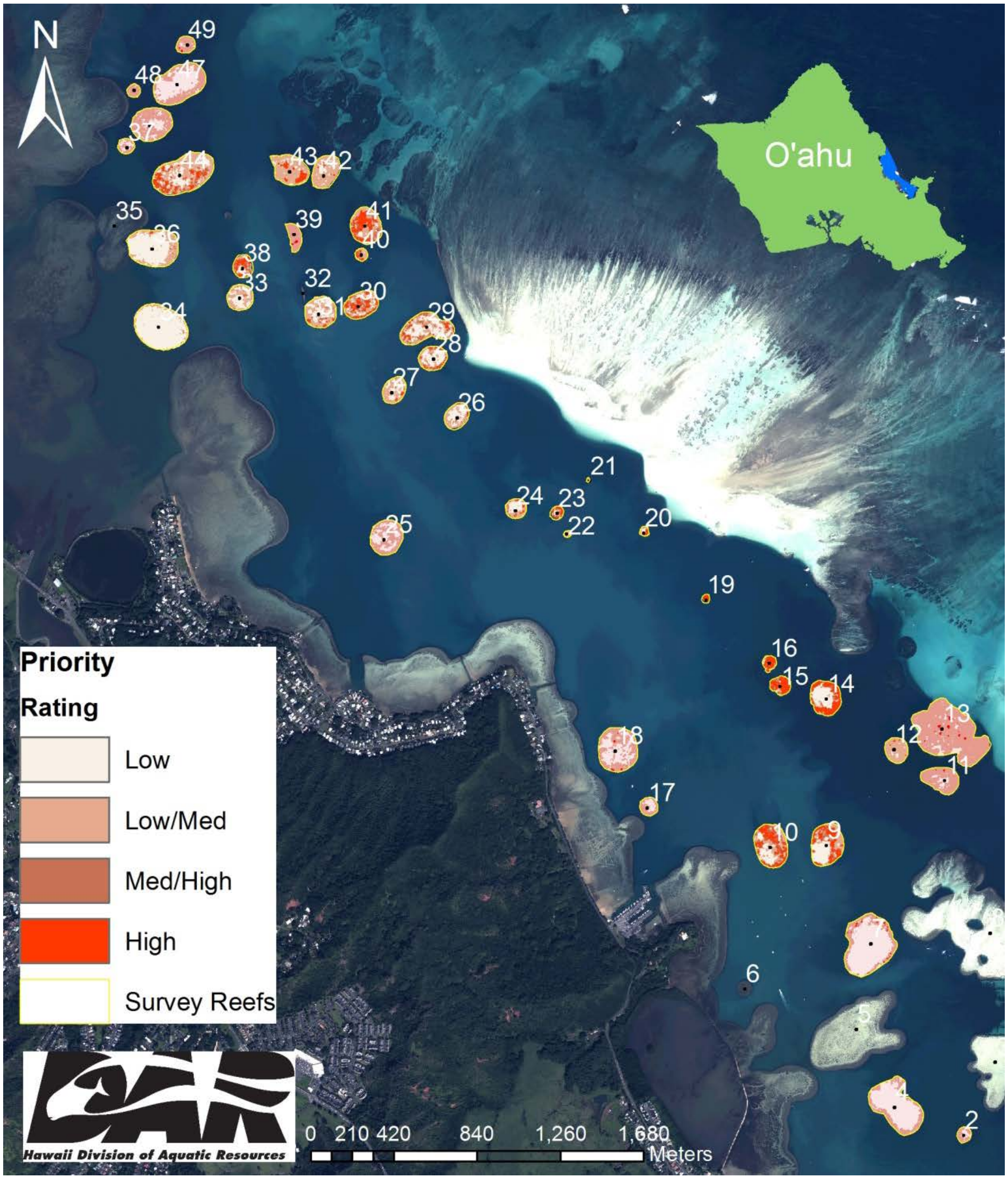


Figure 6. Management prioritization map of surveyed patch reefs. Darker shades of red represent high priority management areas. Lighter shades of red represent lower priority management areas. Reefs outlined in yellow were surveyed as part of the snap assessment.

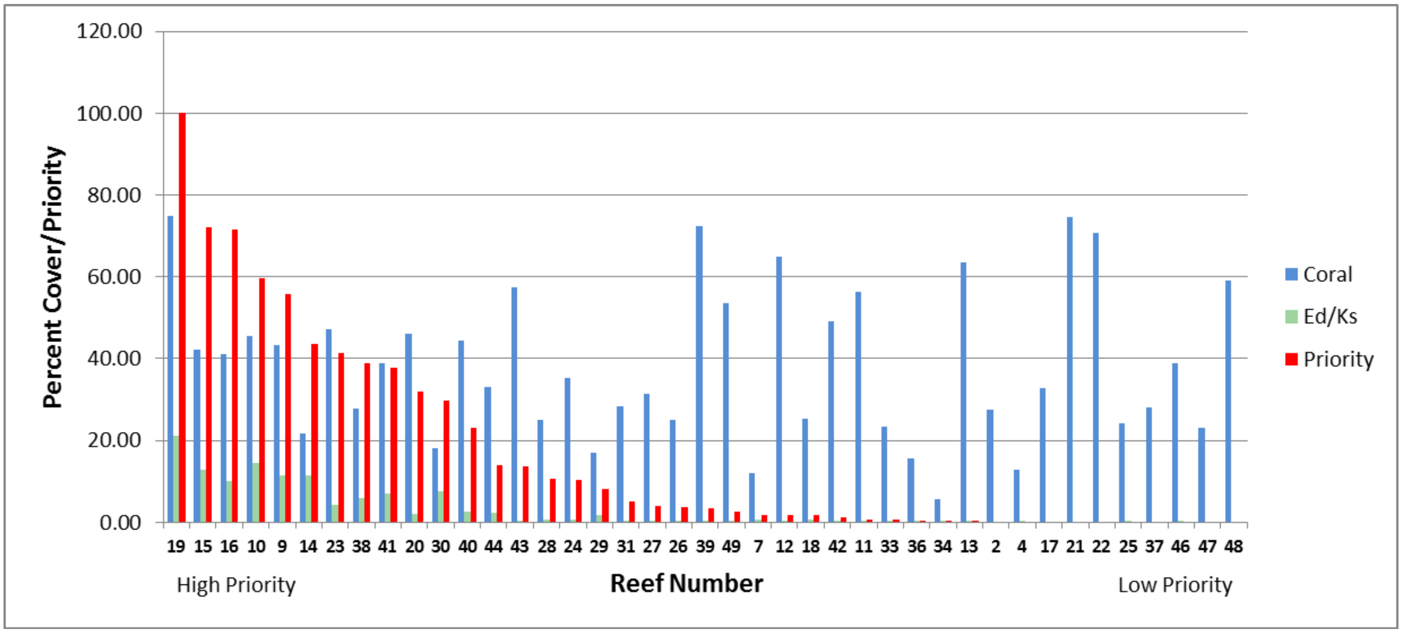


Figure 7. Percent priority, coral cover, and Eucheuma/Kappaphycus cover for patch reefs arranged from left to right along the x-axis according to reef prioritization.

Removal Planning

Reef rank, reef area, mitigation bank designation, algae removal time, urchin stocking density, and invasive algae cover were calculated as a planning tool for invasive algae management (Table 4).

Table 4. Invasive algae management planning table: reef number, reef prioritization rank, reef area, mitigation bank designation, time to remove algae, urchin stocking estimate, and percent cover of *Eucheuma/Kappaphycus* (Ed/Ks) and *Gracilaria/Acanthophora* (Gs/As).

REEF	Rank	AREA (m^2)	Designation	Removal Time (days)	Urchins (3/m^2)	% Ed/Ks	% Gs/As
19	1	1,023	Treatment	3	3,069	21.02	0.00
15	2	7,732	Treatment	19	23,196	12.70	0.01
16	3	4,303	Treatment	11	12,909	10.16	0.00
10	4	30,098	Treatment	75	90,294	14.41	3.08
9	5	28,343	Control	71	85,029	11.54	3.48
14	6	22,122	Control	55	66,366	11.40	3.42
23	7	3,119	Control	8	9,357	4.35	0.00
38	8	8,658		22	25,974	6.00	0.97
41	9	23,100		58	69,300	7.13	0.15
20	10	1,855		5	5,565	1.90	0.01
30	11	18,949		47	56,847	7.48	0.00
40	12	3,228		8	9,684	2.67	0.00
44	13	47,068		118	141,204	2.22	0.02
43	14	21,852		55	65,556	0.41	0.00
28	15	13,974	Control	35	41,922	0.56	3.30
24	16	8,258		21	24,774	0.59	0.44
29	17	29,773		74	89,319	1.78	1.13
31	18	20,742		52	62,226	0.39	0.04
27	19	12,345		31	37,035	0.14	0.03
26	20	12,338		31	37,014	0.19	1.04
39	21	7,848		20	23,544	0.23	0.00
49	22	6,480		16	19,440	0.19	0.00
7	23	60,940		152	182,820	0.74	4.99
12	24	11,854	Reference	30	35,562	0.02	0.00
18	25	36,495		91	109,485	0.58	1.98
42	26	17,693		44	53,079	0.08	0.00
11	27	19,170		48	57,510	0.05	0.00
33	28	14,051	Reference	35	42,153	0.07	0.28
36	29	40,612		102	121,836	0.03	3.02
34	30	49,872		125	149,616	0.03	15.67
4	31	48,488		121	145,464	0.41	0.27
13	31	79,618		199	238,854	0.18	0.00
25	31	23,331		N/A	69,993	0.00	0.02
46	31	27,388		N/A	82,164	0.00	1.69
47	31	40,381		N/A	121,143	0.00	0.30
2	N/A	4,472		N/A	N/A	0.00	0.00
17	N/A	6,881		N/A	N/A	0.00	0.00
21	N/A	271		N/A	N/A	0.00	0.00
22	N/A	1,016	Reference	N/A	N/A	0.00	0.00
37	N/A	5,193		N/A	N/A	0.00	0.00
48	N/A	3,593		N/A	N/A	0.00	0.00

Removal time was estimated at 400 m^2/day, for a 4-person supersucker crew. Biocontrol estimates were based on stocking three hatchery raised *Tripneustes gratilla* per m^2 of reef.

Survey Error Determination

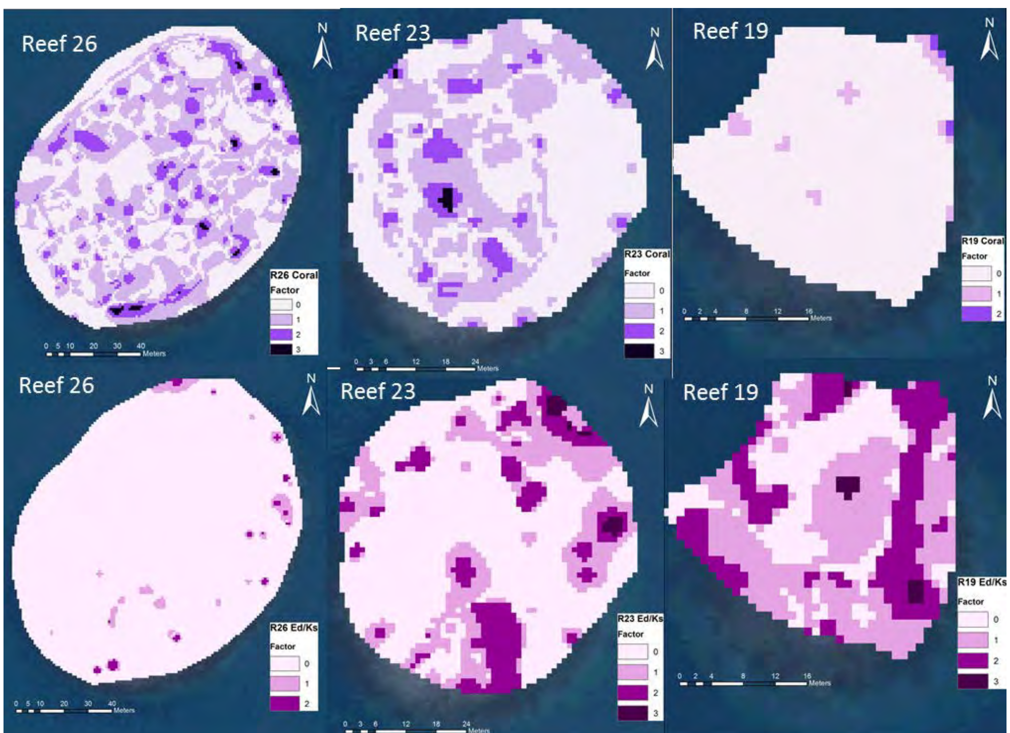
Mean differences in percent cover between repeated surveys 1 and 2 were within 2.25% for coral and 4.82% for *Eucheuma/Kappaphycus* (Table 5). Mean *Gracilaria/Acanthophora* cover differed by less than 1%, however *Gracilaria/Acanthophora* was only detected on Reef 26 which prevented comparison on Reefs 19 and 23.

Table 5. Mean differences of reef estimates of percent coral, Eucheuma/Kappaphycus, Gracilaria/Acanthophora between surveys 1 and survey 2.

Species	Mean difference %	S.E. %	Range %
Coral	2.25	0.67	(1.36-3.56)
Ed/Ks	4.82	3.82	(0.10-11.91)
Gs/As	0.89*	N/A	N/A

Map Coverage Overlay Analysis

Coral, *Eucheuma/Kappaphycus, and Acanthophora/Gracilaria* map coverages showed very similar results between repeated surveys 1 and 2. The majority of reefs re-surveyed in all species differed by one cover class factor or less (Figure 8, Table 6). Reef 26 coral cover classification matched on 46% of the reef area and differed by a factor of one cover class on 44% of the reef area.



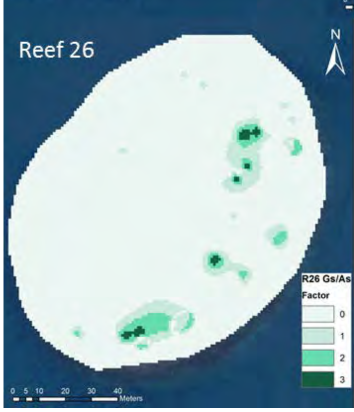


Figure 8. Overlay analysis of three reefs re-surveyed (survey 1 and survey 2). Coral and algae interpolated coverage maps were overlaid to analyze the difference of percent cover classification between survey 1 and survey 2. Lighter colors illustrate greater similarity between surveys 1 and 2. Darker colors (factors) represent the magnitude of the difference in cover class delineation of the reef (e.g. If survey 1 delineated 1 m2 as 10% cover class and survey 2 delineated the same 1 m2 as 11-50% cover class; the above map would display a 1 factor difference between surveys). *Gracilaria/Acanthophora* was not detected on reefs 19 and 23.

Table 6. Overlay analysis of survey 1 and survey 2 of Reefs 19, 23, and 26 interpolated cover classes of coral, *Eucheuma/Kappaphycus* (Ed/Ks), and *Gracilaria/Acanthophora* (Gs/As). The percent match of four cover classes was evaluated (0%, 1-10%, 11-50%, 51-100%). A factor of "0" represents a 100% match between cover classes in a particular area, a factor of "1" differs by one cover class, a factor of "2" differs by two cover classes, etc. *Gracilaria/Acanthophora* was not detected on reefs 19 and 23 in survey 1 or survey 2.

Reef	Species	Factor	% Match	Reef	Species	Factor	% Match	Reef	Species	Factor	% Match
Reef 19	Coral	0	95.76	Reef 19	Ed/Ks	0	27.50	Reef 19	Gs/As	0	100.00
Reef 19	Coral	1	3.70	Reef 19	Ed/Ks	1	45.11	Reef 19	Gs/As	1	0.00
Reef 19	Coral	2	0.54	Reef 19	Ed/Ks	2	25.76	Reef 19	Gs/As	2	0.00
Reef 19	Coral	3	0.00	Reef 19	Ed/Ks	3	1.63	Reef 19	Gs/As	3	0.00
Reef 23	Coral	0	58.49	Reef 23	Ed/Ks	0	61.99	Reef 23	Gs/As	0	100.00
Reef 23	Coral	1	35.90	Reef 23	Ed/Ks	1	23.59	Reef 23	Gs/As	1	0.00
Reef 23	Coral	2	6.92	Reef 23	Ed/Ks	2	13.33	Reef 23	Gs/As	2	0.00
Reef 23	Coral	3	0.41	Reef 23	Ed/Ks	3	1.10	Reef 23	Gs/As	3	0.00
Reef 26	Coral	0	46.20	Reef 26	Ed/Ks	0	96.78	Reef 26	Gs/As	0	91.71
Reef 26	Coral	1	43.76	Reef 26	Ed/Ks	1	2.54	Reef 26	Gs/As	1	5.50
Reef 26	Coral	2	9.33	Reef 26	Ed/Ks	2	0.68	Reef 26	Gs/As	2	2.23
Reef 26	Coral	3	0.70	Reef 26	Ed/Ks	3	0.00	Reef 26	Gs/As	3	0.55

Reef Depth

Reef flat depth ranged from 5.79 cm (reef 33) to 71 cm (reef 14) (Figure 9).

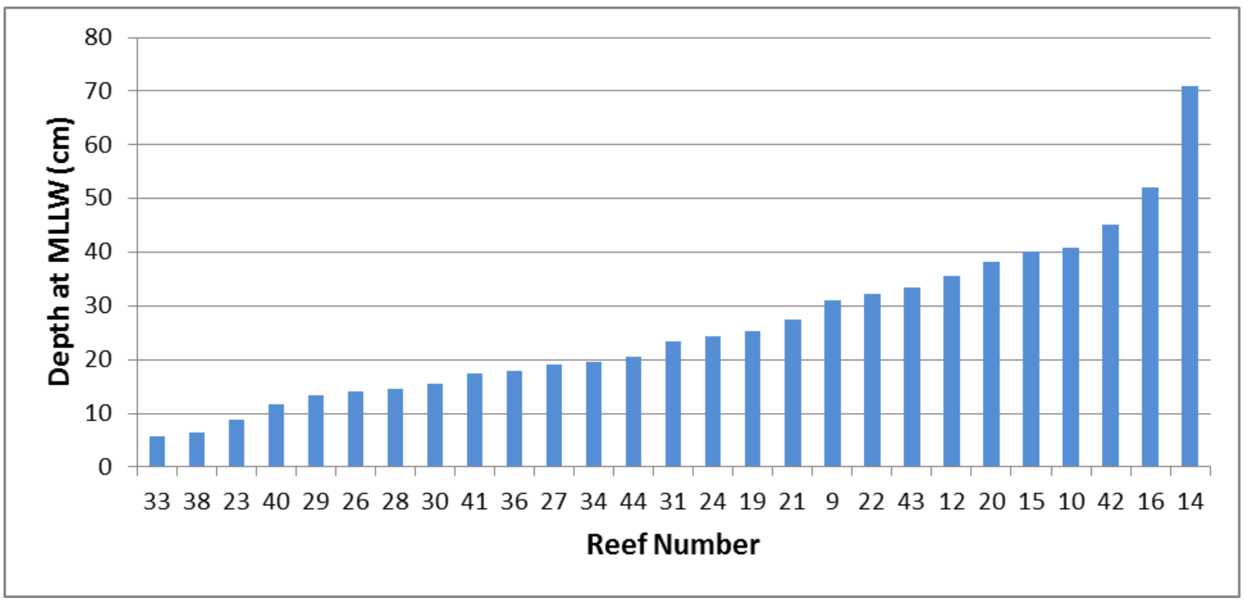


Figure 9. Reef flat depth (cm) at mean lowest low water (MLLW) at 27 Kāne`ohe Bay patch reefs. Reef numbers on the x-axis are arranged from low to high reef flat depth.

Uncommon Coral Species

Three uncommon coral species to Kāne`ohe Bay: *Montipora dilatata, Montipora patula, and Montipora flabellate;* were detected in the surveys (Table 7).

Table 7. Uncommon coral species observed in Kāne`ohe Bay snap-assessment surveys.

Reef #	*M. patula*	*M. flabellata*	*M. dilatata*
10		X	
11	X	X	
12		X	
13	X	X	
14	X	X	
26	X		
27	X		
31		X	
37	X		
42	X	X	
44	X	X	X
46	X	X	
47		X	
48	X		

Survey Effort

The snap assessment survey required approximately 300 man-hours plus additional data entry, data processing, mapping and analysis. The survey rate of the snap assessment was 3,500 m^2/hr per surveyor. The typical survey crew size was 6-people.

Discussion

Invasive algae Distribution

Invasive algae distribution was consistent with past studies, where *Kappaphycus/Eucheuma* and *G. salicornia* were found in varying densities throughout Kāne`ohe Bay (Smith et al. 2002, Conklin and Smith 2005). The Hawaii Division of Aquatic Resources (DAR) has sponsored numerous invasive algae surveys in Kāne`ohe Bay since 2007. Differing survey techniques prevented accurate comparison of percent cover with the snap-assessment data. Presence/absence, however, could be compared. Of the 41 patch reefs surveyed, one reef (Reef 49) was found to be newly colonized since the 2007 survey (DAR unpublished data). These surveys have also detected sparse densities of *Kappaphycus/Eucheuma* in northern Kāne`ohe Bay on Reefs 50, 52, 54 (2007) and Reefs 52, 54, the northern fringing reef and the north channel (2013) (unpublished DAR data).

Smith et al. (2002) invasive algae distribution surveys found *Kappaphycus spp*. had not spread outside of Kāne`ohe Bay. DAR surveys conducted in 2006, however, detected *Kappaphycus/Eucheuma* along the windward coast as far north as Punaluu; suggesting a northward spread (Gewecke 2008). Surveyors also found *Kappaphycus/Eucheuma* near Alii Beach Park, Haleiwa in 2013 (Stubbs et al. 2013). This population may have spread from fragments released by boats launched at Haleiwa Boat Harbor. Continued snap assessment surveys in northern Kāne`ohe Bay and along the windward coast could assess the current level of spread outside of the bay.

Mitigation Bank Reef Selection

Based on the prioritization ranking results and snap assessment data; treatment, control, and reference reefs were selected for inclusion into the mitigation bank prospectus. Four reefs were selected for immediate invasive algae removal (19, 14, 16, and 10). In addition, three control reefs (9, 15, 23) were selected to monitor the effectiveness of invasive algae removal on the treatment reefs. These reefs were found to have similar coral, invasive algae, proximity, and size characteristics to the treatment reef. In addition reef 28 has historical survey data that will help contribute to long-term monitoring. Three reference sites (12, 17, and 22) had high coral cover and little or no invasive algae cover. These reefs were selected as reference sites to use as model systems for assessing post-restoration results. Undesignated reefs will likely be treated in the future based on prioritization rank and the size of the reef.

Snap Assessment Repeatability

The snap assessment surveys were designed to rapidly assess large reef areas in a short amount of time. Even though this method was rapid, our tests revealed that it was relatively robust and repeatable. The repeated survey results demonstrated adequate robustness for tracking changes in coral (± 2.5%) and invasive algae cover (± 5%) over time with use of the ArcGIS IDW interpolation tools. However, examination of the overlay analysis revealed that repeatability errors increased where gaps between survey points exceeded 10 m. Therefore, it is recommended that survey sample densities remain within 5-10 m apart.

Management Recommendations

The results of this survey should be used as a tool for developing a comprehensive invasive algae action plan for Kāne`ohe Bay. The invasive algae issue is a complex problem and will require a whole suite of strategies and techniques to control its spread and restore coral reef ecosystems. In addition to published research and management recommendations (Conklin and Smith 2005, Smith et al. 2002); staff from DAR, Research Corporation of the University of Hawaii, and The Nature Conservancy of Hawaii have informally discussed a number of strategies. These include:

- Target areas of high coral and high *Kappaphycus/Eucheuma* density.
- Target areas of low *Kappaphycus/Eucheuma* density and high coral density.
- Target northern incipient populations of *Kappaphycus/Eucheuma*.
- Reduce the overall standing stock and propagation of *Kappaphycus/Eucheuma* in Kāne`ohe Bay.
- Increase native herbivores in Kāne`ohe Bay.
- Monitor *Kappaphycus/Eucheuma* distribution.
- Conduct rapid response to areas outside of the bay, newly colonized by *Kappaphycus*.
- Reduce nutrification in Kāne`ohe Bay.
- Provide outreach and education to prevent the spread or introduction of invasive species.

The snap assessment data set and decision support tools used in this analysis could also be applied to several of the management objectives stated above. Our analysis selected mitigation bank reefs based on the objective to select areas of high co-occurrence of both coral and *Eucheuma/Kappaphycus*. Decision support tools could also be used to prioritize reefs based on high coral and low *Eucheuma/Kappaphycus* cover to prioritize efforts towards preventing *Eucheuma/Kappaphycus* spread where high coral coverage is at stake.

We also recommend that the snap assessment survey is repeated annually or bi-annually to track invasive algae and coral distribution trends and evaluate management techniques. In addition, patch reefs not included in this 2014 assessment, fringing reefs, and the barrier reef should also be surveyed. The snap assessment could also be applied to other coral reef habitats within the Hawaiian Islands. In addition to areas dominated by invasive algae; this technique could be applied to other at risk areas such as shipping channels (which are susceptible to ship groundings), coral disease outbreaks and coral bleaching sites.

Conclusions

This project successfully developed a rapid and robust coral reef monitoring techniques that can be applied to a large area in a fairly short amount of time. In addition, this dataset provides essential data and decision support tools for developing a bay-wide invasive algae action plan to guide future management efforts. Further, the survey results provide baseline information to compare, past, present, and future coral and invasive algae trends in Kāne`ohe Bay.

Acknowledgements

We would like to acknowledge the field survey team: Jono Blodgett, Cathy Gewecke, Brian Neilson, Andrew Purves, Brad Stubbs, Kendall Tejchma , and Travis Thyberg. We would like to thank The Nature Conservancy of Hawaii for their help in conducting the snap-assessment surveys. We would also like to thank Kate Cullison, David Gulko, Zac Forsman, Frazer McGilvray, and Kim Peyton for their contribution in developing the survey methodology.

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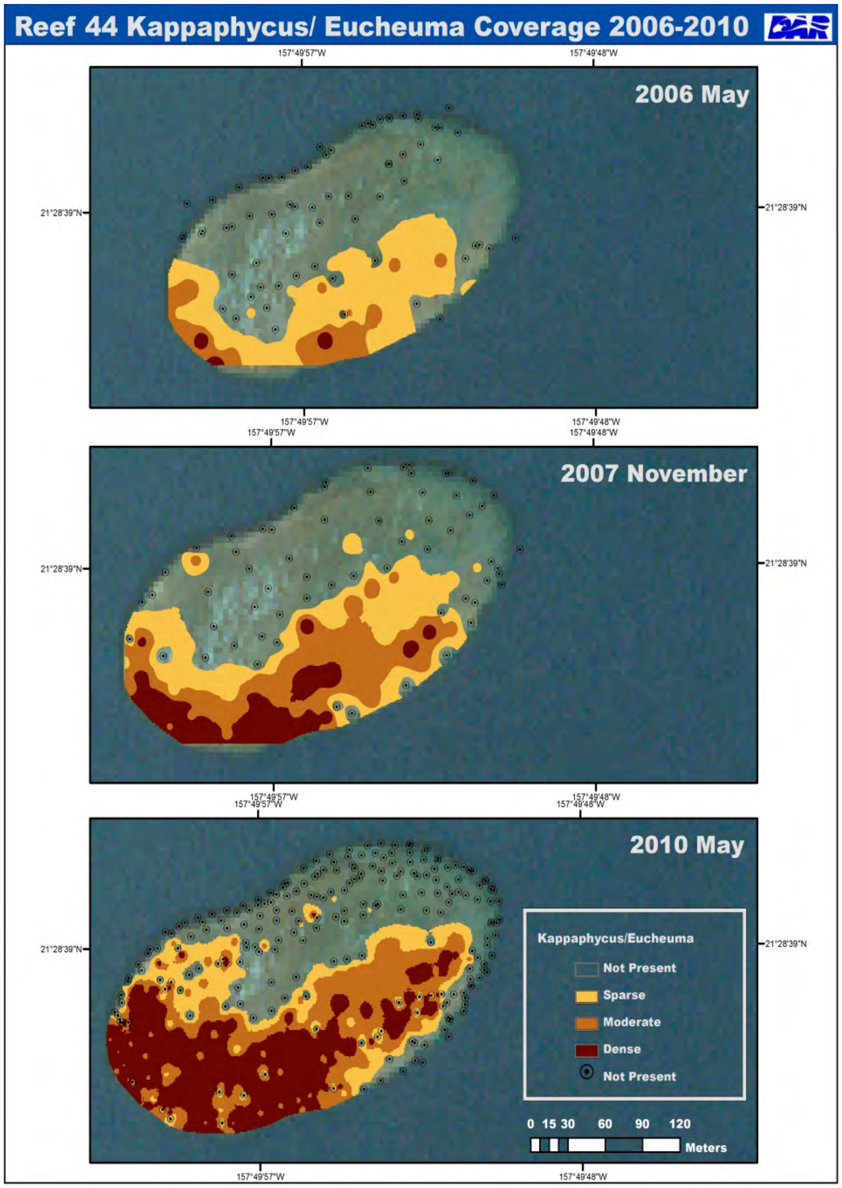
APPENDIX G

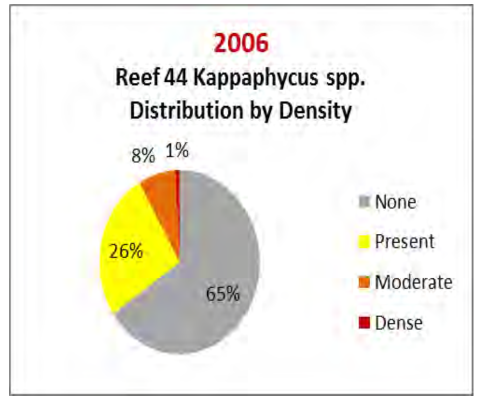
TRENDS OF INVASIVE ALGAE FOR FOUR PATCH REEFS IN KĀNE`OHE BAY

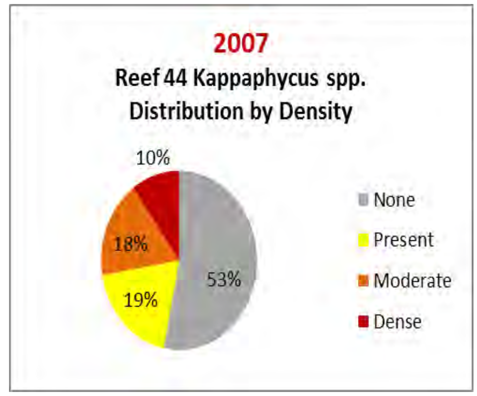
This appendix displays the data from reefs surveyed over multiple years to illustrate trends of algal abundance when the algae was left free to invade (reefs 44, 12) or controlled by removal (reefs 26,27).

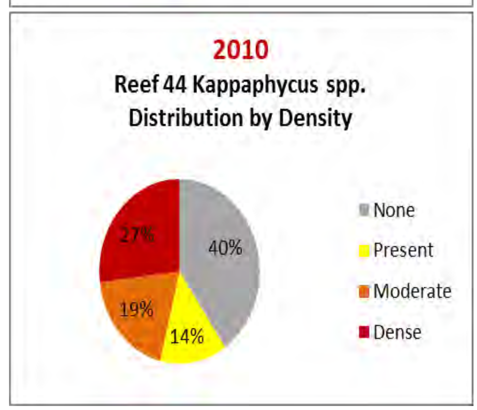
Reef #44 and Marker 12: Pages G-2, G-3. Both reefs, in the absence of any restoration treatment, show steady increase of invasive algae.

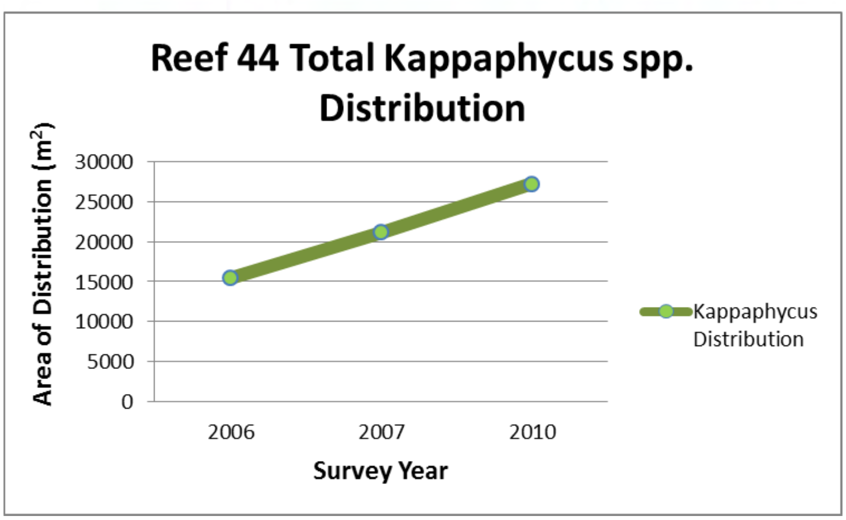
Reefs # 26, 27. Pages G-4, G-5. Both reefs have had restoration treatment, and show significant reduction of invasive algae.





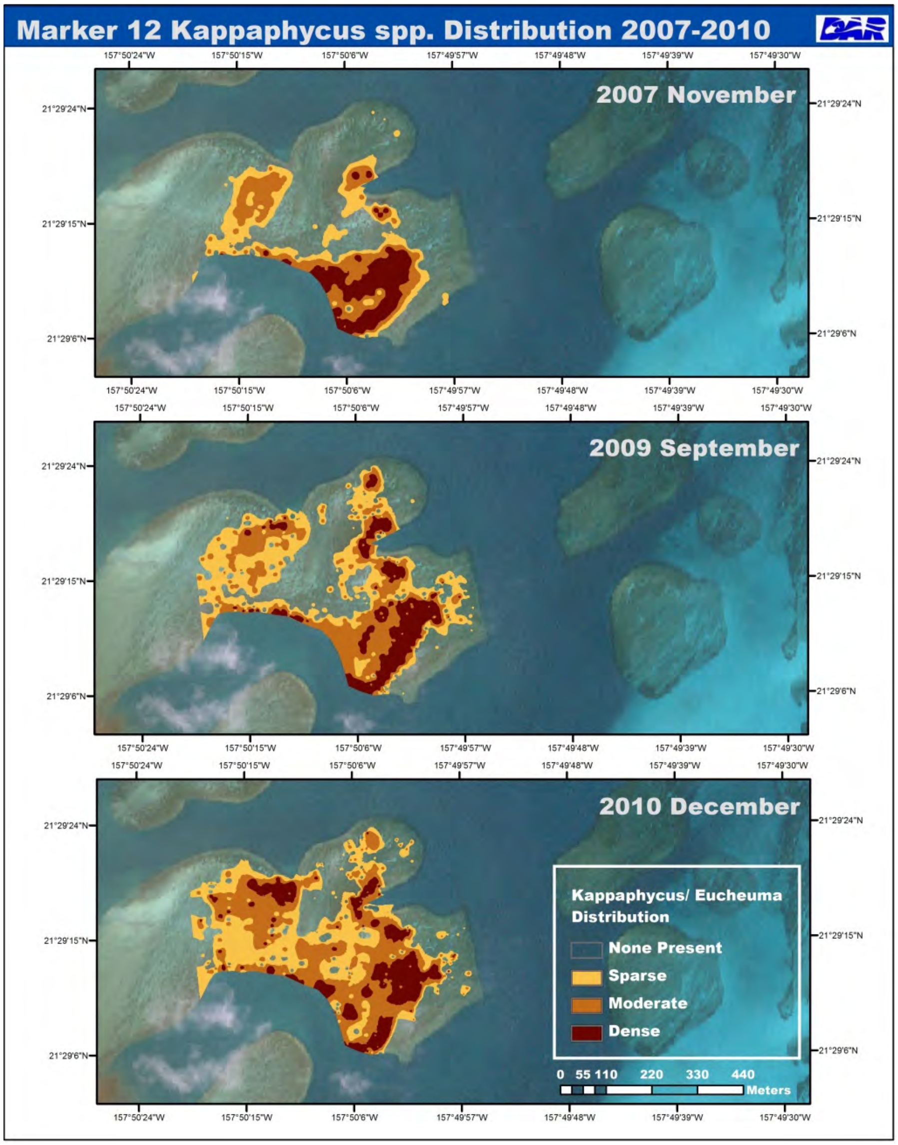


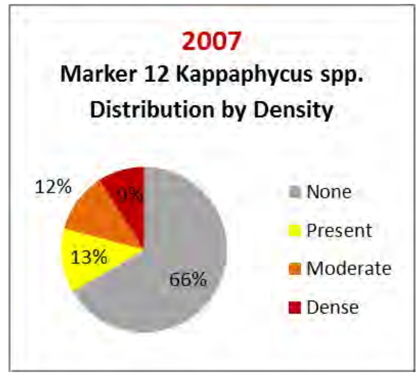


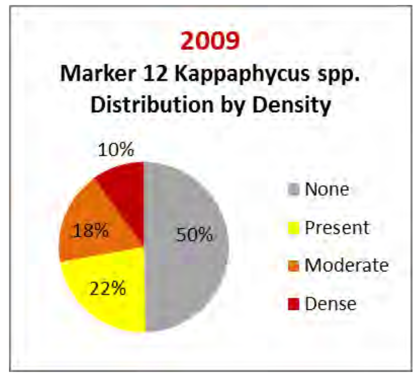


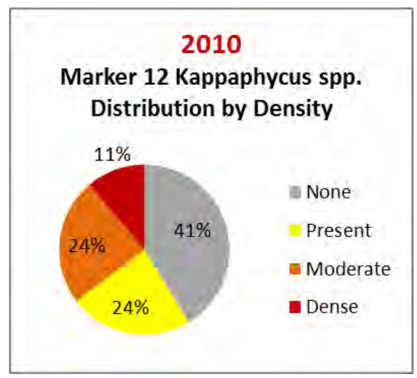
Reef 44	Distribution (m^2)		
Algal Density	**2006**	**2007**	**2010**
None	29,414	24,028	18,466
Present	11,649	8,652	6,160
Moderate	3,410	7,964	8,791
Dense	370	4,526	12,295

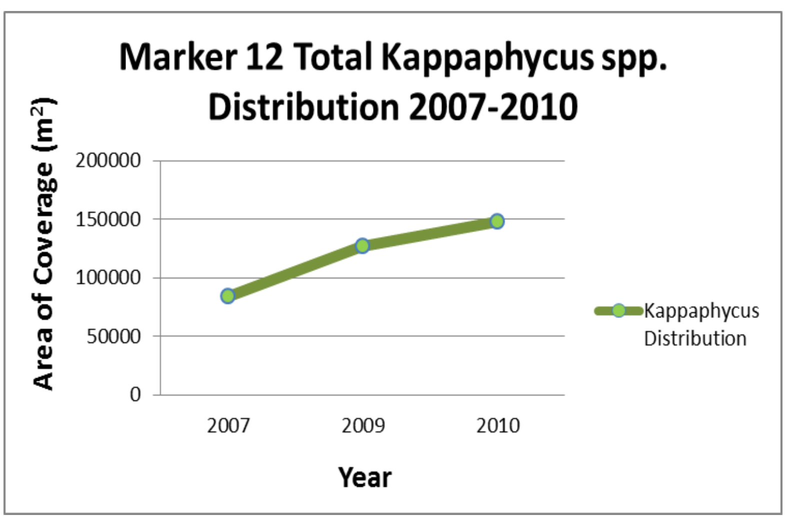
Reef 44	Percent of Reef Covered (%)		
Algal Density	**2006**	**2007**	**2010**
None	65%	53%	40%
Present	26%	19%	14%
Moderate	8%	18%	19%
Dense	1%	10%	27%





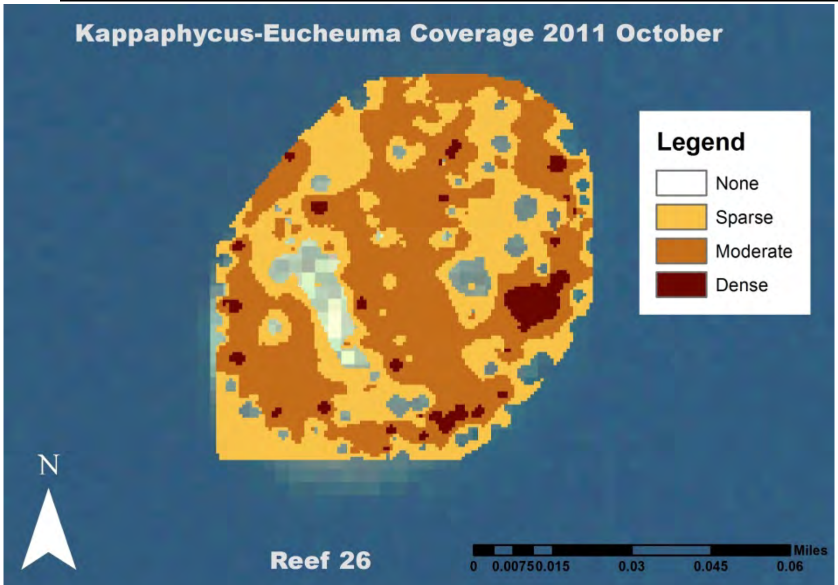


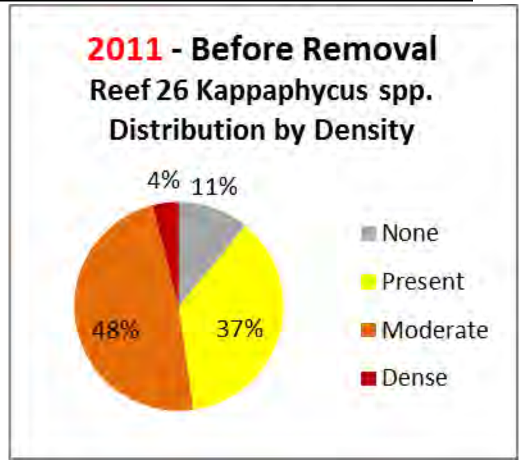


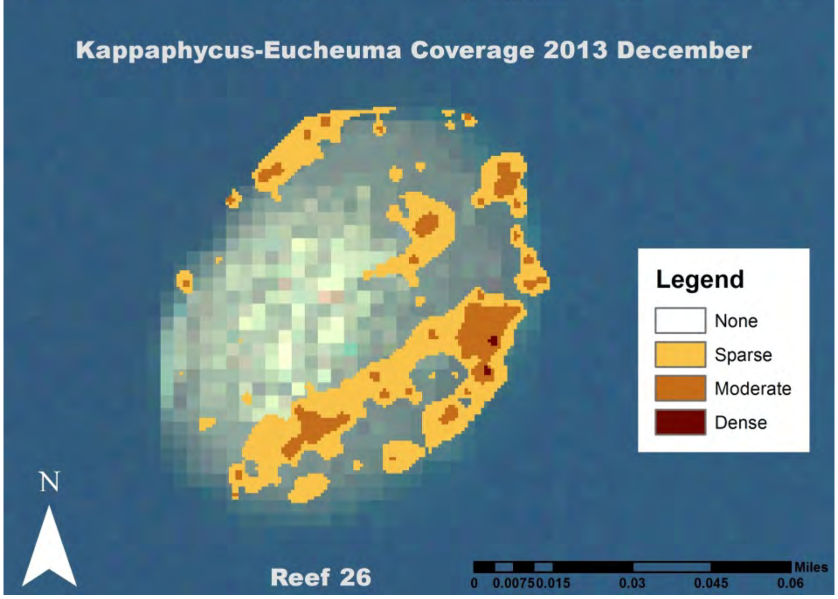


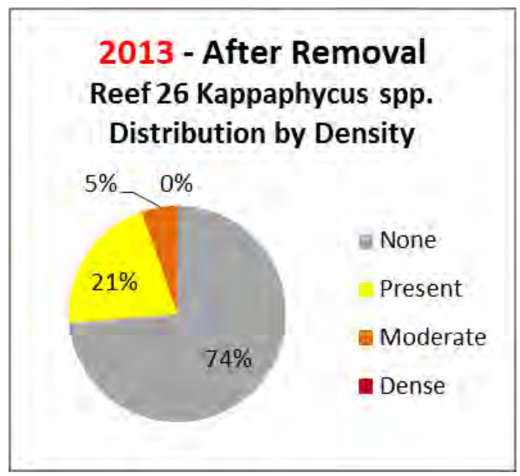
Marker 12	Distribution (m^2)		
Algal Density	2007	2009	2010
None	168,184	125,453	104,274
Present	31,755	57,009	59,039
Moderate	29,685	44,952	61,235
Dense	23,025	25,235	28,101

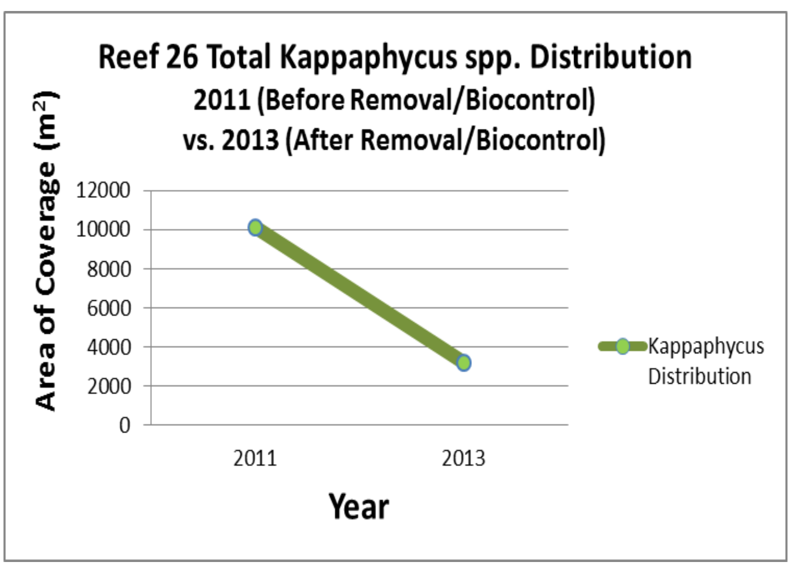
Marker 12	Percent of Reef Covered (%)		
Algal Density	2007	2009	2010
None	66%	50%	41%
Present	13%	22%	24%
Moderate	12%	18%	24%
Dense	9%	10%	11%





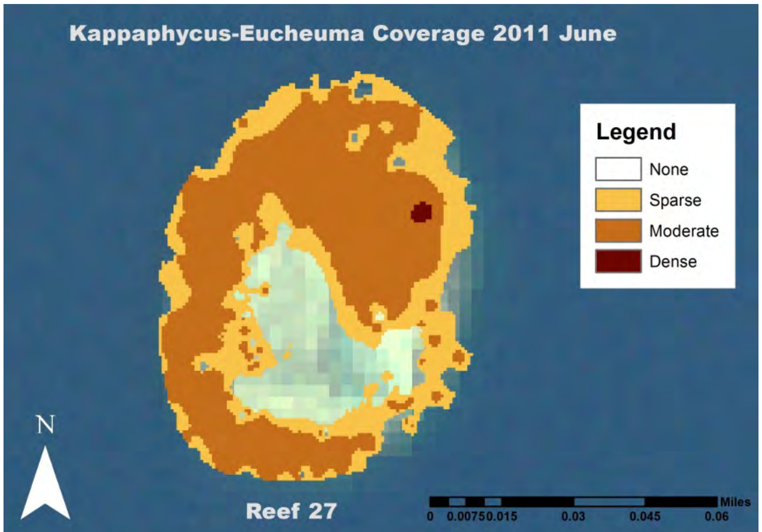


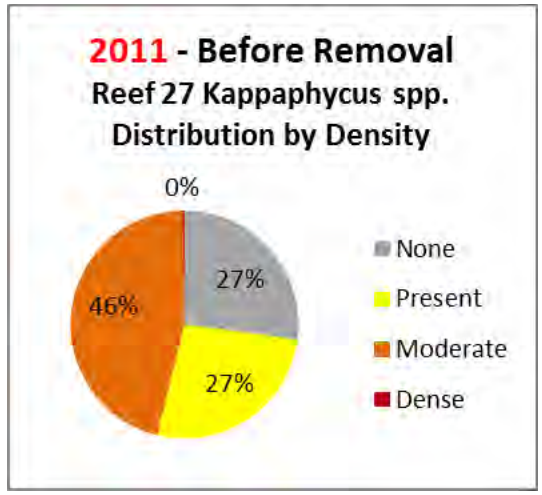


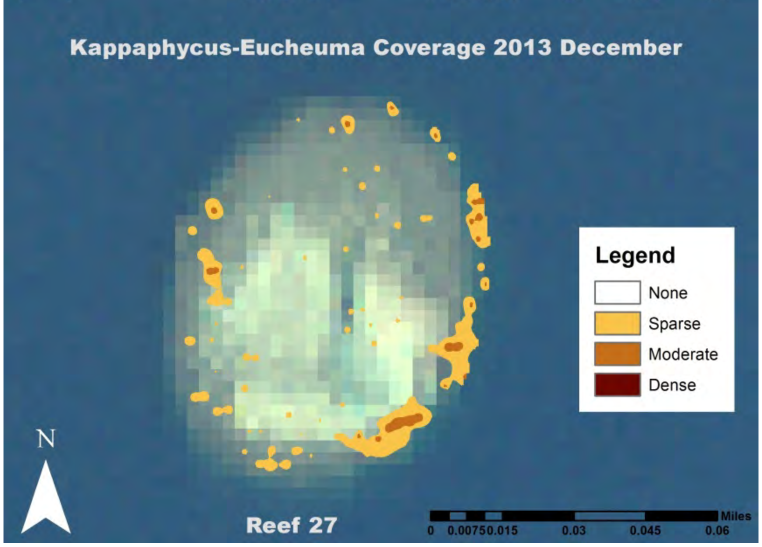


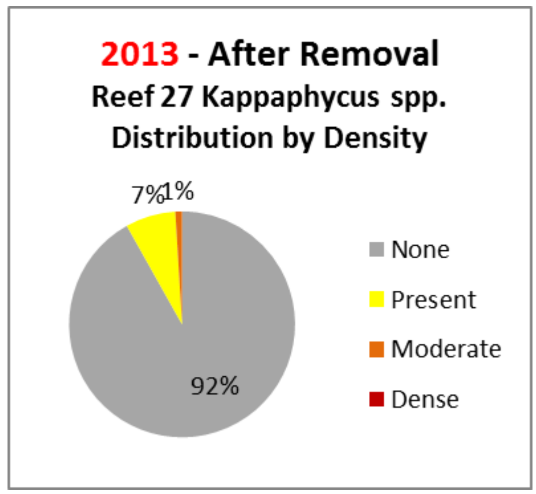
Reef 26	Percent of Reef Covered (%)	
Algal Density	2011	2013
None	11%	74%
Present	37%	21%
Moderate	48%	5%
Dense	4%	0.9%

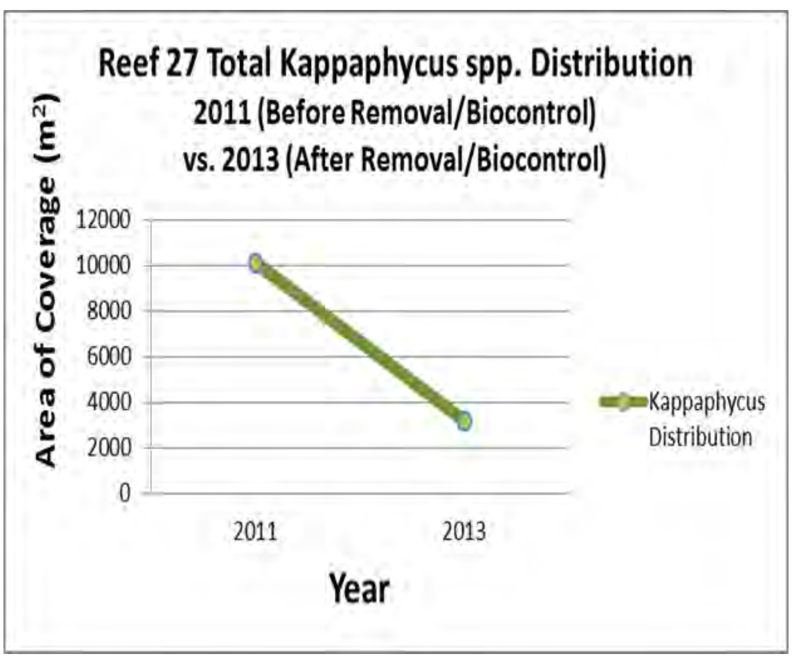
Reef 26	Distribution (m^2)	
Algal Density	2011	2013
None	1,253	8,992
Present	4,176	2,554
Moderate	5,476	641
Dense	460	12











Reef 27	Percent of Reef Covered (%)	
Algal Density	2011	2013
None	27%	92%
Present	27%	1%
Moderate	46%	7%
Dense	0.03%	0.0%

Reef 27	Distribution (m^2)	
Algal Density	2011	2013
None	3,372	11,380
Present	3,333	889
Moderate	5,704	119
Dense	39	0

Appendix H

Senior
Kāne'ohe Bay, O'ahu
13x25' barge
Inaugurated 2006

Junior
O'ahu
8x16' barge
Inaugurated 2007

Manini
Moloka'i
8' pontoon boat
Inaugurated 2008

Operated and managed by:
Division of Aquatic Resources
1151 Punchbowl St. Room 330
Honolulu, HI 96813

Super-Suckers in Hawai'i: Saving Coral Reefs from Alien Algae

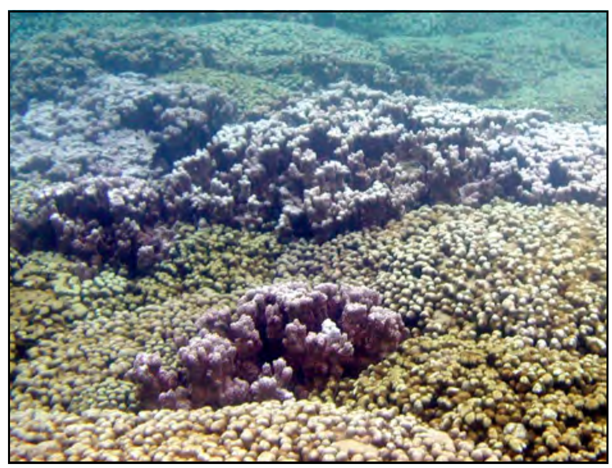
Invasive Algae in Hawai'i

Invasive alien algae, brought to Hawai'i for aquaculture research 30 years ago, is one of the most serious threats to Hawai'i's coral reefs today. Habitat degradation and the overfishing of natural grazers has created the perfect environment for invasive species to thrive. Alien algae dominate large regions of O'ahu's Kāne'ohe Bay and south shore, and are also abundant on the south shores of Maui and Moloka'i. The fragile patch reef system in Kāne'ohe Bay is suffering a critical infestation of two types of algae (*Gracilaria salicornia*, and *Kappaphycus/Eucheuma spp*.) that grow at an alarming rate, capable of forming a dense mat up to 2 feet thick and completely overgrowing a reef in as little as six months. These algae literally block out the sun, eventually killing almost all underlying benthic organisms. The distribution of *Kappaphycus/Eucheuma spp*. is currently contained within Kāne'ohe Bay and poses a constant threat to adjacent areas if it spreads. Controlling the distribution of this species is a top priority of the Super Sucker. It is imperative that the further spread of invasive algae be stopped and that the currently affected reefs be restored.

Algae covered reef prior to clearing by the super sucker

The Super Sucker

The Super Sucker barges are a fleet of mechanical tools used to assist in the control of alien invasive algae. They consist of a floating platform equipped with suction pumps and hoses which divers utilize to selectively remove alien algae from the reef while leaving the native species unharmed. When fully staffed, the barge can clear a patch reef in one week, slurping up to 3,000 pounds a day. Removing the algae exposes the three-dimensional nature of the coral reef and restores homes used by all types of fish and invertebrates. The Super Sucker is not a replacement for better fisheries management, but it is an insurance policy that enables our reefs to survive while a long-term recovery plan is put into place. Ongoing research strives to find a mechanism to restore these reefs to their natural state, but in the interim this manual algae removal can postpone further reef decline.

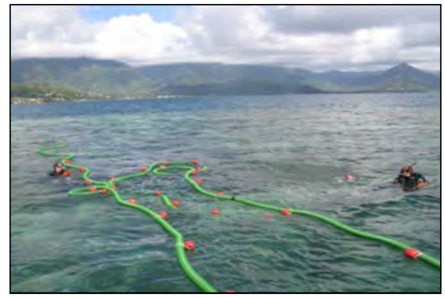


Coral-dominated reef after clearing by super sucker

Super Sucker at Work

The Super Sucker "senior" operates primarily in Kāne'ohe Bay, while the "junior" can be launched from any boat ramp on the island. The algae removal process is accomplished with a five-person crew: 2 divers, 2 top-side sorters, and a boat driver. The divers, equipped with hundreds of feet of flexible four-inch hose, descend below the surface, where they selectively feed the alien algae into the suction hose. Invasive algae re-grows easily from even small fragments, so care is taken to minimize breakage during suction. The venture-style pump has no blades and deposits the algae intact on the barge's sorting table, where any native by-catch is removed and returned to the reef. All remaining algae is drained and bagged, and then recycled through a partnership with upland taro farmers, who utilize the algae as high nutrient fertilizer.

The Super Sucker can remove up to 3,000 pounds of algae per day from severely infested reefs. Often the underlying coral, while stressed from the smothering algae, can thrive once exposed. The team revisits target reefs regularly to keep the algal cover to a manageable level. New methods are being developed to control invasive algae and restore reef health, but until those are implemented the Super Sucker remains the only tool capable of removing significant algal overgrowth and preventing further coral reef decline.



Before removal of invasive algae

After: Live coral uncovered