Summary of Support for Implementation of Priority Strategies at DLNR CAP Sites

Table of Contents

ʻĀhihi-Kīnaʻu Natural Area Reserve	2-7
Molokini Marine Life Conservation District	8-25
Kahekili Herbivore Fishery Management Area	26-78
Kahoʻolawe Island Reserve	79-149

This report was supported by The Nature Conservancy under cooperative agreement award #NA13NOS4820145 from the National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Conservation Program, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA, the NOAA Coral Reef Conservation Program, or the U.S. Department of Commerce.

The Nature Conservancy
Protecting nature. Preserving life.

NOAA CORAL REEF CONSERVATION PROGRAM

ʻĀhihi-Kīnaʻu Natural Area Reserve
Technical Assistance for Management of Roi

Roi – the peacock grouper intentionally introduced to Hawaii from the Marquesas for food in the 1950s. Photo credit: TNC

Managers of the ʻĀhihi-Kīnaʻu NAR asked the Conservancy to help them strategically address the public's questions and perceptions that populations of invasive roi (*Cephalopholis argus* - peacock grouper) are increasing in the NAR. Our marine science advisor Dr. Dwayne Minton began by comparing data on roi abundance from the coral reef and reef fish surveys conducted in the NAR in December 2014, to roi abundance elsewhere in Maui County and across the state. Dr. Minton's analysis showed that both roi abundance and overall reef fish abundance are relatively high in the NAR, which is typical in Hawaiʻi's protected areas. Our Maui marine coordinator Roxie Sylva also worked with volunteers to collect data points on roi abundance in the NAR and mapped that data spatially in GIS density maps. Roxie presented this information at the 2015 Hawaiʻi Conservation Conference (HCC) in August. In June, our Maui marine program director Emily Fielding presented this information to the ʻĀhihi-Kīnaʻu NAR Advisory Group and provided an updated proposal to conduct a pilot roi removal study in the NAR. See the Non-native Fish Management Pilot Project report below.

Non-native Fish Management Pilot Project
ʻĀhihi-Kīnaʻu Natural Area Reserve 2015-1017

Objective: Target and remove *Cephalopholis argus,* roi, from 6 acres of priority habitat as a pilot to understand impact of alien fish species on coral reef fish populations at ʻĀhihi-Kīnaʻu.

Rationale: The non-native predatory grouper roi (*Cephalopholis argus*) was introduced to Hawaiian waters by the State in the 1950s to enhance local fisheries and has since become naturalized on all main Hawaiian Islands. State Division of Aquatic Resources documented that roi populations have increased fifteen-fold since the 1980's to become the dominant predator on Hawaii's reefs. However, due to the prevalence of ciguatera fish poisoning in roi, they are infrequently targeted by fishers. High levels of roi are generally associated with high fish biomass across the state.

Roi and other non-native fish have been identified as a medium level threat in the ʻĀhihi-Kīnaʻu NAR Management Plan (pp 49-50). It is widely believed that roi negatively impact native coral reef fish populations, yet, studies in west Hawaiʻi have not observed a significant response of native fish populations following the removal of roi from coral reef habitat. However, to date, no studies on the response of native fish populations to roi removal have been conducted in areas protected from fishing. In addition, community leaders on Maui popularized manual removal of roi from reefs through years of Roi Round-Up fishing competition.

In order to evaluate the magnitude of the threat roi pose to native fishes, and in order to prioritize funding for management actions within the suite of actions necessary to meet the objectives of ʻĀhihi-Kīnaʻu's management plan, a pilot removal effort involving state and federal partners, community members, and fishers is proposed.

The proposed action consists of three phases, each of which requires effective communication, cooperation, and collaboration among advisory group members, within DOFAW, between divisions of DLNR, with the engaged fishing community, those who utilize ʻĀhihi-Kīnaʻu Natural Area Reserve and among federal, non-profit, County, and University representatives. Honest and open engagement throughout all three phases will ensure that implementation is well-planned, understood, and results are valued and communicated effectively. It is recommended that a working group be formed within the ʻĀhihi-Kīnaʻu Advisory Committee or an appropriate body identified by managers to work closely together on this proposed project.

Phase I: Stakeholder engagement and project design. This will be led by the roi working group of the Advisory committee, a similar group, together with an independent contractor. Stakeholder engagement should include, but need not be limited to, representatives from ʻĀhihi-Kīnaʻu Natural Area Reserve (AKNAR), DLNR's Division of Forestry and Wildlife (DOFAW), Division of Conservation and Resource Enforcement (DOCARE), Division of Aquatic Resources (DAR), Maui County, NOAA Fisheries, Kahoolawe Island Reserve Commission (KIRC), Roi Roundup Maui, regular snorkelers, the University of Hawaiʻi's Fishery Ecology Research Laboratory (FERL), and The Nature Conservancy (TNC) as well as any interested entities who will be instrumental in implementing removal and/or monitoring activities identified by these groups. Engagement will fall under three categories:

1. Participatory science – Spearfishers and snorkel volunteers may be trained to conduct visual surveys of roi (as well as other resource fish species if desired) using standard methods and supported to continuously survey priority areas throughout the course of the project and provide data to AK NAR.
2. Management-driven Research – Scientists may contribute ecological data derived through SCUBA surveys and share design guidance to ensure adequate survey effort to demonstrate removal effects if any, feasible site selection, and realistic goals for tracking progress. Baseline data will also be necessary to evaluate any effect of removal and should include coral reef fish abundance, diversity, biomass, and prey behavior (flight initiation and excursion distance) in the pilot removal area and proximal control sites.
3. Implementation Support – Managers may provide oversight and support for community events and field work including enforcement of existing laws, support for Special Use Permits, and clear communication with project team.
4. Coordination and Outreach – Fishers, volunteers, NARS staff, researchers, and managers may share information with interested parties within ʻĀhihi-Kīnaʻu and more broadly throughout Maui Nui throughout the course of the project.

Progress is already underway with regard to Management-driven Research. TNC completed a comprehensive baseline assessment of coral and fish in December, 2014. Analysis of this assessment will reveal preliminary information about roi density and distribution within AKNAR to inform collaborative project planning which must determine the specifics regarding removal areas, timelines, methods, and monitoring. It is likely that a more geographically discrete baseline of removal areas and control sites will be required to evaluate efficacy of this action, but a reserve-wide baseline provides a head start for this process.

The timeline for completion of Phase I is two months.

Phase 2: Roi removal. Once an implementation plan has been developed and communicated to all relevant stakeholders, necessary permits are in place, and resources are allocated, removal may proceed. A stepwise removal process is recommended to engage the fishing community as well as ensure maximum reduction of roi populations in the pilot project area. Spearfishing community representatives may work with agency staff and project leads to hand select individuals to participate in initial freediving activities in priority areas. Data on catch per unit effort, total length, weight, gonad weight, ripeness, and gut contents will be collected for all roi dispatched throughout the project. Partnerships will be developed with farmers or others who will take roi for fertilizer. Oversight from DOCARE will reduce the risk of take of other fish species. The primary cost of this activity is the staff time necessary to support it and the cost of food for divers, which should be provided to thank them for their help and support.

Following two or more days of volunteer removal, a two-person SCUBA spearfishing team with a support Captain will spend as many days as is necessary dispatching remaining roi from the removal area. Previous studies have shown SCUBA spearfishing to be the most effective way to remove all or nearly all of the roi from discrete sections of coral reef. For a 6 acre pilot reef, five weeks should be budgeted to provide ample time for this activity to be completed.

Subsequent to removal of every roi specimen possible, bimonthly maintenance dives will be necessary to ensure roi levels are kept minimal and to document re-immigration rates.

The timeline for completion of Phase II is six months.

Phase 3: Evaluation and Management Prioritization. Once roi have been removed from the pilot area, biannual scientific and periodic volunteer surveys will be conducted to evaluate native fish populations. Based on the variable rate of coral reef fish recovery, if any, at least 5 years are recommended before a definitive determination of effect can be made. However, if 5 years is not feasible, evaluation for 18 months may demonstrate whether or not an effect is likely in order to justify continued observation if necessary.

Based on the magnitude of any observed effect, the action of invasive fish removal within AKNAR can be ranked alongside other management priorities to maintain and improve coral reef health. This prioritization will improve management efficiency. Additionally, this information can be shared with other managed areas throughout the state to inform their prioritization.

The timeline for completion of Phase III is 18 months.

Summary: Until the magnitude of the impact of non-native predatory fish on native fish populations is better understood, allocating management resources to address the perceived impact is premature. However, it is important to understand the severity of this perceived threat in order to prioritize actions to address it if necessary.

To ensure conservation of limited financial resources and alignment with existing management priorities, a pilot study to evaluate the impact of the introduced predatory grouper roi (*Cephalopholis argus*) is proposed to meet the following goals:

1. Engagement of the community, and particularly fishers and divers, in management of AKNAR;
2. Engagement of partners, both within DLNR and externally, in research and management of AKNAR;
3. Documentation of level of severity of impact presented by roi at AKNAR; and
4. Recommendations for prioritizing management actions for this species based upon the severity of impact.

This proposed project represents a sensible approach to investment in a discrete pilot area to accomplish the above goals, which will be of benefit specifically to AKNAR and also to other marine managed areas in Hawaii

		Design Phase				Implementation Phase				Evaluation Phase					
		2015				2016				2017					
Project Activity	*Cost*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*	*Lead*	*Output*
Phase 1:Monitoring and Project Design	$ 25,250.0														Community engagement, partner buy-in, project design, and permits
Activity 1.1: Reserve wide fish and coral baseline	$ -													TNC	Baseline fish and coral data, maps of roi density in priority areas
Activity 1.2: Priority Area roi visual census - fisher-led	$ 250.0													fisher/vols	roi abundance from visual observations
Activity 1.4: Spearfisher Engagement	$ -													NAR	list of highliners to engage in removal
Activity 1.5: Partner Engagement	$ -													NAR	DLNR, NOAA, and community support
Activity 1.6: Site Selection and Removal Strategy	TBD													NAR	Project design complete
Activity 1.7: Removal reef baseline	$ 25,000.0													TNC/DAR	baseline data for pilot removal area and two control reefs (18 acres)
Phase 2: Pilot Project Implemented*	$ 16,900														removal completed

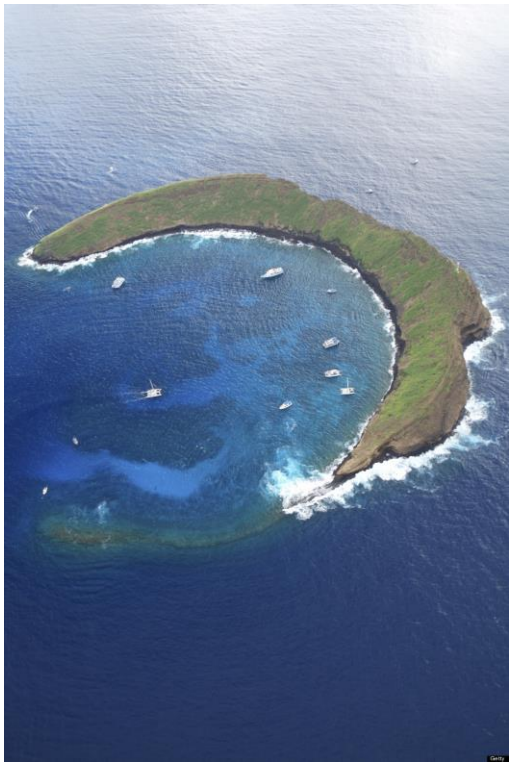
Activity 2.1: Community Spearfisher Removal - invite only**	$ 500													NAR	highline spearfishers remove 50% of roi in priority site
Activity 2.2: Professional Removal - SCUBA	$ 11,000													NAR	2 SCUBA spearfishers remove >90% of roi in priority site
Activity 2.3: Bi-monthly Site Maintenance - SCUBA	$ 5,400													NAR	site maintained at <10% of initial roi population
Phase 3: Pilot Project Evaluated	$ 38,750														management plan made available online and to managers
Activity 3.1: Information on efficacy, cost, CPUE shared	$ 1,500													TNC	updated results chains reflect intermediate results
Activity 3.2: Surveys at 1, 6, 12, and 18 months post removal (also prey behavior study at 18 months)	$ 32,000													TNC	fish and coral data collected
Activity 3.3: Analysis - fisher-led survey and biological monitoring data	$ 5,250													TNC	fish and coral data analyzed to evaluate impact
Activity 3.4: Prioritize and share roi removal strategy	TBD													NAR	information shared to inform management

* Preliminary working draft – work plan will be refined collaboratively during activities 1.4-1.6

** Food and supply cost – not inclusive of staff time (DLNR) to plan, organize, and supervise

Molokini Marine Life Conservation District
Sustainable Financing

TNC Marine Fellow Brad Stubbs wrote a sustainable financing plan for Molokini Shoal Marine Life Conservation District (Molokini MLCD) that analyses and frames the economic landscape, cost of management, and financial mechanism options that could be implemented to provide funding to manage the MLCD. Estimated annual revenue for Molokini MLCD was determined based on commercial tour operator revenue and total visitor expenditures.



Aerial view of Molokini and commercial operators. Photo credit: Huffington Post

A current and optimal annual budget was determined for Molokini MLCD in order to determine the financial resources needed to manage the area. The budget included funding for mooring maintenance, marine conservation and research, enforcement and seabird counts. In order to fund the additional management practices, multiple financial mechanisms were outlined. These financial mechanisms include the establishment of the special fund for Molokini or the Marine Life Conservation District program, and increasing the cost of the commercial operator permit through a rule amendment through the State of Hawaii Board of Land and Natural Resources.

The recommended financial mechanism was rule amendment to reformat the user fee so that it is based on the total annual visitors to the MLCD for each individual vessel. This method would increase the funding for resource protection and distribute the commercial user fee fairly among the commercial tour operators. The analysis was conducted with input and assistance from DLNR's Division of Aquatic Resources, Division of Boating and Ocean Recreation, Division of Conservation and Resources Enforcement, and the Maui Nui Seabird Recovery Project and Malama Kai Foundation; and was reviewed by the Molokini MLCD CAP team. See the Molokini Marine Life Conservation District Sustainable Financing Plan below.

Molokini Shoal

Marine Life Conservation District

Sustainable Finance Plan

May 2016

(Working document, under review by the
State of Hawaiʻi Division of Aquatic Resources)

Table of Contents

Introduction 3

Management Context 3

Marine Recreation and Tourism at Molokini 5

User Value Analysis 5

Willing Ness to Pay 6

Annual Operating Budget 7

Funding Management at Molokini 7

Discussion 8

Conclusion 9

References 10

Appendix 11

This plan was prepared by The Nature Conservancy under cooperative agreement award #NA13NOS4820145 from the National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Conservation Program, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA, the NOAA Coral Reef Conservation Program, or the U.S. Department of Commerce.

NOAA CORAL REEF CONSERVATION PROGRAM

Introduction

The Molokini Shoal Marine Life Conservation District (Molokini MLCD) is a marine protected area surrounding a crescent-shaped island, three miles off of Maui's south shore. Molokini MLCD was established by the Department of Land and Natural Resources (DLNR) in 1977 to protect fisheries, marine wildlife, and marine habitats in the waters surrounding Molokini Island. The island is approximately 22 acres and reaches a height of 160ft. Molokini is a federally owned seabird sanctuary, requiring permission from the U.S. Coast Guard, Hawaiʻi and U.S. Fish and Wildlife Services (USFWS) to go ashore. Molokini MLCD is a popular site for commercial activity and therefore a revenue source for Hawaiʻi's economy. Molokini MLCD received on average 330,000 snorkelers and scuba divers annually via commercial tour operators in 2013 and 2014.

A dedicated multidisciplinary team convened by Division of Aquatic Resources (DAR) Maui developed a Conservation Action Plan (CAP) for Molokini in 2013. The CAP provides a frame work to preserve both the biological and social resources of Molokini today, and to ensure Molokini shoal continues to thrive and be enjoyed by the public well into the future. One objective from the CAP process was to ensure reliable and dedicated funding for management costs of Molokini MLCD (Molokini CAP, 2014). This sustainable finance plan fulfills that objective by framing the economic landscape, cost of management, and financial mechanism options that could be implemented to provide funding to management. Two management budget scenarios are included, the *current* budgeted scenario and the *needed* management budget scenario. The needed budget scenario includes additional conservation and management activities that preserve and enhance Molokini MLCD.

Management Context

The management of Hawaiʻi's natural resources is the responsibility of the State of Hawaiʻi's DLNR. Within DLNR it is a multi-division effort to manage Molokini MLCD. Molokini MLCD is under the shared management responsibilities of four organizations: Division of Aquatic Resources (DAR), Division of Boating and Ocean Recreation (DOBOR), Division of Forestry and Wildlife (DOFAW) and Division of Conservation and Resource Enforcement (DOCARE). DAR manages the state's marine and freshwater resources. Their mission is "to manage, conserve and restore the state's unique aquatic resources and ecosystem for present and future generations."(DAR, 2016) DAR is in charge of the administrative process of commercial permits to operate within Molokini MLCD and the protection and observation of marine life. DOBOR is responsible for the management and administration of statewide ocean recreation and coastal area programs pertaining to the ocean waters and navigable streams of the state (DOBOR, 2016). DOBOR manages the day use mooring program statewide, including the moorings at Molokini. DOFAW manages the island of Molokini in partnership with USFWS, NGO's and non-profits as a seabird sanctuary to protect a large colony of nesting seabirds. DOCARE is responsible for enforcement activities for all of DLNR. DOCARE officers have full police powers and enforce all state laws and rules in and around Molokini MLCD (DOCARE, 2016).

Marine Life Conservation District Program

Marine Life Conservation Districts (MLCDs) are designed for the conservation and replenishment of marine life and nearshore resources. The protection of these key ecosystems is important to maintain healthy populations of critical species for current and future generations. Within the State of Hawaiʻi there are currently eleven MLCDs; three on Oʻahu, five on Hawaiʻi Island and three within Maui County. Within these MLCDs, commercial recreational activities such as commercial boat operations, scuba diving, snorkeling and shore activities are common. Most MLCDs either prohibit fishing or have limited gear usage depending on the season. The MLCDs are managed by Hawaiʻi's Marine Life Conservation Program within DAR.

Molokini Boundaries

Molokini MLCD boundaries are broken into two subzones: subzone A and B (Figure 1). Subzone A is the interior of the crater, the northern boundary is defined by a straight line running West-Northwest from Paheʻe O Lono Point to the end of the submerged crater ridge. The southern portion of the boundary is the high-water mark along the interior of the crater wall, between Paheʻe O Lono Point and Lalilali Point. Subzone B is 100 yards from both the high water mark, relating to the backside of the crater, and from the exterior edge of subzone A (DAR, 2012).

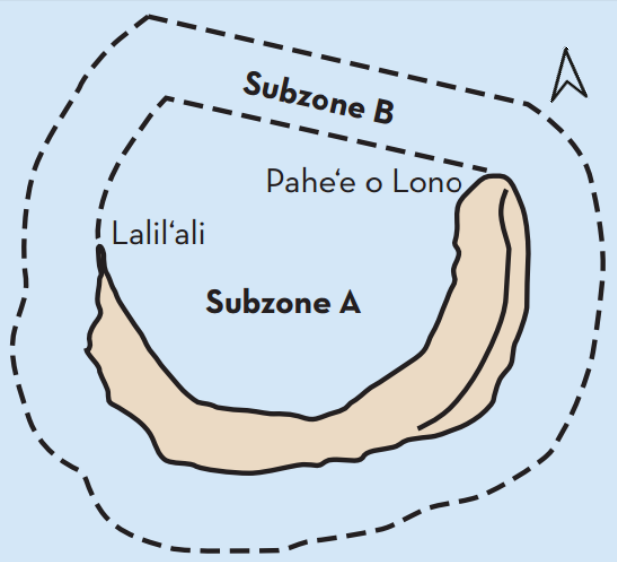


Figure 1: Molokini Boundaries
http://files.Hawai'i.gov/dlnr/dobor/dum/guides/maui2009.pdf

Marine Managed Areas of Hawaiʻi

The financial sustainability of marine managed areas continues to be a significant challenge. In order to meet marine conservation objectives in Hawaiʻi, an increase in funding is needed for a majority of the sites. In addition to the eleven MLCDs in the State of Hawaiʻi, there are twenty Fishery Management Areas (FMAs), nine Fisheries Replenishment area (FRAs), two Wildlife Sanctuaries, two Natural Area Reserves (NARs), one Community-Based Subsistence Fishing Area (CBSFA), eighteen bottom fish restriction zones, and the Hawaiian Islands Humpback Whale National Marine Sanctuary. Although this is not a comprehensive list of all of Hawaiʻi's marine managed areas, all of these and others are needed to properly manage Hawaiʻi's natural marine resources. Molokini MLCD is a unique marine protected area because of its limited access and high volume of visitors. These conditions create an opportunity for Molokini to generate revenue from either the commercial tour operators and/or Molokini MLCD visitors themselves.

Commercial Operator Permit

Commercial recreation was first documented at Molokini in 1974. As activity began to increase, concerns were raised about how this was effecting the natural environment. It was not until 1994, that in order to regulate operator activity within the MLCD, commercial operator permits were issued to all vessels operating within Molokini MLCD. A commercial operator permit was distributed to all those that could prove they visited Molokini more than eight times in the previous year, 1993 (Szuster & Needham 2010). The total commercial operator permits has now been capped at forty. The commercial operator permit states that a permit is required in order to engage in commercial operations including but not limited to: scuba diving, snorkeling, snuba, swimming and sightseeing tours within the boundary. The permit is valid for two years, costs $50, and can only be applied to a single vessel. In order to maintain status as a permit holder, the commercial operator must be able to prove commercial operations within Molokini MLCD during each twelve month period of the two-year permit.

A Day-use Mooring permit is required in addition to the Molokini commercial operator permit. The day-use mooring rules were created by Hawaiʻi Administrative Rules Chapter 13, Subchapter 4, Section 257, which was enacted in 1994 (Markrich, 2004). Commercial vessels are prohibited to use day-use moorings within the MLCD boundaries unless they have both required permits. The Molokini MLCD subzone A (Figure 1)

is broken down further into mooring areas (Figure 2). Mooring area A is reserved for commercial vessels with twelve or more passengers. Mooring area B is designated for commercial vessels carrying less than twelve passengers. Mooring area C is reserved for primary use by recreational boaters. All moorings are on a first come first serve basis. Recreational vessels may also use vacant moorings in area A & B, except between the hours of 8:30am- 11:30am. The fee to obtain a commercial day-use mooring permit is the greater of $100 or 2% of the annual gross receipts. However, this fee is waived for commercial operators paying commercial vessel user fees at state boating facilities. Within the boundaries of Molokini MLCD, the following are prohibited: fishing for take or removal of any finfish, crustacean, mollusk, live coral, algae, or other marine life. Sand, coral rock or other geological features may not be disturbed or removed, and devises such as spears, traps and nets are not allowed within the waters (DAR, 2012). Deliberately feeding fish or using attractants is not allowed and anchoring or mooring a vessel for commercial purposes without a permit is forbidden. Fishing for take by trolling is allowed only in Subzone B.

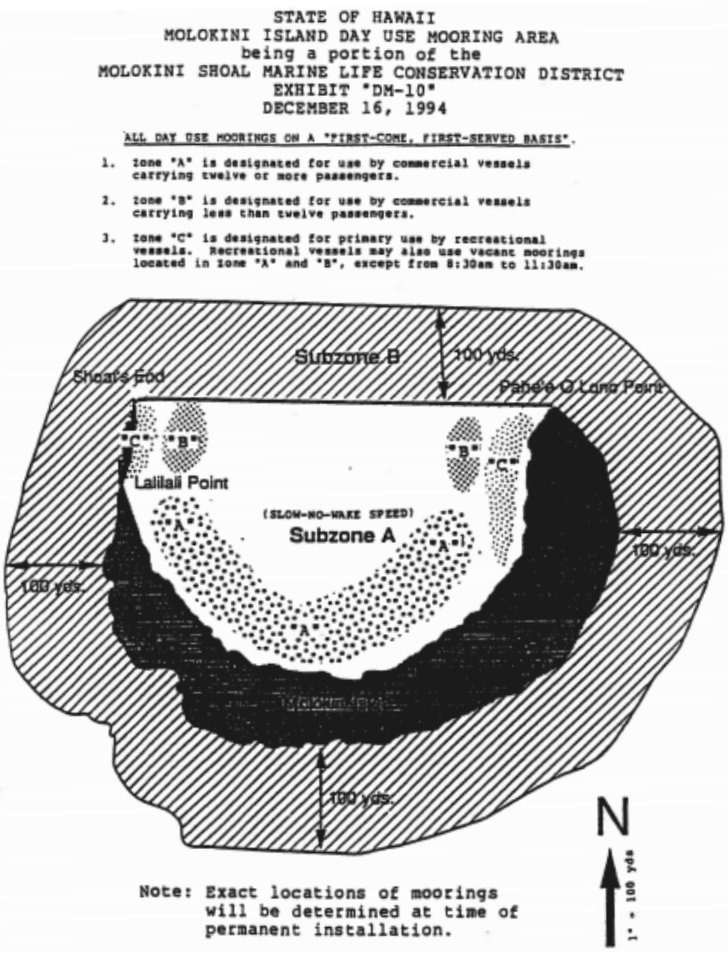


Figure 2: Molokini Zones and Subzone Map

Marine Recreation and Tourism at Molokini

In 2015, the Hawaiʻi Tourism Authority reported a fourth straight record year at 8.6 million visitors, with visitor expenditures generating revenue at $15.2 billion (HTA, 2016). The average daily visitor spending was $197 per person per day. There were approximately 214,000 visitors in Hawaiʻi on any given day. This was an increase of 3.5% over 2014 levels (HTA, 2016). Hawaiʻi's tourism sector is the largest part of the state's economy; one of the reasons visitors come to Hawaiʻi is for the natural beauty and ocean. In 2013, 86% of U.S. mainland visitors to Hawaiʻi participated in marine recreation; 47% went snorkeling or scuba diving (DBEDT, 2014). The coral reefs of Hawaiʻi provide environmental protection, recreation, cultural significance and financial benefits to Hawaiʻi's economy. It is estimated that Hawaiʻi coral reefs are valued at $9.7 billion in total with a value of $356-451 million per year, 85% of which is from recreational activities (Cesar & Beukering, 2004; Edwards, 2013). It is estimated that 80% of Hawaiʻi visitors engage in recreational activities at beaches or nearshore areas. A majority of these visitors participate in snorkeling, estimated at 3 million per year, or scuba diving, estimated at 200,000 per year (Cesar & Beukering, 2004; Edwards, 2013). Molokini with 330,000 visitors annually and an average visitor cost of $95 per person represents approximately 9% of Hawaiʻi's marine recreation revenue, an estimated value of $31.6 million annually.

User Value Analysis

The economic value of natural resources is difficult to put a price on, in order to do so, economists in partnership with resource managers have developed different models. Neoclassical economics tends to think of nature as a collection of services that an ecosystem provides to humans. In the marine environment, fisheries would be an example of a direct economic benefit. There are also indirect uses provided by ecosystem services, for example, coral reefs provide coastal protection and recreational enjoyment. Placing a value on coastal protection is difficult because of the inability to determine how much coastal protection is provided directly from coral. Recreational enjoyment of coral reefs is easier to determine as you can systematically add up all costs involved for a given person to experience a coral reef ecosystem. This type of calculation is called the *travel cost method* for ecosystem valuation. The travel cost method is a well-known and developed methodology for measuring the economic values of outdoor recreation benefits (Carr et al., 2003; Font, 2000) The travel cost method relies on the assumption that time and costs associated with travel make up a portion of the actual price it costs for visiting a site (Font, 2000). By using the travel cost method, it is estimated that Molokini is valued at $49.6 million annually. The present value of Molokini can be calculated as perpetuity, which is the amount of money needed today in order to generate $49.6 million every year. Using a simple present value calculation with a modest inflation rate of 3%, Molokini is valued at $1.65 billion (Table 1). This is the equivalent to 9% of the value of Hawaiʻi's reefs. A detailed travel cost analysis methods are included in Appendix 1.

Table 1: Travel Cost Method calculation

Travel Cost Method		
Average Annual Visitors		333,000
Average Ticket Cost	$	95.00
Portion of Air Fair $418 *weighted by region & divided by average length of trip 8.25 days then by 1/3 portion of the day	$	16.89
Portion of Lodging Expense $98 *divided by 1/3 to account 8hr visit	$	32.67
Portion of Rental Car Expense $13.10 *divided by 1/3 to account portion of daily time	$	4.37
Annual Travel Cost Value	$	49,592,925
Travel Cost Perpetuity *3% inflation rate	$	1,653,097,486

There is additional *non-use economic values* that should be considered that do not factor into the travel cost method. The *bequest value* is a value placed on an individual's willingness to pay for maintaining or preserving Molokini for future generations. This could pertain to both people that have and have not visited Molokini. There is also the *existence value,* which is the benefit people receive from knowing that Molokini exists and is being maintained (Hollier, 2015). People are willing to spend money for the protection of a place even though they don't plan on visiting it or are unable to visit it. One such example is that of the Papahānaumokuākea Marine National Monument. Papahānaumokuākea is funded by taxes and the importance of it is realized by Hawaiʻi residence. There is also the economic benefit Molokini MLCD provides through the *spillover effect* which are the profits received from fisheries enhancement in adjacent waters by adult fish spillover and recruitment spillover outside of the MLCD. These are additional non-use and indirect-use values that Molokini MLCD provides that are not easily determined and therefore not included in user value. It also should be noted that the financial value of Molokini MLCD is not constant, but rather fluctuates with the global economy, Hawaiʻi tourism, and quality of Molokini MLCD compared to other marine recreational sites.

Willingness to Pay

It is common practice at MPAs around the world to charge entry fees for commercial activity or visitors as a means to provide funding for resources protection. These types of fees establish a direct connection between the users and a way to generate money. It is possible for entrance fees to generate enough revenue to pay for most of the protected area's operating cost if visitors are frequent and fees are adequate. For this system to be beneficial revenue needs to be linked back to the MPA. This then can provide economic incentives and a willingness to pay by the commercial tour operator or visitors. The Gálapagos Islands National Park collects a $100 park entry fee from each of the 80,000 foreign visitors. Although these fees can be seen as high, foreign visitors have continued to increase despite the high fee. (Spergel & Moye, 2004; Benitez, 2001) The Great Barrier Reef Marine Park charges $3.25 to commercial tour operators per tourist per day as an environmental management charge. This additional revenue provides the park staff with more resources available for management corresponding to total park users. (Spergel & Moye, 2004; Skeat 2003) These are both examples of commercial and visitor that have willing to pay for the preservation of a MPA.

Annual Operating Budget

In order to know how much money to raise, managers must first know how much it takes to operate and effectively manage Molokini MLCD on an annual basis. A categorized budget for the *current* and *needed* scenario is provided to understand the current and potential financial state of Molokini MLCD. The *needed* budget is what programs should be added if additional funding is made available. The *needed* budget includes funds for mooring maintenance, conservation, education programs and enforcement (Appendix 2). There are currently existing unmet needs that are included in the *needed* scenario to improve Molokini MLCD.

Current Management Scenario

Molokini MLCD is currently managed with an annual budget of $40,100. This budget is well below the minimum budget to effectively manage the MLCD. The budget for this scenario includes DAR administrative costs to process user permits, survey the Coral Reef Assessment and Monitoring Program Site (CRAMP Site), and conduct fish monitoring and coral disease assessments. This is the baseline budget to which other scenarios are added. At this current budget amount, moorings were not maintained and ultimately deteriorated over time. Tour operators, non-profits and NGOs provided funds to maintain the moorings because of its necessity for their businesses.

Needed Management Scenarios

The *needed* management scenario annual budget for Molokini would be $232,371. In addition to the *current* budget, the *needed* management scenario includes mooring maintenance, additional conservation practices, enforcement and education. This scenario provides funding for several objectives and strategies from the Molokini CAP (Molokini CAP, 2014). The scenario includes funds for short term projects, for example, ant eradication for the protection of nesting seabirds and the development of an education certification class for tour operators, crew and naturalist.

Funding Management at Molokini

Financial mechanisms are the tools designed to raise, generate or mobilize funds to cover the different costs related to the protection of the natural resources. For Molokini and other marine conservation sites in Hawai'i, a combination of funding mechanisms are usually used for each site. Prior to picking a financial method, the feasibility, effort and likelihood of providing consistent funding should be determined.

Current Financial Funding Mechanisms

The current funding for the management and maintenance of Molokini MLCD is provided by several sources. Mooring maintenance is currently unfunded resulting in moorings being repaired and maintained either by grants or donations from commercial tour operators. This method places an unfair burden and liability on commercial operators. DOBOR receives funding from commercial use permits for state ocean waters and the Day-use Mooring program but none of these funds are directly connected back to Molokini. Additional funding would be necessary for an NGO to properly manage the moorings at Molokini. The commercial vessel permit of $50 every two years generates $1,000 annually. At this current rate, the funds generated by the commercial vessel permits does not cover staff time required to process the permits. DAR also receives funding for Molokini in the DAR general budget and from the Sport Fish Restoration Act. The DAR funding that can be applied to Molokini is estimated to be $41,100 annually. The Sport Fish Restoration Act is funded via excise taxes on recreational fishing equipment. All other aspects of management at Molokini either receive funding from grants or currently go unfunded.

BLNR Rule Change Process

The current Molokini MLCD rules were placed into action by the Board of Land and Natural Resources (BLNR) including language stating that a user fee will be collected from each commercial vessel at a rate of $50 for a two-year commercial operator permit. In order to modify this or any other aspect of these rules at Molokini, a public review hearing process would need to take place. The procedure for administrative rules is set by Hawai'i Revised Statutes, Chapter 91. A rule change process would take engagement with commercial tour operators, the community and support prior to a BLNR hearing.

Proposed Funding Mechanism: Total Annual Visitor by Vessel Financial Mechanism

A promising funding mechanism is the total annual visitor by vessel financial mechanism, which uses five different commercial user fee rates based on the total number of annual visitors, table 2. The total visitors taken to Molokini MLCD from the previous year would be used to determine the next year's user fees.

Table 2: Total Annual Visitors by Vessel

Total Annual Visitor by Vessel			
Annual Visitors	# Vessels	Annual Fee	Funds Generated
<1,000	4	$ 2,000	$ 8,000
1,000-4,999	19	$ 4,000	$ 76,000
5,000-9,999	8	$ 6,500	$ 52,000
10,000-24,999	5	$ 9,000	$ 45,000
>25,000	4	$ 12,500	$ 50,000
total # of Vessels	**40**		**$ 231,000**

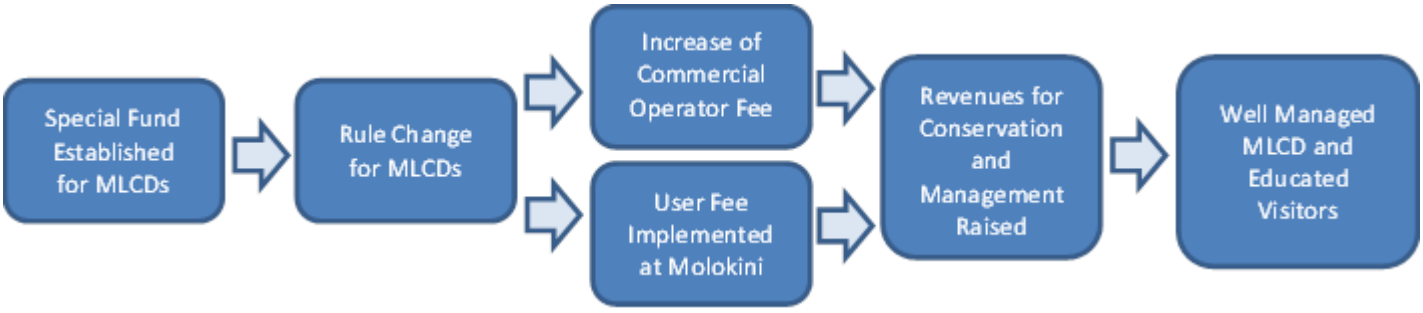
It should be noted that this mechanism would fluctuate with the tourism industry. This mechanism could also increase the potential for commercial users to intentionally misreport their user data information in order to lower their commercial fee. This mechanism and any variation of it would require additional DAR staff time. The data used to create the table and estimated annual earnings is based off of the 2015 Molokini vessel entry data.

An alternate funding mechanism by way of creating a special fund is discussed in Appendix 3. This financial mechanism was not proposed as a viable option at this time because of low feasibility. The current legislation is not in favor of additional special funds being created.

Discussion

Commercial activity at Molokini MLCD is estimated to generate $31.6 million in gross annual revenue. The needed annual budget for Molokini is $232,371. The reflection of the needed annual budget as a percentage of the gross annual revenue comes out to 0.7%. Although industry pushback is likely, the cost for the *needed* management scenario would have a relatively minimal impact on the commercial tour operators' net annual revenue. Of the financial mechanisms presented, it is recommended that DLNR pursues a rule amendment to implement user fees based on total annual visitors by vessel. This method would increase the funding for resource protection at Molokini MLCD and distribute the fee fairly among the commercial tour operators. The commercial tour operators on average would be charged $0.71 for every person that visited Molokini MLCD. Since this method only accounts for occupied seats, vessels that consistently don't use their full capacity will not be unfairly charged. A variation of this method could be calculated by DAR where for each user a flat rate is collected instead of increased fee by increments. This method would result in a unique user fee for each commercial tour operator based off of the previous year's visitor data.

A recommended next step for DAR is to internally review the proposed model and adapt it as they see necessary. DAR should consider devoting funds to the amendment process for either internal personnel or an outside contractor. The commercial tour operators, local community groups and general public would need to be engaged. The benefit of increasing commercial operator permit fees will provide enough funding for the long-term protection of the natural resources in which the marine recreation tourism industry depends on. A possible chain of events in presented below to demonstrate the necessary steps to properly manage the Molokini and the MLCD programs.



The mooring maintenance budget is considered the most important due to the necessity of it for the commercial tours operator's revenue and safety of their guest at Molokini. The moorings are also critical to the protection of the coral reef and reef ecosystem species visitors come to see. The maintenance and inspection portion of the budget should be contracted to a local NGO that is in partnership with the commercial tour operators. The reason for this is the tour operators want moorings maintained and fixed immediately or they will be losing business. The NGO would have the ability to do repairs quickly. This would also show the value the commercial tour operators are getting from the increase cost of their commercial permit. There also has been discussion to convert two moorings to surface moorings for exclusive use by the non-commercial recreational users. These moorings would have easier access and give the general public a dedicated dive location from their personal vessels.

An alternative funding method of a legislative special fund is outlined in Appendix One. A user fee of $1 would generate significantly more funding however the feasibility of creating a special fund just for the purpose of Molokini MLCD would be difficult to implement politically. The creation of a special fund benefiting

the MLCD program in its entirety would be recommended. If a special fund is pursued in the future, further financial analysis of all eleven MLCDs should be done. A user fee of $1 per person could be charged to all MLCD visitors that enter any of the MLCDs by a paid guided tour. The collection and distribution of special fund revenue should be further understood. While it is politically difficult to create a special fund, it is not impossible.

Conclusion

Molokini MLCD is both a natural and economic resource for Hawaiʻi. The diverse coral and fish populations at Molokini MLCD need to be conserved and replenished by enhancing the budget for resources protection. The revenue generated from tourism indicates its financial importance for the commercial tour operators and the tourism sector of Hawaiʻi's economy. The preservation of Molokini MLCD is necessary for both environmental and economic reasons.

References

Benitez, Silvia P. 2001. Visitor Use Fees and Concession Systems in Protected Areas: Galápagos National Park Case Study. Arlington, Virginia: The Nature Conservancy. Ecotourism Program, Technical Report Series Number 3

Carr, L., & Mendelsohn, R. (2003). Valuing coral reefs: A travel cost analysis of the Great Barrier Reef. Ambio, 32(5).

Spergel, Barry and Melissa Moye. 2004. Washington, D.C.: WWF Center for Conservation Finance.

Cesar, H., & Beukering, P. (2004). Economic Valuation of the Coral Reefs of Hawaii. Pacific Science, 58(2), 231–242.

DAR, Department of Land and Natural Resources, Division of Aquatic Resources. (2016). Retrieved from http://dlnr.hawaii.gov/dar/division-overview

DAR, Department of Land and Natural Resources, Division of Aquatic Resources. (2012) Marine Life Conservation Districts: Molokini Shoal. Accessed at: http://hawaii.gov/dlnr/dar/mlcd_molokini.html

DBEDT, Department of Land and Natural Resources, D. of B., Economic Development & Tourism. (2014). 2013 Annual Visitor Research Report. Visitor Statistics. Retrieved from http://dbedt.hawaii.gov/visitor/visitor-research/

DOBOR, Department of Land and Natural Resources, Division of Boating and Ocean Recreation. (2016). Retrieved from http://dlnr.hawaii.gov/dobor/

DOCARE, Department of Land and Natural Resources, Division of Conservation and Resource Enforcement Recreation . (2016). Retrieved from http://dlnr.hawaii.gov/docare/

Edwards, P. (Ed.). (2013). Summary Report: The Economic Value of U.S. Coral Reefs, 2001-2011. NOAA Coral Reef Conservation Program.

Font, A.R. 2000. Mass tourism and the demand for protected natural areas: A travel cost approach. J. Environ. Econ. Mgmt 39, 97–116.

Hollier, D. (2015, January). What's Hawaii's Environment Worth? Hawaii Business, 66–70

Hollingsworth, L. (Ed.). (2008). Hawaii Coral Reef Assessment & Monitoring Program. Hawaii Institute of Marine Biology. Retrieved from: http://cramp.wcc.hawaii.edu/CRAMP_Information/overview.htm

HTA, Hawaii Tourism Authority. (2016). 2015 Annual Visitor Research Report. Hawaii Tourism Authority Retrieved http://www.hawaiitourismauthority.org/research/reports/annual-visitor-research/

Markrich, M. (2004). The Hawaii boating Industry 2003- A Survey and Economic Description. Dba/Markrich Research

Molokini CAP. (2014). Molokini Shoal Marine Life Conservation District, Conservation Action Plan (CAP)

O'Halloran, T., & Bourdon, K. (2010). Hawaii Day-Use Mooring Buoy 10-Year Strategic Plan, April 2010. Prepared for: Division of Aquatic Resources Prepared by: Malama Kai Foundation.

State Auditor, State of Hawaii. (2015). Review of Special Funds, Revolving Funds, Trust Funds and Trust Accounts. Office of the Auditor, Report No. 15-17. Retrieved from: http://files.hawaii.gov/auditor/Reports/2015/15-17.pdf

Skeat, Andrew, and Hilary Skeat. 2003. Systems to Make Tourism and Others Contribute to Protected Areas - the Great Barrier Reef. Background paper for Vth World Parks Congress, Durban, South Africa, September. Available on-line, CFA, see Sustainable Financing Stream at the World Parks Congress: http://www.conservationfinance.org

Szuster, B. and M. Needham. 2010. Marine Recreation at the Molokini Shoal MLCD. Final project report for Hawaii Division of Aquatic Resources, Department of Land and Natural Resources. Honolulu, HI: University of Hawaii at Manoa, Department of Geography.

Work, T.M., Russell, Robin, & Aeby, G.S. (2012). Tissue loss (white syndrome) in the coral Montipora capitata is a dynamic disease with multiple host responses and potential causes. Proceedings of the Royal Society B-Biological Sciences, 279(1746), 4334-4341

Appendix 1: Travel Cost Method

Annual Visitors: Molokini tour operators are required to fill out monthly report logs with how many times they visit Molokini and include how many visitors they took to Molokini. From this, the 2014 visitor data is used to be consistent with the rest of the data collected from Hawaiʻi Tourism Authority, Table 3.

Trip to Molokini Cost: The Trip to Molokini cost was based off of internet data from a sample population of tour companies. Molokini has 42 permitted tour operators and tour cost data from 20 of them was averaged to determine the average trip cost.

Airfare Cost: The Airfare price was determined by Maui's 2014 visitor data from Hawaiʻi Tourism Authority. An average airfare price was determined for seven regions: U.S. West, U.S. East, Canada, Oceania, Asia, Japan, other and inter-island travel. These average airfare prices were then weighted by percentage of Maui visitors from each region. This resulted in an average airfare price of $418 which was divided by the average trip length to Maui of 8.25 day, then divided again by 1/3 to estimate the average length of day a visitor would spend at Molokini.

Lodging Cost: Hawaiʻi Tourism Authority data from 2014 determined a lodging cost of $98 per person per night for the island of Maui. This was then divided by 1/3 to determine the portion of the visitor's night's stay that would be applied to the time they spent at Molokini.

Rental Car Cost: Hawaiʻi Tourism Authority data from 2014 determined a rental car rate of $13.10 per person per day for the island of Maui. This was then divided by 1/3 to determine the portion of the visitor's rental car usage that could be applied to visiting Molokini.

Table 3: Travel Cost Method Calculation

Travel Cost Method		
Average Annual Visitors		333,000
Average Ticket Cost	$	95.00
Portion of Air Fair $418 *weighted by region & divided by average length trip 8.25 days then by 1/3 portion of the day	$	16.89
Portion of Lodging Expense $98 *divided by 1/3 to account 8 hr. visit	$	32.67
Portion Rental Car Expense $13.10 *divided by 1/3 to account portion of daily time	$	4.37
Annual Travel Cost Value	$	49,592,925
Travel Cost Perpetuity *inflation 3%	$	1,653,097,486

Appendix 2: Detailed Budget

Mooring Maintenance & Inspection Budget

The moorings at Molokini require regular maintenance. The estimated cost of materials for a single mooring maintenance would be $595.45, which includes the replacement of all parts except for the ground tackle. The most commonly used system at Molokini is the manta anchor system. The day-use moorings are in need of replacement approximately every four years. Due to state regulations relating to safety,

Table 4: Material cost on average for a full mooring replacement

Maintenance Material Cost Full Replacement			
Item	Unit Cost	QTY	Item Cost
1/2" Galvanized Chain	$ 7.20	25	$ 180.00
1" Nylon Line	$ 4.49	50	$ 224.50
7/8" S.S. Thimbles	$ 12.49	2	$ 24.98
5/8" S.S. Shackles	$ 67.99	2	$ 135.98
18" Reeving Buoy	$ 29.99	1	$ 29.99
Estimated Gear Total			$ 595.45
*individual replacement cost will deviate			

DAR and DOBOR employees are not allowed to conduct operations needed to replace the day-use moorings themselves. In order for this work to be completed, two options are available: contracting out a commercial diving company or working with an NGO in partnership with the recreational dive charters. For the design of this budget the NGO and recreational dive industry model was chosen. This option is less expensive, offers more stakeholder engagement with tour operators and increases flexibility.

The calculated cost for replacement moorings by the recreational dive industry is $1,500/day, at an estimate of three moorings per day. This is calculated by the estimated cost for a boat, captain, crew of two divers and fuel (O'Halloran & Bourdon, 2010). Six moorings would be replaced in the course of two days with a third day budgeted for unforeseen repairs or circumstances. In addition to this all 26 moorings should be spot checked to determine their safety which would require an additional three days at the same rate. It is estimated that the total annual cost for the replacement of 13 moorings and inspection of all 26 moorings twice annually, would be $41,141. This mooring maintenance portion of the budget is based off of assumptions and regulations taken from the Hawai'i Day-Use Mooring Buoy 10-Year Strategic Plan. There is currently no budget for Molokini MLCD moorings. NGOs and commercial tour operators currently seek grants, donations or provide personal funds for the maintenance of moorings.

Table 5: Current and needed annual budget for mooring maintenance & inspection

Annual Mooring Maintenance & Inspection Budget			
Item Description	Unit Cost	QTY	Item Total
Material Cost for Maintenance (full replacement)	$ 595	13	$ 7,741
Replacement of existing moorings (daily trip cost)	$ 1,500	5	$ 7,500
Site Inspection every 6 months (daily trip cost)	$ 1,500	8	$ 12,000
Wall Pin Replacment	$ 300	13	$ 3,900
NGO Administration and Management Fee	$ 10,000	1	$ 10,000
Current Annual Budget			$` 0
Needed Annual Budget			$ 41,141

Marine Conservation Practices

Research is important at MLCDs to document the changes that may occur inside and outside of the area. It gives managers the knowledge they need to effectively respond to threats and showcase successful conservation practices. The total research budget at Molokini is currently $40,100 which includes DARs administrative cost to process user permits, the Coral Reef Assessment and Monitoring Program Site (CRAMP Site), fish monitoring and coral disease assessment. The needed budget would be $140,100, this would include an additional $100,000 of awardable funds for research and conservation practices at Molokini. This additional $100,000 would be used for projects that do not occur year after year but are short term projects that either answer necessary research needs for management or enhance conservation practices within the MLCD. If this additional funding was made available on a consistent basis, DAR would be responsible for the distribution of these funds for either internal DAR projects or external research agencies that conduct work within and around Molokini MLCD.

DAR Administrative Fee

The Division of Aquatic Resources is the organization in charge of the MLCD and therefore tasked with the administrative process relating to documentation of the commercial operator permits at Molokini. This process is currently done by the DAR Maui Aquatic Biologist and legal fellow within the division. The total cost of this is estimated at $3,000 a year. This is calculated at seven days per year of the Maui Biologist's time and two days per year of the legal fellow's time. If the permitting process is changed, it should be noted that the budget would change based on the length of time the permit is allocated, and the amount of time necessary for the new process.

CRAMP Site

DAR in partnership with Hawai'i Institute of Marine Biology (HIMB) has a CRAMP site at Molokini they visit once a year. It is a research site designed to identify the controlling factors, both natural and anthropogenic, contributing to the stability, decline, or recovery of Hawaiian reefs (Hollingsworth, 2008). CRAMP is a statewide program with standardized methodology to provide a quick response for researchers and managers to environmental threats. The total cost for the CRAMP site at Molokini is $3,100 annually.

Table 6: Current and needed budget for marine conservation practices.

Marine Conservation Practices		
DAR Adminstrative Fee		
DAR Biologist (7 days/yr.)	*$*	*2,600*
Legal Fellow (2 days/yr.)	*$*	*400*
Subtotal	*$*	*3,000*
DAR CRAMP Site		
Field Work (1 day /yr.)	*$*	*1,600*
Cramp Data Analysis	*$*	*1,500*
Subtotal	*$*	*3,100*
Fish Monitoring		
Fish Surveys (3 days/yr.)	*$*	*6,600*
Fish Data Analysis	*$*	*600*
Subtotal	*$*	*7,200*
Coral Disease Assessment		
Monitoring Cost (12 days/yr.)	*$*	*22,800*
Coral Disease Analysis	*$*	*4,000*
Subtotal	*$*	*26,800*
Research Contracts		
Awardable Research	*$*	*50,000-100,000*
Current Annual Budget	*$*	*40,100*
Needed Annual Budget	***$***	***140,100***

Fish Monitoring

DAR conducts fish monitoring trips to Molokini three times a year. These fish surveys follow standardized methodology to determine fish biomass to the species level. The recording of fish biomass provides data to compare Molokini to other areas in the state. The total cost for the Fish Monitoring is $7,200 annually.

Coral Disease Assessment

Coral disease outbreaks are indicators that something is out of balance in the environment (Work et al., 2012). The ability to understand causes and drivers of coral disease are important to inform management decisions to prevent future coral disease outbreaks. The cause of these diseases can be both local and global in context. The continued documentation of coral disease at Molokini is critical to better understand current and future management decisions. The total cost for the coral disease assessment is $26,800. The work consists of 12 site visits at $1,900 per visit, and coral disease analysis at $4,000 annually.

Table 7: Current and needed budget for DOCARE enforcement.

Enforcement (DOCARE) Budget Summary		
DOCARE Officer Hourly (4 hr. minimum)	$	40
DOCARE Vessel Hourly (4 hr. minimum)	$	50
Required Staff for Vessel Operations		3
5 DOCARE visits/yr. (current amount)	**$**	**3,400**
12 DOCARE visits/yr. (enhanced)	$	8,160
52 DOCARE visits/yr. (needed)	$	35,360

DOCARE Enforcement

The Division of Conservation and Resources Enforcement (DOCARE) provides the enforcement for laws that serve to protect the natural and cultural resources of Hawai'i. DOCARE estimated their annual visits to Molokini at 3-5 visits per year. These visits usually overlapped with patrols within the Humpback Whale Sanctuary. These trips do not have any direct cost for Molokini but it can be estimated to be valued at $3,400. An increase in DOCARE presence at Molokini would be advantageous, however funding and time constraints currently prevent this; Molokini receives a majority of its daily traffic from the commercial tours operators between 7:30am and 10:30am. The presence of DOCARE during tour operator hours would be valuable to make sure no vessels are partaking in illegal commercial operations within the MCLD. In addition to this, random spot checks in the afternoon and night at Molokini would be beneficial. To increase the DOACRE presence to once a month, the budget would be $8,160. To increase DOCARE presence at Molokini to weekly, it would be $35,360.

Game Camera

Table 8: Current and needed game camera budget

Game Camera Budget Summary		
Camera, Parts & Installation	$	750
Data Analysis (35/hr) (2 days/month)	$	6,720
Current Annual Budget	$`	0
Needed Annual Budget	**$**	**7,470**

The addition of a game camera would give managers and DOCARE officers the ability to monitor activity at Molokini remotely. The afternoon and night activity is currently unknown. There is also the possibility of illegal fishing within the MLCD boundary. The purchase of a remote game camera would cost a total of $750, and would include all materials and installation of the camera. The additional $750 annually would fund upkeep and replacement materials. In addition to this, there would be a $6,720 annual budget for the analysis of photos. The camera would have the ability to remotely transfer data to either e-mail or a cell phone for constant updates to managers and DOCARE officers. The addition of a game camera and the data analysis would have a total annual budget of $7,470.

Education Program

The Molokini CAP determined an education program to be a project objective. An education program would provide the visitors with basic knowledge of reef etiquette and the natural and cultural history of Molokini. For this program to be successful and implemented $25,000 is needed to finish creating training materials to educate Molokini naturalist. Once this material is completed an annual budget of $5,000 would be used to implement trainings three times per year.

Maui Nui Seabird Recovery Project Budget

Table 9: Current and needed seabird recovery project budget

Maui Nui Seabird Recovery Project Budget Summary		
Staff Time (Preparation , Field Day & Data Processing)	$	1,500
Skilled Volunteer Labor (In-Kind) $25/hr	$	1,400
Equipment & Materials	$	200
Transportation Fuel Cost	$	200
Transportation Captain & Crew Time	Donation	
Ant Eradication Project (one time project)	$	75,600
Curent Annual Budget	$	0
Needed Annual Budget	**$**	**3,300**

Molokini is home to a variety of seabirds, the dominate species is the Wedge-tailed shearwater (*Ardenna pacifica*) and other species observed include Great Frigatebirds *(Fregata minor)*, Bulwer's Petrel (*Bulweria Bulwerii*),Red-footed Boobies *(sula sula),*

White-tailed Tropicbirds *(Phaethon lepturus),* and Red-tailed Tropicbirds *(Phaethon rubricauda)*. Of these birds species, the Wedge-tailed Shearwater and the Bulwer's Petrel are nesting and possibly Red-Tailed tropic birds. The Maui Nui Seabird Recovery Project (MNSRP) started documenting and banding chicks at Molokini in 2008, a continuation of the work by Dr. Fern Duvall DOFAW. To conduct this work MNSRP visits Molokini for a single day annually with a budget of $3,300. For a budget break down please refer to Table 9. In addition to this work MNSRP is seeking funding from U.S Fish and Wildlife Services to perform an eradication of the tropical fire ant (*Solenopsis gemenata).* The tropical fire ant is extremely abundant and detrimental to the success of seabirds breeding on Molokini. The ant eradication project would have a large upfront cost of $75,600, followed by a smaller reoccurring cost.

Budget Summary

Molokini MLCD is currently managed with an annual budget of $40,100. This budget is well below the minimum budget to effectively manage the MLCD. The budget for this scenario includes DAR administrative costs to process user permits, survey the Coral Reef Assessment and Monitoring Program Site (CRAMP Site), and conduct fish monitoring and coral disease assessments. This is the baseline budget to which other scenarios are added. The *needed* management scenario annual budget for Molokini would be $232,371. In addition to the current budget the *needed* management scenario includes mooring maintenance, additional conservation practices, enforcement and education. This scenario provides funding for several objectives and strategies from the Molokini CAP. The scenario includes funds for short term projects for example ant eradication for the protection of nesting seabirds and the development of an education certification class for tour operators, crew and naturalist.

Table 10: Comparison of current and needed annual budget

Budget Sections	Current Annual Budget	Needed Annual Budget
Mooring Maitenance	$ -	$ 41,141
Marine Conservation	$ 40,100	$ 140,100
Enforcement	$ -	$ 35,360
Game Camera	$ -	$ 7,470
Education	$ -	$ 5,000
Seabird Recovery	$ -	$ 3,300
Total Budgets	$ 40,100	$ 232,371

Appendix 3: Alternate Funding Methods

Special Fund Financial Mechanism

A special fund is designed to account for and hold revenue designated for a particular purpose. Hawai'i Revised Statutes', Section 37-62, defines a special fund as one that is "dedicated or set aside by law for a specified object or purpose, but excluding revolving funds and trust funds."(State Auditor, 2015) The establishment of a special fund for Molokini MLCD or the MLCD Program as a whole shall only be established pursuant to an act of the legislature. The considerations of a special fund are as follows: (1) serves the purpose for which it was originally established; (2) reflects a clear nexus between the benefits sought and charges made upon the users or beneficiaries of the program, as opposed to serving primarily as a means to provide the program or users with an automatic means of support that is removed from the normal budget and appropriation process; (3) provides an appropriate means of financing for the program or activity; (4) and demonstrates the capacity to be financially self- sustaining. [L 2002, c 178, pt of §2](State Auditor, 2015)

The establishment of the special fund for Molokini MCLD or the MLCD Program would be the collection of user fees from individuals within the MLCD Program. It has been documented in conservation finance research that small user fees for conservation measures do not affect visitor attendance. A suggested user fee would be that of $1 per person for entrance into the Molokini MLCD. The collected money would be deposited into a special fund for Molokini; any funds exceeding the agreed upon budget for Molokini would be applied to the MLCD Program. These additional funds would then be used for the purposes of monitoring, research, regulatory measures, enforcement actions, education activities, MLCD mooring input or maintenance and/or any other marine conservation and resources enhancement within the MLCD Program.

The Molokini user entry information data suggest a current estimated entrance of approximately 333,000 visitors annually; this would generate $333,000 of funding annually for the Molokini Shoal MLCD. It should be noted that tourism revenue can be tricky to predict and subject to decline from outside factors, this concern must be noted and cautioned with tourism funding sources. Diverse funding sources or financial reserves may need to be considered.

Table 11: Individual user fee applied at $1 per person to use for a special fund.

Individual User Fee Financial Mechanism		
Avg. Annual Visitors	User Fee Per Person	Annual Earnings
333,000	$ 1	$ 333,000

Kahekili Herbivore Fishery Management Area
Quality-Assured Water Quality Monitoring

Sediment delivery to coral reefs via Honokowai Stream highlights the need for water quality monitoring in the Kahekili Herbivore Fishery Management Area. Photo credit: Maui News

The development of a Quality Assurance Project Plan (QAPP) was determined to be the best fit for TNC support of the Kahekili Herbivore Fishery Management Area (KHFMA)'s CAP priorities. TNC's role was to participate in team meetings to discuss priority setting and implementation progress, and to include KHFMA in a meeting in May 2014 to develop a Maui Nui (QAPP) for water quality monitoring and to seek additional funding for its implementation.

TNC staff worked with partners to identify monitoring team leaders for community groups, including the Kahekili Fisheries Management Area (FMA), and selected long-term sampling sites in the Wahikuli and Honokowai watershed coastlines based on the input from the West Maui Ridge to Reef working group. These sites will be used for long-term community sampling, and are currently not sampled continuously by the State of Hawai'i's Department of Health (DOH).

Through a grant from the National Fish and Wildlife Foundation, we purchased the initial equipment to begin sampling, worked with potential volunteers to make sure that our standard operating procedures were clear and understandable, and consulted with Quality Assurance agents at DOH to standardize our methods. We completed a pilot test run of the equipment and protocols with prospective volunteers with the turbidity and multiparameter probes to see how well the step-by-step standard operating procedures (SOPs) worked. The results were favorable, in that the volunteers were able to take and record samples using the SOPs. Small corrections were made to improve the protocols.

This project supports the Kahekili FMA by generating quality-assured data that can be used to improve the quality of their coastal waters by addressing land-based sources of pollution. **See the** Quality Assurance Project Plan below.

Hui O Ka Wai Ola
Quality Assurance Project Plan

Prepared for:

Hui O Ka Wai Ola

Prepared by:

Scott Larned, The Nature Conservancy of Hawai‘i

Dana Reed, Maui Nui Marine Resource Council

Kim Falinski, The Nature Conservancy of Hawai‘i

Refer correspondence to:

Kim Falinski

The Nature Conservancy

923 Nu‘uanu Ave, Honolulu HI 96817

Revision: 1.0v17-2016

Date: 05/08/2016

19 **Approval List**

Name	Phone, Fax, Email	Mailing Address
HI-DOH, Clean Water Branch Watson Okubo	(808) 586-4309 watson.okubo@doh.hawaii.gov	Hawaii Department of Health 919 Ala Moana Blvd, Room 301 Honolulu, HI 96814-4920
Maui Nui Resource Council Robin Newbold	(808) 276-7025 robin@mauirobin.com	
The Nature Conservancy Maui Marine Program Director Emily Fielding	808-856-7668 efielding@tnc.org	81 Makawao Avenue #203A Pukalani, HI 96768
Hui O Ka Wai Ola Quality Assurance Officer	808-587-6216 kim.falinski@tnc.org	923 Nuuanu Ave Honolulu, HI 96817

20

21

Signature Page

_____

Watson Okubo, HI Department of Health, Clean Water Branch

_____

Emily, Fielding, The Nature Conservancy, Hui o Ka Wai Ola Project Manager

_____

Kim Falinski, The Nature Conservancy, Hui o Ka Wai Ola Quality Assurance Officer

Distribution List

The following people should receive a copy of this document. This document and any amendments will be distributed once all approval signatures have been received.

Name	Project Role	Address
Emily Fielding	Project Manager	The Nature Conservancy Maui Marine Program, PO Box 1716, Makawao, HI 96768
Kim Falinski	Quality Assurance Officer, Training Leader, Technical Advisory Board	The Nature Conservancy, Hawaii Marine Program, 923 Nuuanu Ave, Honolulu, HI 96817
Dana Reed	Monitoring Team Leader	Maui Nui Marine Resource Council, West Maui Ridge to Reef Initiative, 100 Ridge Road #1221, Lahaina, HI 96761
Roxie Silva	Monitoring Team Leader	The Nature Conservancy Maui Marine Program, PO Box 1716, Makawao, HI 96768
Dana Reed	Monitoring Team Leader	Maui Nui Marine Resource Council, Maui Coral Reef Recovery Plan Coordinator
Scott Larned	Technical Advisory Group	Freshwater Ecology, 10 Kyle St, Riccarton, Christchurch, New Zealand
Kathleen Ruttenberg	Technical Advisory Group	Department of Oceanography, University of Hawai‘i at Mānoa 1000 Pope Road, Honolulu, HI 96822
Tracy Wiegner	Technical Advisory Group	Marine Science Department, University of Hawai‘i at Hilo
Eric De Carlo	Technical Advisory Group	Department of Oceanography, University of Hawai‘i at Mānoa 1000 Pope Road, Honolulu, HI 96822
Craig Nelson	Technical Advisory Group	Department of Oceanography, University of Hawai‘i at Mānoa 1000 Pope Road, Honolulu, HI 96822
Ann “Frannie” Coopersmith	Technical Advisory Group	UH Maui College Science, Technology, Electronics, & Mathematics 310 Kaahumanu Avenue Kahului, HI 96732

Name	Project Role	Address
Curt Storlazzi	Technical Advisory Group	USGS, Pacific Coastal and Marine Science Center, 400 Natural Bridges Drive Santa Cruz, CA 95060
Patricia Bradley	Technical Advisory Group	USEPA, Atlantic Ecology Division, 27 Tarzwell Driver, Narragansett, RI 02882
Watson Okubo	Supervisor Monitoring and Analysis Section, Clean Water Branch	Clean Water Branch Department of Health 919 Ala Moana Blvd., Room 301 Honolulu, Hawaii 96814-4920
Myron Honda	Quality Assurance Officer, Environmental Management Division	Environmental Management Division Department of Health 919 Ala Moana Blvd., Room 300 Honolulu, Hawaii 96814-4920
Roland Asakura	Maui Environmental Health Specialist, Clean Water Branch	Clean Water Branch - Maui Maui District Health Office 54 High Street, Room 300 Wailuku, Hawaii 96793
Danielle Hull	SOEST Laboratory Manager	Marine Science Building RM406, University of Hawai‘i at Mānoa, Honolulu, HI 96822
Wendy Wiltse	USEPA District 9	Pacific Islands Contact Office, U.S. EPA, Region 9, P.O. Box 50003, Honolulu, HI 96850
Hudson Slay	USEPA District 9	Pacific Islands Contact Office, U.S. EPA, Region 9, P.O. Box 50003, Honolulu, HI 96850

40

41

Table of Contents

Approval List ii

Signature Page iii

Distribution List iv

List of Tables viii

List of Figures viii

Acronyms and abbreviations ix

1. Introduction 1

2. Project Management 1

2.1. Project Organization 1

2.1.1. Ongoing project roles 5

2.1.2. Advisory group 7

2.1.3. Laboratory facilities 8

2.1.4. Data users 8

2.2. Documentation and records 8

3. Problem Definition 9

3.1. Problem statement 9

3.2. Mission and goals 9

3.3. Sampling and analysis summary 10

3.4. Quality assurance objectives 11

4. Measurement and Data Acquisition 13

4.1. Sampling Design 13

4.1.1. Monitoring sites 13

4.1.2. Sampling schedule 13

4.1.3. Field measurements 14

4.1.4. Laboratory analyses 16

4.1.5. External data sources 17

4.2. Sampling methods 18

4.3. Sample handling and custody Requirements 19

4.3.1. Sample transport 19

4.3.2. Sampling bottles and preservation 19

4.3.3. Sample chain-of-custody 21
4.3.4. Sample labeling 21
4.4. Analytical methods 21
5. QA/QC Requirements 23
5.1. Instrument and equipment maintenance, testing, inspection and calibration 23
5.2. Sampling 24
5.2.1. Field calibration and maintenance 24
5.2.1. Field duplicates and sample blanks 25
5.3. Shipping and handling 26
5.4. Training requirements 26
5.5. Laboratory analyses 27
5.5.1. Water quality laboratory facilities 27
5.5.2. Bacterial testing laboratory facilities and equipment 28
5.5.1. Analytical lab quality control: replicates, standards and blanks: 29
5.6. Data Management 33
5.6.1. Documentation standards 33
5.6.2. Field data management 33
5.6.3. Analytical laboratory data management 34
5.6.4. Access 35
5.6.5. Reporting 35
5.7. Assessment and Oversight 35
6. Data Quality Assessment 36
6.1. Data validation and verification methods 36
6.1.1. Field Parameters Verification 37
6.1.2. Laboratory Data Verification 37
6.2. Reconciliation with data quality assurance objectives 37
7. References 39
Appendix List 40

List of Tables

Table 2-1: Key personnel for the Hui O Ka Wai Ola program. TBD: to be designated..... 3
Table 4-1: Field instruments for measurements of in-situ parameters. 15
Table 4-2: Analytical methods used in water quality analysis. 16
Table 4-3: Sources of external data. Station numbers in parentheses..... 18
Table 4-4: Seawater sample handling and preservation. 20
Table 5-1: Calibration schedule and field check criteria; The field check criteria is the largest range within the instrument is expected to be functioning. 24
Table 5-2: Field instrument performance specifications. 25
Table 5-3: Quality control sampling activities in laboratory and field, with frequencies 31
Table 5-4: Acceptable analytical methods and quality control acceptance criteria. RPD: relative percent difference, based on duplicate samples. 32

List of Figures

Figure 2-1: Hui O Ka Wai Ola organizational chart..... 4

Acronyms and abbreviations

COC	Chain of custody
CWB	Clean Water Branch
HAR	Hawai‘i Administrative Rules
HI-DOH	State of Hawai’i Department of Health
MNMRC	Maui Nui Marine Resource Council
MPN	Most Probable Number of Colony Forming Units
PM	Project Manager
QAPP	Quality Assurance Project Plan
QA Officer	Quality Assurance Officer
QC	Quality Control
S-LAB	SOEST Laboratory for Analytical Biogeochemistry
SOEST	School of Ocean and Earth Science and Technology
SOP	Standard Operating Procedures
TAG	Technical Advisory Group
TMDL	Total maximum daily load
TNC	The Nature Conservancy
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WRRC	Water Resources Research Center

1. Introduction

This Quality Assurance Project Plan (QAPP) has been prepared for water-quality monitoring along the Maui Island coastline to assist the State of Hawai'i Department of Health Clean Water Branch (HI-DOH-CWB) beach monitoring Program. This document was prepared by members of Hui O Ka Wai Ola, a community-based, quality-assured coastal-monitoring program based on Maui Island. The project was initiated in 2014 by the following partner organizations: The Nature Conservancy (TNC), Maui Nui Marine Resource Council (MNMRC), NOAA Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS), West Maui Ridge-to-Reef Initiative, University of Hawai'i-Maui College (UHMC) and University of Hawai‘i at Mānoa Water Resources Research Center (WRRC).

The monitoring activities of Hui O Ka Wai Ola program are intended to begin in 2016. The overarching goals of the program are to increase the capacity for monitoring water quality in Maui coastal waters by generating reliable data that can be used to assess long-term water-quality conditions and detect temporal trends. These data will augment the data produced by the HI-DOH-CWB beach monitoring program on Maui. To reach these goals, Hui O Ka Wai Ola is organizing a network of monitoring teams drawn from watershed stewardship groups that will operate under the same quality assurance guidelines outlined in this document. The teams will be trained in monitoring procedures, and will conduct regular monthly monitoring and opportunistic, event-based monitoring at sites in Maui's coastal waters at predetermined sites. Producing reliable water-quality data will require that the teams work with water-quality professionals to operate in accordance with an approved QAPP.

This document defines the scope of the program, sets out the organization and goals of the project, and describes the quality control and quality assurance (QC/QA) procedures that will be used to ensure that data generated in the program are accurate, complete, and representative of actual field conditions. The content and format of this QAPP follows the requirements and guidance of the United States Environmental Protection Agency (USEPA) QA/R-5, EPA Requirements for Quality Assurance Project Plans (U.S. Environmental Protection Agency 2001). Detailed procedures for water-quality monitoring are provided in Standard Operating Procedures (SOPs), which are also included in this document.

2. Project Management

2.1. Project Organization

The Hui O Ka Wai Ola program will consist of four monitoring teams, each with a team leader, who are supported by a centralized group that will provide project management, data management, and technical advice. Each team will monitor one of the following sections of Maui coastline: Māʻalaea to ʻĀhihi-Kīnaʻu, Lahaina to Olowalu, Hāna to Kahului, Honolua to Wahikuli. All teams will use identical calibration, operating and handling procedures (Appendix

A, Standard Operating Procedures) to measure the same suite of water-quality parameters or some subset of the parameter suite based on resources available to each regional team.

The six primary roles for participants in the Hui O Ka Wai Ola program are Project Manager (PM), Quality Assurance Officer (QA officer), Monitoring Team Leader, Training Leader, Monitoring Team Member, and Technical Advisory Group (TAG) member. In general, the PM is responsible for administering and coordinating the program; the QA officer is responsible for data management and program quality assurance and quality control (QA/QC), and management of QAPP review and update; the monitoring team leaders and monitoring teams are responsible for field monitoring, some laboratory analyses, and training of new team members; the training leader is responsible for preparing and conducting training sessions; and, the TAG is responsible for providing guidance on technical issues such as instrumentation and sample processing. In addition, the Hui O Ka Wai Ola project has a working group composed of representatives of the organizations that established the project. The working group is responsible for strategic decisions such as the geographic scope of the project, outreach, and coordinating with community organizations and agencies. Specific responsibilities are set out below. Figure 2.1 and Table 2.1 show the personnel designated for the roles in Hui O Ka Wai Ola.

Note that the PM can seek advice from the supervisor of the HI-DOH-CWB Monitoring and Analysis Section, from the TAG and from the director of the SOEST Laboratory for Analytical Biogeochemistry (S-LAB). The QA Officer can seek advice from the QA Officer at HI-DOH-CWB. The QA Officer operates independently from the PM and the monitoring teams.

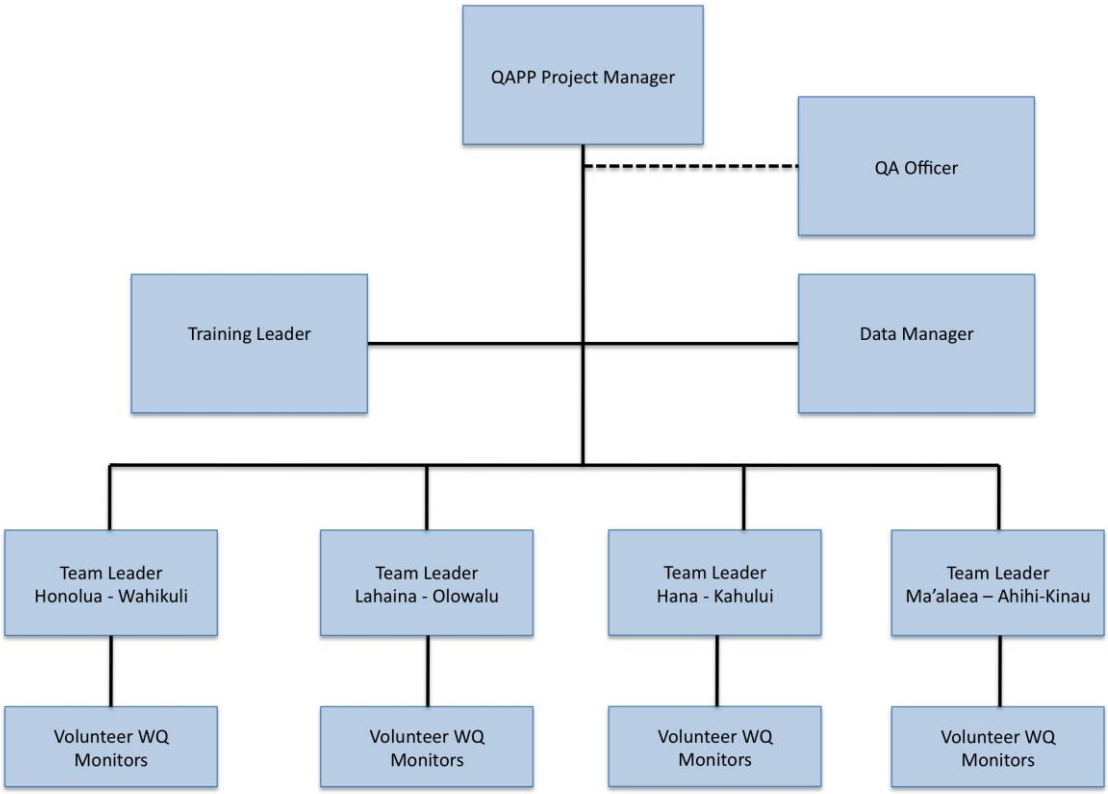
196

197 **Table 2-1: Key personnel for the Hui O Ka Wai Ola program. TBD: to be designated.**

Name	Project Role	Affiliation
Emily Fielding	Project Manager	The Nature Conservancy, Hawaii Marine Program
Kim Falinski	QA Officer, Training Leader, Technical Advisory Group	The Nature Conservancy, Hawai Marine Program
Watson Okubo	Supervisor, Monitoring and Analysis Section, Clean Water Branch	Clean Water Branch, Department of Health
Myron Honda	Quality Assurance Manager, Environmental Management Division	Environmental Management Division, Department of Health
Roland Asakura	Maui Environmental Health Specialist, Clean Water Branch, Maui District Health Office	Clean Water Branch, Department of Health
Danielle Hull	Analytical Laboratory Manager	SOEST S-LAB, University of Hawai‘i at Mānoa
Dana Reed	Monitoring Team Leader – Lahaina to Olowalu	Maui Nui Marine Resource Council
Roxie Sylva	Monitoring Team Leader – Hāna to Kahului	The Nature Conservancy of Hawaii
TBD	Monitoring Team Leader – Mā‘alaea to ‘Āhihi-Kīna‘u	University of Hawai‘i, Maui College
Dana Reed	Monitoring Team Leader – Honolua to Wahikuli	Maui Nui Marine Resource Council, West Maui Ridge-to-Reef Initiative
TBD	Data Manager	

198

Technical Advisory Group	Affiliation
Kim Falinski	The Nature Conservancy
Scott Larned	NIWA New Zealand
Kathleen Ruttenberg	Department of Oceanography, University of Hawai‘i at Mānoa
Tracy Wiegner	Marine Science Department, University of Hawai‘i at Hilo
Craig Nelson	Department of Oceanography, University of Hawai‘i at Mānoa
Curt Storlazzi	USGS, Pacific Coastal and Marine Science Center
Patricia Bradley	USEPA, Atlantic Ecology Division
Eric De Carlo	Department of Oceanography, University of Hawai‘i at Mānoa
Wendy Wiltse	USAEPA, Pacific Division
Hudson Slay	USAEPA, Pacific Division



199

Technical Advisory Group

Scott Larned – Nature Conservancy Hawaii
Kim Falinski – UH Manoa Water Resources Research Center
Kathleen Ruttenberg – UH Manoa Oceanography
Craig Nelson – UH Manoa Oceanography
Eric De Carlo – UH Manoa Oceanography
Tracy Wiegner – UH Hilo Marine Sciences
Curt Storlazzi – USGS
Patricia Bradley – EPA
Wendy Wiltze – EPA
Hudson Slay – EPA

Analytical Laboratory

School of Ocean and Earth Science and Technology (SOEST) Lab
Rebecca Briggs

200

201 **Figure 2-1: Hui O Ka Wai Ola organizational chart**

202

2.1.1. Ongoing project roles

Project Manager

The PM is responsible for administering the project and coordination and communication with partner organizations. Specific responsibilities for the PM are:

- Assist with program start-up, and ongoing communications with community groups, MNMRC, TNC, HI-DOH, HIHWNS and the S-LAB.
- Coordinate facilities, equipment and supply purchases, payments for analytical services and sample shipping, maintain supply inventory, reorder supplies as necessary.
- Coordinate monitoring team training with the training leader, QA Officer, team leaders and community organizations (through the working group).
- Manage permitting and paperwork (e.g., health and safety, boating, volunteer waivers).
- Provide ongoing program oversight (e.g., ensure samples get shipped to analytical lab, data gets reviewed by QA officer and uploaded). Maintain program membership and contact lists.
- Lead changes in monitoring design as necessary (e.g., parameters, procedures, locations).
- Coordinate additions of new groups and new sites to the program, and maintain records of document training class completion.
- Liaise with other monitoring groups and agencies. Represent program at workshops and conferences.
- Assist the working group with grant proposal preparation and other fundraising efforts.
- Resolve challenges encountered by monitoring teams (e.g., beach access).

Quality Assurance Officer

The QA Officer is responsible for ensuring that the project is carried out according to the QAPP. Specific QA Officer responsibilities are:

- Conduct data review, validation and verification, including reviewing data prior to submission to HI-DOH to ensure that all information is accurate and conforms to the QAPP.
- Ensure that all field information is correctly documented.
- Maintain and oversee records (raw data sheets, laboratory reports, chain-of-custody forms, QC checks and calibrations, SOPs, QAPP, laboratory QA/QC plans, training records for monitoring team members).
- Assist in monitoring team training in field and laboratory procedures and data entry.
- Review the QAPP and SOPs twice per year. Identify required procedural changes. Update QAPP as necessary in coordination with DOH.
- Prepare SOPs (with training leaders and monitoring team leaders).

- Ensure that everyone on the distribution list has updated copies of the controlled documents (QAPP, SOPs, laboratory QA/QC plans, etc.).
- Review the field and lab data that has been entered into the database by the Data Manager to help minimize transcription/translation errors.

The QA officer must remain independent of all generation activities, including sample collection, field measurements and laboratory analyses.

Data Manager

The Data Manager is responsible for the data generated by the program, and is a single point of contact for data entry and storage. Initially, the duties assigned to the Data Manager will be performed by the Monitoring Team Leaders. Each site will have a database managed by a single person to enter data. Specific responsibilities for the Data Manager are:

- Enter field and laboratory data into program database.
- Return field and laboratory data sheets to the Program Manager for permanent archive.
- Backup the electronic database weekly.
- Modify the database as required if additional data fields become necessary.

Monitoring Team Leaders

The Team Leaders will be responsible for the volunteer monitoring teams. Four Team Leaders have been designated (Table 2-1). Specific responsibilities for the Monitoring Team Leaders are:

- Schedule monitoring dates and times with team members.
- Ensure that field conditions are safe for team members.
- Maintain, calibrate and properly store field and laboratory equipment.
- Ensure that all field measurements are made in accordance with the QAPP and associated SOPs.
- Ensure that samples for laboratory analysis are collected, processed, stored and shipped in accordance with the QAPP and associated SOPs.
- Ensure that original datasheets are filled out accurately and delivered to the QA Officer on schedule. Maintain copies of all datasheets.
- Store and ship applicable seawater samples for laboratory analysis after collection by Team Members.
- Train new members of the monitoring team using Training Leader training documentation and maintain training records.
- Maintain training documentation of team members.

All staff members associated with data generation (sample collection, field measurements, lab analysis, data analysis, data reporting, etc.) will also review the QAPP. The QAPP reflects the procedures that are actually in use or should be in use by all staff members. Review of the QAPP

by staff members helps to ensure that the procedures used are consistent with what is specified in the QAPP. Review of the QAPP must be performed at least once per year. Any inconsistencies identified by any staff member will be promptly resolved by the QA officer and PM.

Training Leader

The Training Leader is responsible for producing training materials and scheduling and leading training sessions. Specific responsibilities for the Training Leader are:

- Produce training modules consisting of class material and instructor's guide.
- Design field and laboratory demonstrations.
- Schedule training days and coordinate facilities and attendees with the PM.
- Present classroom, field and laboratory material to trainees, including demonstrations.
- Train the Monitoring Team Leaders to train other volunteers locally.
- Prepare SOPs with the QA Officer and the Monitoring Team Leaders.

Monitoring Team Members

The Monitoring Team Members will carry out water-quality monitoring tasks and some laboratory tasks, all under the supervision of the Monitoring Team Leaders. Specific responsibilities of the Team Members are:

- Make field measurements in accordance with the QAPP and associated SOPs.
- Collect, store, and process samples in accordance with the QAPP and associated SOPs.
- Carry out analyses of *Enterococcus*, suspended sediment and other parameters in accordance with the corresponding SOPs.
- Record monitoring information and sample custody information on data sheets and chain-of-custody (COC) forms accurately and completely.
- Complete annual training under the supervision of the Training Leader, and biannual check ups with the Monitoring Team Leader.

2.1.2. Advisory group

Consultation will be provided by the TAG, the HI-DOH Monitoring and Analysis Section Supervisor, the HI-DOH Clean Water Branch QA Officer, and the director of the S-LAB at the School of Ocean and Earth Science and Technology (SOEST) at the University of Hawai‘i at Mānoa.

The TAG currently consists of eight scientists with expertise in water-quality monitoring and data analysis, marine and estuarine biogeochemistry, soil watershed processes, and microbiology. The TAG members have agreed to provide technical advice and training to the PM, QA Officer, and monitoring team leaders. The current TAG members are listed in Table 2.1. The HI-DOH Monitoring and Analysis Section Supervisor will provide advice to the Hui O Ka

Wai Ola PM, and the HI-DOH Clean Water Branch Quality Assurance Officer will provide advice to the Hui O Ka Wai Ola QA Officer.

Strategic planning and consulting will be provided by the Hui O Ka Wai Ola working group. The working group has representatives from the five partner organizations that established the project: The Nature Conservancy, Maui Nui Marine Resource Council, NOAA Hawaiian Islands Humpback Whale National Marine Sanctuary, West Maui Ridge-to-Reef Initiative, and UH-Maui College.

2.1.3. Laboratory facilities

Laboratory analysis services will be provided by the School of Ocean and Earth Science and Technology, Laboratory for Analytical Biogeochemistry (hereafter, S-LAB). The laboratory director of S-LABs has consulted with Hui O Ka Wai Ola to coordinate protocols on nutrient analyses, sample collection, processing and shipping, laboratory quality control.

The regional Maui laboratories will be used by volunteers to prepare and store samples for shipping to the S-LAB laboratory. These regional laboratories will also be used for testing water samples for *Enterococcus*, filtering samples in a clean environment, and determining suspended sediment concentrations (SSC) of the sites under test. Different regional laboratories have been identified to minimize the transport time from sample sites to the regional laboratories. Volunteers sampling at west Maui sites will utilize the microbiology lab at Lahainaluna High School. Volunteers sampling north Maui sites will utilize laboratory facilities at the University of Hawai‘i Maui College.

2.1.4. Data users

The primary users of data generated by Hui O Ka Wai Ola will be HI-DOH CWB. In addition, the data will be made available for public use and data analysis at multiple online locations. Details of data provision and public access are given in Section 5.5.1. Additional data users may include environmental scientists, fishpond operators, community organizations, high-school and college instructors, local and state and federal regulatory agencies, and participants in watershed restoration projects.

2.2. Documentation and records

Controlled documents for the Hui O Ka Wai Ola program include this document and laboratory QA/QC plans. Version control is maintained using a version number and effective date on the cover sheet of each document. This QAPP, any subsequent revisions or addenda, are reviewed and approved by the Project Manager and the QA Officer. When a new version is approved, it is distributed and the old versions are destroyed or marked “Obsolete.” It is the responsibility of the QA Officer to ensure that all relevant project personnel (including everyone on the distribution list) have the most current version. To ensure that they are up-to-date, the QAPP and associated

SOPs must be reviewed twice a year by the QA Officer with guidance from HI-DOH-CWB, and updated as needed.

This QAPP is valid for a period of no longer than five years from the date of approval. If major changes are made, the QAPP must be re-submitted for approval.

3. Problem Definition

3.1. Problem statement

Long term measurements to collect physical and chemical water-quality data are needed to assess current conditions in the coastal waters of Maui Island, to detect and quantify temporal trends in water quality, and to support water-quality management decisions. The suite of water-quality parameters for which data are needed include (but are not limited to) water temperature, salinity, pH, turbidity, dissolved oxygen and dissolved and particulate forms of nitrogen and phosphorus. In addition, data from measurements of fecal indicator bacteria such as *Enterococcus* are needed to assess the suitability of coastal waters for contact recreation. Coastal water quality is affected by the presence and concentration of many other chemical and microbial constituents (e.g., pesticides, dissolved metals, *Staphylococcus, Clostridium*). However, those parameters are out of scope for the Hui O Ka Wai Ola program.

HI-DOH CWB is currently responsible for nearshore water-quality monitoring in Maui coastal waters (hereafter, 'beach monitoring') and identifying water-quality impaired and unimpaired waters. Ongoing beach monitoring is required under the Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000. HI-DOH CWB uses beach-monitoring data for the state's biennial Integrated Water Quality Monitoring and Assessment Report to the USEPA (hereafter, 'integrated report'). The data may also be used for developing TMDLs for impaired water bodies, for assessing restoration and mitigation projects, and for basic environmental research. The most recent Water Quality Monitoring and Assessment Report includes assessments of 160 of 575 marine water-bodies in the state; the small proportion of water-bodies assessed was due to the limited availability of data (HI-DOH CWB 2014). Recent state budget cuts led to a reduction-in-force and position vacancies meaning that fewer coastal sites are monitored and there are less samples collected by CWB staff. The Hui O Ka Wai Ola program is intended to reduce this shortfall. Of the 160 assessed water bodies described in the 2014 integrated report, 85% were designated as impaired as they did not attain state numeric water-quality criteria for at least one or more pollutant. The large proportion of impaired sites provides an indication of the wide-spread water-quality problems in the Hawai'i coastal zone.

3.2. Mission and goals

The mission of Hui O Ka Wai Ola is to generate quality-assured coastal water-quality data, and to provide this data to HI-DOH, other resource agencies, non-governmental organizations, researchers and the public.

Specific goals of Hui O Ka Wai Ola are to 1) increase community capacity for long-term monitoring water quality in Maui coastal waters; 2) generate quality-assured reliable data that can be used to assess coastal water quality conditions and detect temporal trends that can augment HI-DOH CWB beach monitoring program sampling and be compared to state standards; 3) thereby empowering community and government mangers to take action to improve coastal water quality, benefiting the coral reef ecosystem and people alike.

We anticipate that HI-DOH CWB will use data from the Hui O Ka Wai Ola program for preparing integrated reports to USEPA, and potentially for TMDL development.

The Hui O Ka Wai Ola data will be distributed for use by the HI-DOH, non-profit partners, and academic researchers for future analyses.

3.3. Sampling and analysis summary

Data collection will include measurements of physical parameters of coastal waters including temperature, salinity, turbidity and pH. Chemical parameters collected will include dissolved nutrient analysis of water samples, conducted at S-LABs at the University of Hawai‘i at Mānoa. Lastly, biological parameters include bacteria analysis for *Enterococcus*, analysis will be conducted at the regional Maui laboratories as described in this document. External continuous data inputs including rainfall, ocean conditions and stream flow conditions provided by outside agencies. Additional observations will include weather conditions, beach use and qualitative water quality notes.

Analytical work will follow the guidance of the HI-DOH and the EPA as found in the Water Quality Standards Handbook (EPA Section 304(a)). SOPs are included that describe methods for operating and maintaining the equipment required to collect and process the collected water samples. Sampling methods and analytical procedures meet the water quality standards available from U.S. EPA Region IX (Hawaii Administrative Rule 11-54). Quality control of the data will be established through the identification of consistent sampling sites, documentation of uniform procedures, and analysis of duplicate samples and laboratory control samples as described in Section 4.5 of this QAPP. Individual samples exceeding the limits specified in HAR 11-54 will be reported to the CWB for possible follow-up action.

The sampling will be carried out at multiple sites along the northern and western Maui coast, from Kahuli to Ahihi-Kinau. Samples will be collected from the nearshore environment at locations noted in Appendix B. There is no specified end date to sampling, as the project strives to achieve a long term continuous data collection effort, however this QAPP covers a five year period from its approval. After the initial five year period, the QAPP will undergo review before it is re-submitted for approval again. Sites that do not meet HI-DOH water quality standards will be reported to the CWB for evaluation as soon as practicable.

3.4. Quality assurance objectives

The goal of the Hui o Ka Wai Ola QA/QC program is to ensure that all data collected by the Hui volunteers are scientifically sound and of known and documented quality. Integrating quality control procedures into water-related monitoring activities, including collection, analysis, validation, reporting, sample storage, and dissemination of data requires implementation of standardized procedures, adequate documentation, and training of volunteers[1].

The QA/QC Program provides guidance documents and technical training to help ensure that sufficient QA measures are established before sampling. The QA objectives of this effort are:

- Study design is statistically sound (sampling sites are representative of the environment, number of samples have appropriate power)
- Proper sampling, equipment and analytical procedures are used
- Field and lab volunteers are properly trained
- QC samples such as blanks and replicates are incorporated in sampling plans
- Sample chain of custody procedures are in place
- Labs analyzing the data follow appropriate QC procedures
- The QA officer performs lab results validation in a timely manner
- Corrective actions are applied when QC measures identify errors, or defects at any point in the data acquisition process
- The data management system is adequate to ensure archival and retrieval of analytical results with all their metadata

This QAPP describes efforts to reduce sampling and analytical bias through careful selection during the planning process of the sampling locations (Section 4.1), sampling times, sampling amount (volume), sampling frequency (or estimates) and the total number of samples (or estimates) for a given location and careful adherence to the established plan. In addition to standard practices described in Section 4, quality control measures are presented in Section 5 and Appendix D.

The PARCCs parameters are used to describe the quality of analytical data in quantitative and qualitative terms using the information provided by the laboratory quality control information. The PARCCs parameters – precision, accuracy, representativeness, comparability, completeness, and sensitivity – are described below.

Precision

Precision will be quantified in the field through replicate measurements of physical and chemical parameters, including pH, turbidity, salinity, temperature and dissolved oxygen. The laboratory

[1] State of California, Department of Water Resources

analyses will include replicate measurements, splits and repeated measurements of the same sample to assess the precision of the data.

Accuracy

Accuracy is controlled by adequate calibration and verification. We plan to adhere to calibration schedules recommended by manufacturer and intend to verify accuracy before every trip out into the field by using verification standards (pH, salinity) or secondary standards (turbidity meter). Temperature will be verified by comparison with a NIST thermometer if we have one.

Measurement error is generated by variation in the operation, calibration and output of sensors and other measurement instruments. Instruments will be maintained, checked for drift, with a documented precision and accuracy (Table 5-1). Calibration schedules are presented in Tables 5-1 and 5-2 to ensure that the equipment is functioning according to specifications.

Representativeness

Representativeness of the data collected in monitoring projects is considered in the sampling design and field plan, especially in site selection and by sampling at the same time of day. It will not be routinely monitored throughout the project, but will need to be considered when interpreting the data. It is obvious that water flowing past a given location on land is constantly changing in response to inflow, tidal cycle, weather, etc. Periodic collection of data can help develop a better understanding of the variance associated with time series measurements of selected environmental variables. Such data collection can also provide increased resolution and sensitivity to localized and short term effects of storm events.

Comparability

Comparability will be assured by using standardized sampling and analytical methods, units of reporting, site selection procedures, adherence to the specified sampling design, and proper training of lab and field personnel. Analytical comparability will be determined by the use of split samples between the different labs and a reference lab.

The protocols used for nutrient, sediment and bacterial concentrations are described in Section 4. The protocols are specific so as to document the procedures to be reproduced by another laboratory, if necessary.

Completeness

Completeness will be measured as the percentage of total samples collected that were analyzed as a whole and for individual parameters and sites. We anticipate sampling efforts to be either weekly, bi-monthly or monthly, depending on community resources.

4. Measurement and Data Acquisition

4.1. Sampling Design

The following sampling design describes sampling and measurement of the following suite of water-quality parameters: water temperature, salinity, dissolved oxygen (DO), pH, turbidity, ammonia nitrogen (NH4), nitrate + nitrite nitrogen (NNN), dissolved reactive phosphorus (DRP), total dissolved nitrogen and phosphorus (TDN and TDP), particulate nitrogen and phosphorus (PN and PP), dissolved silica, suspended sediment concentration (SSC), and *Enterococcus*.

4.1.1. Monitoring sites

Sampling will take place at predetermined dates and times at sites selected in advance and consistent within 10 m. The sites identified are listed in Appendix B, with the first sites to be sampled focusing on west Maui. Additional sites will be selected through consultation with HI-DOH and community groups. The CWB will be informed of all new and eliminated sites. Monitoring sites will include sites that were formerly part of the HI-DOH beach monitoring program, but discontinued or monitored at a significantly reduced periodicity due to funding cuts. Resumed monitoring at these sites will serve to extend existing data time-series, and provide data for sites that lack sufficient data for assessment. Priority will be given to sites that have active management partners interested in the resulting data. Other criteria for site selection will be priority watersheds and sites in watersheds with CWA Section 319-funded projects already underway.

The following criteria are used to evaluate monitoring sites with community partners:

- Access is safe,
- Location is adjacent to a public access point, or permission to cross private property is granted,
- Samples can be taken in areas of well-mixed water,
- Samples will be representative of a broad area around the sampling point,
- Location corresponds to a CWB monitoring site, particularly a site where monitoring has been discontinued, or monitored at a significantly reduced periodicity
- Location represents an area with high recreational use, high importance for food gathering, or high community concern about perceived water-quality problems, and/or
- Location coincides with environmental research areas with potential for data-sharing.

4.1.2. Sampling schedule

Two general monitoring modes will be used: regularly scheduled monitoring at fixed sites, and unscheduled (opportunistic) monitoring in response to rain and runoff events at affected sites.

The **pre-scheduled monitoring** will take place regardless of current and antecedent weather conditions, unless safety is a concern. This sampling mode will produce an unbiased estimate of average water-quality conditions at each site. For each monitoring team, the constituents to be analyzed and the frequency of the sampling will be pre-determined. At minimum, active sites will be sampled once per month. Some sites might be sampled at a greater frequency during certain seasons or if resources allow for more frequent sampling for that site. in the wet or dry seasons. To minimize bias, samples will be taken at the same time of day (for instance at 10a) on a predetermined day and time of the month, depending on the weather. Sampling will be delayed by a day if there is high surf making sampling unsafe.

Opportunistic monitoring will be used to measure water-quality conditions during and after large, infrequent rainstorms, to generate information about water quality during brown-water periods and about relationships between runoff and water quality. Samples will be collected at the first safe opportunity after the storm has passed.

4.1.3. Field measurements

Instantaneous temperature, salinity, dissolved oxygen (DO), pH, and turbidity measurements will be made at the monitoring sites by the monitoring teams using hand-held instruments. Dissolved and particulate nutrients will be measured at the SOEST Analytical Laboratory in samples collected, filtered and shipped by the monitoring teams. SSC and *Enterococcus* will be measured by the monitoring teams at laboratory facilities on Maui.

Procedures for in situ measurements, and sample collection and processing are described in the SOPs attached to this QAPP. The SOPs related to sample collection, processing and parameter measurements are listed in Table A.1.

Water-quality parameters measured in the field and the instruments used for those measurements are listed in Table 4.1. The instruments in Table 4.1 are intended to be comparable to the instruments used by HI-DOH-CWB. They are currently in production, so replacement parts and repair services are available. The sensor specifications indicate that they are accurate and precise. The primary departure from the HIDOW-CWB instruments is the dissolved oxygen sensor listed in Table 4.1. HIDOW-CWB uses a Clark-type polargraphic sensor with electrolyte and membrane. These sensors require frequent maintenance and calibration, and are affected by variation in water motion, oxygen consumption at the membrane surface, and signal drift. To avoid this issue, the Hui O Ka Wai Ola program will use optical sensors (optodes) that require annual calibration and minimal maintenance, do not consume oxygen, and provide comparable accuracy and precision. The operation, maintenance and calibration of these instruments are set out in Section 4.3 and the operating manuals (Appendix A).

Table 4-1: Field instruments for measurements of in-situ parameters.

Parameter	Method/instrument	Units
Water temperature	NSIT-traceable waterproof digital Thermometer	°C
Salinity/ electrical conductivity	Hach HQ40d meter and IntelliCAL CDC401 conductivity probe	PSU µS/cm
Dissolved oxygen concentration/ % saturation	Hach HQ40d meter and IntelliCAL LDO101 dissolved oxygen probe	mg/L %
pH	Hach HQ40d meter and IntelliCAL PHC101 pH Electrode	pH
Turbidity	Hach 2100Q turbidometer	NTU

4.1.4. Laboratory analyses

The S-LAB at the University of Hawai'i Mānoa will carry out dissolved nutrient and silicate analyses, and particulate analyses for nitrogen and carbon. *Enterococcus* measurements and suspended sediment measurements will be carried out in satellite laboratory facilities on Maui, as described in Section 2.1.3. Methods numbers for the standardized analyses are listed in Table 4.2.

Table 4-2: Analytical methods used in water quality analysis.

Parameter	Method number or description	Method/instrument	Units
NH4	EPA Method 350.1	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg N/L
NNN	EPA Methods 353.2	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg N/L
DRP	EPA 365.1	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg P/L
TDN	UV-Digestion, EPA 353.2, Rev.2	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg N/L
TDP	EPA Method 365.1	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg P/L
Silicate	EPA Method 366.0	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg/L
PN	EPA Method 440.0	GF/F-filters, Exeter Elemental Analyzer	% by mass
PC	EPA Method 440.0	GF/F-filters, Exeter Elemental Analyzer	% by mass
Enterococcus	IDEXX Enterolert instructions	Fluorogenic substrate test (Idexx Enterolert Quanti-tray)	cfu/100ml
Suspended sediment	ASTM Method D3977-97B	Gravimetric, Dried at 103 - 105°C	mg/L

[1] Mean detection limit – reported as three times the standard deviation of the blank (n=15) for autoanalyzer samples

4.1.5. External data sources

Federal agencies will provide four types of external data from gauges and sensors with data recorders: streamflow, rainfall, physical ocean conditions and coastal water quality. Data from these sources will be downloaded from agency websites at yearly intervals to maintain relatively current datasets, and incorporated into the annual reports at the direction of the Project Manager. Additional rain gauges within the watershed may have data that will be included and annotated by source. The primary use of these datasets is to help understand variability in the monthly water-quality data produced by Hui O Ka Wai Ola, therefore, higher frequency downloads are not required. The gauge and sensor locations and station numbers are listed in Table 4.3.

Streamflow data

There are nine USGS-managed flow recorders currently operating on Maui streams, all of which are telemetered. All nine recorders are located above 300 feet elevation due to restrictions on channel morphology and to diversions at lower elevations. Therefore, flow data at the recorders does not represent flow at the coast near beach monitoring sites. However, synoptic and antecedent streamflow data will be useful for explaining variation in instantaneous coast water-quality conditions. Streamflow data will be downloaded quarterly from the USGS National Water Information System database by the Data Manager (http://waterdata.usgs.gov/hi/nwis/rt).

Rainfall data

The National Weather Service compiles data from eight low-elevation rain gauges that are currently operating on the Maui coast between Hana and Kihei. Data from the low-elevation gauges corresponds most closely to rainfall at the beach monitoring sites, due to the steep elevation rainfall gradients in Hawai‘i. Rainfall data will be downloaded from the National Weather Service hydrological data website (http://www.nws.noaa.gov/view/prodsByState.php?state=HI&prodtype=hydro), and the USGS rainfall gauging site at Pu‘u Kukui (http://waterdata.usgs.gov/nwis/uv?site_no=205327156351102).

Ocean condition data

The NOAA National Ocean Service and the Pacific Islands Ocean Observing System (PacIOOS) operate two telemetered monitoring buoys near Maui, one in Kahului Harbor and the other north of Pauwela in water 193 m in depth. Instruments on these buoys measure wind direction and speed, atmospheric pressure, air and water temperature, and wave height, period and direction. Data from these buoys will be downloaded from the National Data Buoy Center (http://www.ndbc.noaa.gov).

PacIOOS also operates two water-quality sensor platforms on the Maui coast, one in Kahului Harbor and the other at Kalama Beach, Kīhei. The Kahului platforms is telemetered and the sensors on the Kīhei platform are downloaded approximately monthly. The sensors measure salinity, water temperature, dissolved oxygen, pH, chlorophyll, turbidity and depth. Data from

the platforms will be downloaded from the PacIOOS data access program (http://oos.soest.hawaii.edu/erddap/index.html).

Table 4-3: Sources of external data. Station numbers in parentheses.

USGS stream gauge	Rain gauge	Ocean buoy	Water quality platform
Oheo (USGS)	Hana Airport (HNAH1)	Pawela offshore (51205)	Kalama Beach, Kihei (NS12)
W. Wailuaiki (16518000)	Haiku (AIKH1)	Kahului Harbor (KLIH1)	Kahului Harbor (NS13)
Hanawi (16508000)	Kahakuloa (KHKH1)		
Waikamoi (16552800)	Mahinahina (MABH1)		
Honopou (16587000)	Lahainaluna (LAHH1)		
Iao (16604500)	Kihei2 (KHIH1)		
Waihee (16614000)	Kahului Airport (HOG)		
Kahakuloa (16618000)	Wailuku (WUKH1)		
Honokohau (1662000)			

4.2. Sampling methods

Instantaneous temperature, salinity, dissolved oxygen (DO), pH, and turbidity measurements will be made at the monitoring sites by the monitoring teams using hand-held instruments. For in situ measurements, water will be collected at 0.1 m below the water surface in a bucket or similar collection device. The bucket will be relocated above the high tide line to a shady place for in situ measurement for safety reasons.

For sediment samples, a 500 mL sample will be collected for analysis of suspended sediment concentration.

For nutrient samples, 125 mL bottles will be collected at the 0.1m depth for water quality analyses. Dissolved and particulate nutrients will be measured, per site sampling specifications, at the SOEST Analytical Laboratory in samples collected, filtered and shipped by the monitoring teams.

For bacterial samples, sterile bags (Whirlpacks) will be used to collect water for *Enterococcus* samples. Sample water will be collected by placing the bags under water, filling and then sealed. SSC and *Enterococcus* will be measured by the monitoring teams at regional laboratory facilities on Maui.

Bottles and buckets will be rinsed three times in the field before each sample is collected.

Procedures for in situ measurements, and sample collection and processing are described in the SOPs attached to this QAPP. The SOPs related to sample collection, processing and parameter measurements are listed in Table A-1.

4.3. Sample handling and custody Requirements

4.3.1. Sample transport

Samples will be transported in coolers with ice from the field to the regional laboratory where they will be either processed further (*Enterococcus* and SSC) or prepared for shipment to the S-Lab (nutrient analysis). Samples for nutrient analysis will be frozen at the local laboratories until they are shipped. Shipments will be made using FedEx or similar carrier using blue ice and coolers to keep the samples frozen during transit. Nutrient samples for analysis will be delivered to the lab within two weeks of collection. Samples arriving at S-Lab will be immediately frozen and processed within 28 days of the sampling date.

4.3.2. Sampling bottles and preservation

Sample containers, volumes, preservation details, and holding times for the near shore chemistry monitoring samples are listed in Table 4.4. The information in Table 4.4 was compiled from the S-Lab requirements and the HI-DOH-CWB Coastal Chemistry Monitoring QAPP.

All sample bottles that will be used for analyzing nutrients will be acid-washed.

Table 4-4: Seawater sample handling and preservation.

Variable	Bottle	Volume	Field preservation	Lab preservation	Holding time
NH_4	Brown HDPE 125ml	80 mL	Filter, transport on ice	Freeze < -20°C	7 d
NNN	Brown HDPE 125ml	80 mL	Filter, transport on ice	Freeze < -20°C	28 d
DRP	Brown HDPE 125ml	80 mL	Filter, transport on ice	Freeze < -20°C	28 d
TDN	Brown HDPE 125ml	80 mL	Filter, transport on ice	Freeze < -20°C	28 d
TDP	Brown HDPE 125ml	80 mL	Filter, transport on ice	Freeze < -20°C	28 d
Silicate	Brown HDPE 125ml	80 mL	Filter, transport on ice	Freeze < -20°C	28 d
PN	GF/F filter	80 mL	Filter, transport on ice	Freeze < -20°C	28 d
PC	GF/F filter	NA	Filter, transport on ice	Freeze < -20°C	28 d
Suspended sediment	HDPE 1 L	500 mL	Transport on ice	Refrigerate < 6°C	60 d
Enterococcus (Collection device)	Sterile Whirl-Paks Nasco B01489WA	7oz	Transport on ice	Refrigerate < 6°C	6 hr
Enterococcus (Sample preparation)	Sterile clear bottle	100 ml	None	Pour into Quantitray for incubation	0 hr

4.3.3. Sample chain-of-custody

A chain-of-custody form is to accompany each set of water samples shipped to the S-LAB for nutrient analyses and to the Maui facilities for *Enterococcus* and suspended sediment analyses. The chain-of-custody form must be signed and dated by the field person who maintained custody of the samples during collection, and also by the person who receives them at the local laboratory. This form then accompanies the samples that are shipped to the S-LAB and is signed and dated by the person shipping the samples and also by the person who receives the samples at the S-LAB. The COC form is attached as Appendix C.

When coolers with samples arrive at the Maui facilities and the S-LAB, the sample receiver is to inspect the contents of each cooler, verify that it agrees with the COC, and sign and date the COC form. If any discrepancies are noted, or if laboratory acceptance criteria are not met, the laboratory must contact the PM for resolution of the problem. The discrepancy, its resolution, and the identity of the person contacted must be documented by the laboratory. In many cases, the sample collector and the sample Maui receiver/laboratory analyst are the same individual. If this is the case the COC will be initiated by the sampler/analyst and completed by the analyst who reads the Enterolert results and/or records the SSC results the following day.

4.3.4. Sample labeling

Each sample collected will be labeled with the following information prior to or during the collection of the sample:

a. a unique sample number,
b. sample type,
c. name of collector,
d. date and time of collection, and
e. place of collection

The sample number will follow this code: 3-letter site location code, two-digit year, two-digit month, two-digit day – sample type code (N for nutrients, S for suspended sediment) – sample number. Letters are used for sample duplicates. For instance, a sample at Honokowai Beach Park to be analyzed for nutrients might be: HBP150601-N-1. The initials of the sampler will be listed separate from the sample ID.

4.4. Analytical methods

Suspended sediment concentration

Suspended sediment concentration (SSC) will be measured according to the USGS, 1999, protocol in either the satellite labs or the S-LAB facility.

Nutrient and silicate analyses

For nutrient and silicate analysis, S-LABS uses an AA3 Nutrient Autoanalyzer from Sea Analytical. The S-LAB utilizes methods and procedures outlined by Seal Analytical that are, optimized for the AA3 Nutrient Autoanalyzer; references and procedures for each constituent are listed below.

Ammonium

Ammonium is measured fluorometrically following the method of Kerouel and Aminot (1997). The sample is reacted with o-phthalaldehyde (OPA) at 75°C in the presence of borate buffer and sodium sulfite to form a fluorescent species in a quantity that is proportional to the ammonium concentration. Fluorescence is measured at 460 nm following excitation at 370 nm.

Nitrate and Nitrite

Nitrate and Nitrite are analyzed via the diazo reaction based on the methods of Armstrong et al (1967) and Grasshoff (1983). This automated procedure involves reduction of nitrate to nitrite by a copper-cadmium reductor column. The nitrite then reacts with sulfanilamide under acidic conditions to form a diazo compound, which then couples with N-1-naphthylethylene diamine dihydrochloride to form a purple azo dye. The concentration is determined colorimetrically at 550 nm.

Silicate

Silicate measurement is based on the reduction of silicomolybdate in acidic solution to molybdenum blue by ascorbic acid (Grashoff and Kremling 1983). Oxalic acid is introduced to the sample stream before the addition of ascorbic acid to minimize interference from phosphates. The concentration is determined colorimetrically at 820 nm.

Orthophosphate (DRP)

This automated procedure for the determination of orthophosphate is based on the colorimetric method of Murphy and Riley (1962) in which a blue color is formed by the reaction of orthophosphate, molybdate ion and antimony ion followed by reduction with ascorbic acid at a pH of 1. The reduced blue phospho-molybdenum complex is determined colorimetrically at 880 nm.

Total Phosphorus

Following the method developed by the University of Hamburg in co-operation with the Ocean University of Qingdao, this automated procedure for the determination of dissolved phosphorus in seawater takes place in three stages. First, the sample is irradiated in a UV digestor. In this digestion step organically bound phosphorus is released. Second, acid persulfate is added, which further promotes breakdown of orgniac matter that persists after UV digestion, and polyphosphates are converted to ortho-phosphate by acid hydrolysis at 90°C. Third, the ortho-phosphate is determined by reaction with molybdate, antimony and ascorbic acid, producing a phospho-molybdenum blue complex which is determined colorimetricallyat 880 nm.

Total Nitrogen

Following the procedure developed by the University of Hamburg, inorganic and organic nitrogen compounds are oxidized to nitrate by persulfate under alkaline conditions in an on-line UV digestor. The nitrate is reduced to nitrite in a cadmium column and then determined using the sulfanilamide/NEDD reaction with colorimetric detection at 520 nm.

Particulate N and C

The Exeter Analytical model CE 440 elemental analyzer provides automated analysis of particulate carbon, hydrogen, nitrogen and sulfur following the general methodology outlined by Gordon (1969) and Sharp (1974).

Bacteria concentration

The bacterial concentration protocol follows the Enterolert detection protocol. The Enterolert reagent, based on IDEXX's Defined Substrate Technology**,** is used for the detection of enterococci in water. Enterolert® uses 4-methylumbelliferyl-β-D-glucoside as the defined substrate nutrient-indicator. This compound, when hydrolyzed by enterococcus β- glucosidase, releases 4-methylumbelliferone which exhibits fluorescence under a UV365nm lamp. This reagent system is specifically formulated to achieve optimum sensitivity and specificity in the detection and identification of enterococcus. After 24 hours incubation at 41°C, if enterococcus is present, the reagent should show fluorescence when exposed to a long-wave (365-366 nm) UV lamp. The test should detect one (1) enterococcus in 100 mL of water within 24 hours.

Additional information about the above protocols is found in Appendix A.

5. QA/QC Requirements

5.1. Instrument and equipment maintenance, testing, inspection and calibration

All equipment and instrument maintenance and service, testing, inspection and calibration will be documented in lab notebooks available to the QA officer for review. A summary of the procedures for documenting quality control non-conformances is in Appendix D. Appendix D also presents common data qualifiers used in the final data management system to identify types of non-conformances.

Measurement error is generated by variation in the operation, calibration and output of sensors and other measurement instruments. Instruments will be maintained, checked for drift, with a documented precision and accuracy (Table 4-1). Calibration schedules are presented in Tables 4-5 and 4-6 to ensure that the equipment is functioning according to specifications.

5.2. Sampling

5.2.1. Field calibration and maintenance

All field calibrations/verifications, quality control measures, and sampling activities will be documented in a field log book.

To ensure that field instruments for in situ measurement have acceptably low amount of systematic error/bias, the instruments are to be calibrated following the procedures and at the frequencies specified by manufacturers. The calibration schedule and acceptance criteria for field instruments are summarized in Table 5-1. The field-check acceptance criteria refer to the similarity of measured or indicated values and the reference values (e.g., standard calibration solutions for pH, conductivity and turbidity).

All field instruments used for the collection of water samples or data for the program will be maintained according to the manufacturer's performance specifications and instrument SOPs and the manufacturer instructions in the operating manuals (Table 5-2, Appendix A). The Hach instruments run self-checks when they are powered on. All field equipment is to be visually inspected before use for damage. An inventory of spare parts inventory and extra equipment is to be maintained to minimize effects of equipment problems on sampling schedules. However, funding limitations prohibit the purchase of duplicate Hach instruments, and problems with those instruments may cause delays. Further details on field instrument maintenance and inspection are in the user's manuals.

Table 5-1: Calibration schedule and field check criteria; The field check criteria is the largest range within the instrument is expected to be functioning.

Instrument	Parameter	Schedule	Field-check acceptance criteria	Field check range
NSIT-traceable waterproof digital thermometer	Temperature	None (factory-calibrated)	None	20 - 35°C
Hach HQ40d meter, IntelliCAL CDC401 conductivity probe	Salinity/ conductivity	Quarterly or as needed	± 3% of calibration solution	20 - 38ppt
Hach HQ40d meter, IntelliCAL LDO101 luminescent/optical DO sensor	Dissolved oxygen	Quarterly or as needed	Post-check ± 5 % of pre-check	0 - 100%
Hach HQ40d meter, IntelliCAL PHC101 pH Electrode	pH	Every time equipment is used	± 3 % of calibration solution	6 - 8
Hach 2100Q turbidometer	Turbidity	Yearly or as needed	± 5 % of Gelex standards (5, 50, 500 NTU). Deionized/turbidity-free bank < 0.25 NTU	0-1600 NTUs

Table 5-2: Field instrument performance specifications.

Variable	Instrument	Range	Accuracy	Precision
Water temperature	NSIT-traceable waterproof digital thermometer	50 – 300 °C	± 0.4°C between 0 and 100°C	0.1°C
Salinity & electrical conductivity	Hach HQ40d meter and IntelliCAL CDC401 conductivity probe	0.01 – 200 µS/cm 0 – 42 PSU	± 0.5 µS/cm 0.01 PSU	0.01 µS/cm
Dissolved oxygen concentration & % saturation	Hach HQ40d meter and IntelliCAL LDO101 luminescent/optical DO sensor	0.05 – 20.0 mg/L 0-200 % saturation	± 0.1 (0-8 mg/L) ± 0.2 (>8 mg/L) 1 % saturation	0.01 mg/L
pH	Hach HQ40d meter and IntelliCAL PHC101 pH Electrode	2 - 14	± 0.02	0.001 - 0.1
Turbidity	Hach 2100Q turbidometer	0 – 1000 NTU	± 2 %	0.01 NTU

All bottles, buckets and instruments that are used for sample collection will be washed with phosphate-free soap and rinsed three times after use.

5.2.1. Field duplicates and sample blanks

Replicates and sample blanks. For every 10-20 seawater samples collected per site for nutrient, *Enterococcus* and suspended sediment analysis, one replicate sample (i.e., two samples collected from the same sample site at approximately the same time) will be collected for each type of analysis. Each field replicate will be analyzed as a separate sample. The accumulated replicate data will be used to assess measurement error in field collection protocol. The field replicate samples will be given unique sample identification numbers and treated as discrete samples. Additionally, sample blanks (distilled water only) will be analyzed once every six months per project area to ensure quality in the shipping and processing process.

For opportunistic sampling, or if the turbidity measurement in-field is above 2 NTU, duplicate samples for suspended sediment analysis will be taken automatically.

The facilities will carry out analyses of sample duplicates and blanks as part of a continuous check on performance. Performance records will be maintained and available to HI-DOH-CWB. Where applicable, split sample analyses will be carried out with commercial or university analytical laboratories.

5.3. Shipping and handling

The Maui satellite labs will prepare samples for shipment using standard protocols as described in Section 4.3.1. Each set of samples shipped will be accompanied by a chain of custody form. The form will be filled out on receipt of the analyzing lab for QA nonconformities (broken seals, incorrect temperature on arrival).

Shipping frozen samples will only happen between Monday and Weds, so that the lab can process the samples when they arrive. In the event a package arrives on the weekend, this will be noted on the QA forms.

5.4. Training requirements

Each monitoring team member will receive consistent, documented training, and will sample sites in pairs to reduce bias in the sampling protocol.

Field team members will receive annual training in sampling methods and procedures outlined in this plan and the SOP associated with this plan, and then observed to ensure that protocol is followed consistently. All field team members will be required to read the most updated QAPP document. The training will be documented by the Training Leader, including the name of the trainee, type of training they received (first time or re-training, volunteer sampler or team leader), date and name of the trainer. Training documents will be available to the CWB on request. Field team members will sample sites in pairs as a check to maintain sampling standards.

Prior to a staff member's independent performance of a procedure, a quantitative comparison should be conducted when possible and applicable to ensure that the trainee results are comparable to those of an experienced staff member. Documentation of this training should be provided to the Training Leader. Specifically, field team members will have training in the following field activities:

- Water grab sampling and processing (manual);
- Instrument operation, calibration/verification checks, and routine maintenance (for the Hach HQ40D multi-parameter probe and Hach 2100Q turbidimeters);
- Sample filtering, including weighing and drying filters, for SSC
- Idexx Quanti-tray System operation and procedures for measuring *Enterococcus* levels
- Data recording and summarization procedures;
- Sample handling and chain of custody procedures; and,
- General and project-specific safety.

Training records for all Hui O Ka Wai Ola volunteers are maintained by the Training Leader. The addition of new personnel will require training documentation. The Monitoring Team Leader is responsible for scheduling and arranging refresher courses when applicable.

5.5. Laboratory analyses

General. The floor and work surfaces of the laboratory facility must be non-absorbent, easy to clean and disinfect. Each laboratory should have sufficient and clean storage/work space. All food and drinks are prohibited in the laboratory work area. Each laboratory should have adequate ventilation, facilities, and safety protocols.

Thermometers. Thermometers should be graduated in 0.5 ° C or less. Incubator thermometers should be graduated at 0.2 °C or less. All laboratory thermometers should be calibrated semiannually against a NIST certified thermometer, and the results documented. Both the NIST thermometer and the thermometer being calibrated should be immersed in water to avoid rapid fluctuations while reading. Allow at least 5 minutes for stabilization. Each calibrated thermometer should be tagged with the following information: date of calibration, NIST reading, thermometer reading, correction factor, and technician initials.

5.5.1. Water quality laboratory facilities

Instrument maintenance. S-LAB will prepare and follow a maintenance schedule for each instrument used to analyze samples collected from the watershed areas. All instruments will be serviced at scheduled intervals necessary to optimize factory specifications. Routine preventive maintenance and major repairs will be documented in a maintenance logbook. An inventory of items to be kept ready for use in case of instrument failure will be maintained and restocked as needed. The list of spare parts will include equipment replacement parts subject to frequent failure, parts that have a limited lifetime of optimum performance, and parts that cannot be obtained in a timely manner.

Refrigerators and drying ovens. Refrigerator units must be maintained between 0 - 6 ºC. The temperature should be checked and recorded on the temperature log sheet once per day on each day of use (depending on the laboratory and frequency of analysis). The refrigerator unit should be cleaned monthly and all materials identified and dated. All outdated materials should be disposed of properly and no food or drinks should be stored in the refrigerator unit. Similarly, ovens for drying filters will be inspected before each use to ensure cleanliness.

Analytical balances. Analytical balances will be calibrated once per year, and certified as necessary by national certification boards. All maintenance records will be kept on file.

Reagent water. For the reagent water system, the lab will check daily the TOC (ppb) and MOhms. This is observed for passable standards prior to using water (18.2 MOhms, and <4 ppb TOC). Monthly, the system is checked for volume of water through each filter, rejection feed on the feed water, and temp of feed water. The S-LAB maintains three, six, and twelve month upkeep protocols documented for the reagent water maintenance.

Cleaning protocols. An acid-washing protocol to ensure clean bottles for analyses will entail soaking for a minimum of 24 hours in 0.1N HCl bath, and will be performed at S-LABs or the

satellite labs. Bottles will be rinsed three times and dried prior to their reuse in sampling. Between sampling in the field, equipment will be rinsed with deionized water.

Inspection for supplies and consumables. Once per year, an inventory of all consumables will be conducted to evaluate the physical condition of bottles, hoses and equipment. Any equipment that is substandard will be discarded. Chemical reagents will be discarded properly if past their expiration date. These inspections will be documented in the laboratory notebook for QA review, if necessary.

5.5.2. Bacterial testing laboratory facilities and equipment

Incubators

Incubators should be maintained at 41 ± 0.5 ºC for Enterolert® method of analysis. The uniformity of the temperature should be established. The temperature should be checked at least once daily and recorded in the laboratory log, on each day of use. A lab technician will also check the temperature as the samples are read. If applicable, the thermometers should be placed on the highest and lowest shelves and immersed in liquid. If the incubator is out of acceptable range for more than 2 hours, the samples should be discarded and reported as "temperature out of range". Preventative maintenance is completed and recorded in equipment maintenance log book.

Autoclave

For each cycle, the technician will record the date, contents, sterilization time, pressure, temperature, and technician initials in an autoclave log. The autoclave performance will be tested for each run using sterility tape, only if the Quanti-Trays will be reused. At least once during each month the autoclave is being used, appropriate biological indicators should be used to determine effective sterilization. Preventative maintenance is performed and recorded in the equipment maintenance log book.

Sealer

The Quanti-Tray 2000 sealer is checked on a monthly basis using 100 mL of water mixed with a dark colored dye or bromescol purple to ensure adequate sealing of the quanti-trays. If dye is observed outside of the wells, the sealer is serviced by a technician before use. All quality checks and maintenance are recorded on the Sealer QC Log Sheet. The long-wave ultraviolet bulb should produce a wavelength of 365 nm. Quality checks can be completed by reading the positive controls.

Consumables

Each lot of Enterolert® media will be used before the listed expiration date and stored in a cool (20-30°C) dry place out of direct sunlight. The expiration date of the media will be noted on each data form. Each lot will be quality checked using a positive culture to ensure growth of the target organism, and all Quanti-Tray cells must exhibit fluorescence and the expected reaction to the target organism. Each lot of media is also tested using two negative controls to demonstrate the media does not support the growth of non-target organisms. Each laboratory also processes one blank (distilled water and media) for each group of samples processed. The data quality objective for blanks is <10 MPN. For each laboratory 10% of the laboratory samples are duplicated and the RPD regularly assessed.

Reagent water

Each lot of reagent water either distilled water or water from deionization units is quality checked yearly and must meet the following criteria:

- Conductivity > 0.5 megaohms resistance or less than 2 micromhos cm^{-1} (microsiemens cm^{-1}) at 25°C.
- Total chlorine < 0.1 mg L^{-1} residual.

Conductivity will be reported each time a batch of distilled water is processed. Chlorine residuals will be tested annually using test kits (for instance, the Hach chlorinity test kit).

Water to be used in bacteriological analyses will not be stored for more than 60 days before use.

5.5.1. Analytical lab quality control: replicates, standards and blanks:

A summary of quality control activities is presented in Table 5-3.

Target levels for accuracy and precision (expressed as relative percent difference) provide measurement quality objectives, and are presented in Table 5-4.

Target levels for suspended sediment concentration are from American Society for Testing and Materials (1997).

Enterolert specifications and target levels for *Enterococcus* are from the Enterolert User's guide.

Nutrient and silicate analyses

The S-LAB, responsible for analyzing for nutrient and silicate parameters, has a formal quality control program. Each sample run includes a blank and mid-level calibration duplicates every 10-15 samples. Values that are out of range are corrected on site before the sample results are finalized. Results of the blanks and mid-level calibration duplicates will be noted in the lab report when sample results are reported. In addition, the % recovery of the mid standards will be calculated for each run. During each run, the lab will also test quality control samples collected from station ALOHA. The data from these samples is used to ensure precision between individual runs. Finally, during the run standardized nutrient seawater reference material from

the National Meteorology Institute of Japan (NMIJ) is analyzed and the data is provided on the run sheet.

Suspended sediment analyses

During the pre-weighing of the filters, each filter will be weighed twice and the average used as the initial weight. Post filtration, and after the samples have been dried, the filters will also be weighed twice and the average recorded in the lab notebook.

Bacterial analysis quality control

Laboratory quality control protocols for bacterial analysis include laboratory blanks and repeated positive readings that will be confirmed by a second trained analyst. Lab duplicates will be measured every 20 samples, in addition to field duplicates every 20 samples. Additionally, the media will be tested for each batch by inoculating intentionally for both

Table 5-3: Quality control sampling activities in laboratory and field, with frequencies

QC Sample or Activity used to Assess Measurement Performance	Frequency	Measurement Performance Criteria
In situ parameters		
Bench calibration (turbidity, pH)	Before every group of samples	Table 5-1
Field blank (turbidity)	After every group of samples	<0.1 NTU
Repeated samples	▪ Temperature: If there is a difference of 1ºC or greater between any of your three measurements ▪ pH: If there is a difference of 0.2 or greater between any of your three measurements ▪ Conductivity: If there is a difference of greater than 10 uS between any of your three measurements ▪ Dissolved Oxygen: If there is a difference of 0.4 ppm or greater between any of your three measurements ▪ Turbidity: If there is a difference of 0.2 NTU or greater between any of your three measurements	
Historical trend analysis	Every 5 sampling events	Baseline average is not trending
Nutrient analysis		
Field duplicate	Every 20 samples	
Lab blank	Once per group of samples	
Lab mid-level calibration	Once per sample run	
Standard reference material		
Method detection limit	As needed by lab	
Suspended sediment concentration analysis		
Field duplicate	When turbidity >2 NTU	
Repeated weighing	Every sample	
Bacterial analysis		
Field duplicate	Every 20 samples	
Lab reagent blank	One per group of samples	<10 MPN
Lab duplicate	Every 20 samples	
Repeated measures	Positive samples checked by second trained analyst	

Table 5-4: Acceptable analytical methods and quality control acceptance criteria. RPD: relative percent difference, based on duplicate samples.

Parameter	Method number or description	Method/instrument	Units	Minimum Detection Limit[1]	Sensitivity resolution	Accuracy
S-LAB Analyses						
NH4	EPA Method 350.1	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg N/L	1.0 µg N/L	< 20% RPD	80% - 120%
NNN	EPA Methods 353.2	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg N/L	0.8 / 2.4 µg N/L	< 20% RPD	80% - 120%
DRP	EPA 365.1	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg P/L	0.56 µg P/L	< 20% RPD	80% - 120%
TDN	UV-Digestion, EPA 353.2, Rev.2	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg N/L	0.8 / 2.4 µg N/L	< 30% RPD	80% - 120%
TDP	EPA Method 365.1	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg P/L	0.56 µg P/L	< 30% RPD	80% - 120%
Silicate	EPA Method 366.0	GF/F-filtered grab samples, SEAL Analytical AA3 autoanalyzer	µg/L	9.8 / 35.7 µg/L	< 20% RPD	80% - 120%
PN	EPA Method 440.0	GF/F-filters, Exeter Elemental Analyzer	% by mass			99%
PC	EPA Method 440.0	GF/F-filters, Exeter Elemental Analyzer	% by mass			93-99%
Enterolert lab analyses						
Enterococcus	IDEXX Enterolert instructions	Fluorogenic substrate test (Idexx Enterolert Quanti-tray)	cfu/100ml	<10 MPN	1 MPN	95%
Sediment analyses						
Suspended sediment	ASTM Method D3977-97B	Vacuum filtration	mg/L	0.001 mg	0.2 mg/L	90% - 110%

5.6. Data Management

Field and analytical data collected from this project are critical to assess water quality in the study area, assess risks to human health and the environment, and, if necessary, recommend mitigation measures in the form of waste load allocations where required. An information management system is necessary to ensure efficient access to these data, and will be created specifically for this ongoing project.

5.6.1. Documentation standards

The PM, QA Officer, monitoring teams and the S-LAB have written procedures for all activities related to the collection, processing, analysis, reporting, and tracking of water-quality data. This documentation must be in either the SOPs or QA manual, and must be readily available to field and laboratory personnel. The documentation of field and laboratory activities must meet the following requirements:

- Data must be documented directly, promptly, and legibly.
- All reported data must be uniquely traceable to the raw data through sample identification numbers that are on each sample as labels, and recorded in the field and laboratory log books.
- All data reduction formulas (such as dilutions) must be documented and include the initials of the data collector.
- Handwritten data must be recorded in ink, and changes crossed out and initialed.
- All original data records include, as appropriate, a description of the data collected, units of measurement, unique sample identification (ID) and station or location ID (if applicable), name (signature or initials) of the person collecting the data, and date of data collection.
- Any changes to the original (raw data) entry must not obscure the original entry.
- The reason for the change must be documented.

5.6.2. Field data management

All field activities must be conducted using the data collection procedures described in this document and the accompanying SOPs.

Log book. The Monitoring Team Leader will keep a bound field notebook that accompanies the volunteers to every sampling. The Monitoring Team Leader will maintain documentation of sampling, logging, and field measurements, and will note any variance from SOPs. All information pertinent to a field survey or sampling will be recorded. At a minimum, the log book will include the following: purpose of sampling; location of sampling point; name of field contact; type of samples taken; and method, date, and time of preservation. Additional qualitative

information includes wind (speed and direction), sea state, number of visitors in the beach, moon phase and tidal phase will also be noted as appropriate. The log book will also provide suspected sample composition, including concentrations; number and volume of sample(s) taken; description of sampling point and sampling method; date and time of collection; collectors sample identification number(s). The log book will be protected and kept in a safe place.

Data sheets. Monitoring teams use the field data sheets developed for the program (Appendix C) to document sample collection and field measurements. The originals of the field data sheets are photocopied twice by the Monitoring Team Leaders when field work is completed. The original datasheets go to the QA Officer, and an additional copy is kept with the field team. The analytical lab will return the signed data sheets with the coolers and acid-washed sample bottles. In addition to the field data sheets, the QA Officer requires reports from the S-LAB with nutrient data, and from the monitoring teams with suspended sediment data and bacterial data. These will be stored electronically and in hard copy with the QA Officer.

COC forms. The monitoring teams also fill out COC forms with spaces provided to indicate who relinquished and who received the samples and when. The use of COC forms is set out below in Section 5. The COC form is attached as Appendix C. A COC form will be used for each laboratory that samples are sent to.

Data upload. Qualitative field data (pH, turbidity, salinity, DO and temperature) first recorded into a field log book will be entered remotely into a spreadsheet (MS Excel or Google Spreadsheets) in a way that will be compatible with the EPA and HI-DOH database guidelines, acknowledging that the spreadsheet is only accessible to the Team Leaders and QA officer. Current technology (c 2016) allows for Google Forms to be used to upload data without having access to the full database. Hard data sheets will be copied and then passed to the Quality Assurance officer, once the data is entered electronically for verification.

QA review. The QA Officer will review the field sheets monthly, and review the entered data, compare a subset of the electronic data to the original data sheets, and correct entry errors. Range checks and other QA/QC methods will be performed before accepting the dataset. Upon entering the data the QA officer will sign and archive the field data sheets. A set of codes will be used to acknowledge if there are QA flags. The data will be coded as P for preliminary until the QA checks are performed and the data is accepted, upon which the A code will be used.

5.6.3. Analytical laboratory data management

Each laboratory will keep a notebook or digital system to register incoming samples.

When samples are received at the laboratory, the laboratory technician will inspect the sample containers and custody records, and verify sample integrity and preservation (temperature). The technician will reconcile the information on the chain-of-custody forms with the sample bottles received. The sample custodian will document any anomalies and report them to the laboratory project manager, who will contact the QA officer. Anomalies will be resolved with the Hui o Ka

Wai Ola QA officer. The information on the COC forms will then be entered into the laboratory's information management system.

The S-LAB will report results directly to the QA Officer. The QA Officer will verify sample identification information, review the chain-of-custody forms, document the measurement performance objective for quality control samples and identify/code the data appropriately in the database.

Samples will be tracked from the time of receipt through each stage of sample preparation, analysis, and final reporting using the laboratory's information management system correlated to the unique label identifier associated with each sample. The laboratory will be responsible for tracking all QC parameters and sample results by sample delivery group. Any data that exceed the specified QC limits specified for this project will be documented. QC anomalies that directly affect data quality will immediately be communicated to the QA Officer.

Bacterial testing. Both the SSC and the *Enterococcus* results are read and recorded on the laboratory data sheet that is initiated on sample day and completed when read the following day by that day's sampling team.

5.6.4. Access

All data will be open-access once it has been approved by the QA Officer. Preliminary data will be available with codes indicating its status before it has been through the QA process to project partners.

5.6.5. Reporting

Hui o Ka Wai Ola Interim reports will be produced and distributed in May (data collected from January-April) and September (data collected from May-August). A year-end report will be produced and distributed in January of the following year (data collected from September-December, as well as full-year results). The PM is responsible for all report production and distribution. Reports will be forwarded to the distribution list noted at the beginning of this document. Summaries of all reports, highlighting the assessment results, project status, and volunteer achievements, will be distributed to all volunteers and watershed partners.

Raw data will be provided to HI-DOH-CWB in electronic form at least once per year so that it can be included in the 305(b) report. Appropriate quality assurance information may be provided on request.

5.7. Assessment and Oversight

All Hui o Ka Wai Ola field and laboratory data are reviewed by the PM and QA Officer to determine if the data meet QAPP objectives. Review protocols for the QA officer are described in Section 6. In addition, personnel at HI-DOH who are not directly connected to this project will

also be contacted to review data once a year, if necessary. Decisions to reject or qualify data are made by the QA Officer.

Review of Hui o Ka Wai Ola field activities is the responsibility of the Monitoring Team Leaders in conjunction with the PM and the QA Officer.

Performance evaluations. Each monitoring team will be accompanied and their performance evaluated by the PM or QA Officer once a year. If possible, volunteers in need of performance improvement will be retrained on-site by the Training Leader during the evaluation. In addition, monitoring team members will attend yearly training renewal workshops. All training and re-training will be documented, including the name of the trainee, name of the trainer, type of training, and date.

Technical systems review. If errors in sampling techniques are consistently identified, a thorough and systematic onsite qualitative audit will be conducted of facilities, equipment, volunteers, training and record keeping. In some cases, retraining may be scheduled more frequently. Field and laboratory activities may be reviewed by state quality assurance officers as requested. Systems and data quality audits are performed by the QA Officer twice yearly. Any identified procedural problems will be corrected based on recommendations from the QA Officer.

All data review and validation results for both field and laboratory activities must be documented and maintained on file. All activities (including procedures and anticipated results) not conforming to the specifications of this QAPP must be identified and corrective actions implemented. A responsible member of the team, with approval by the QA Officer, will document and keep hard copies of all assessments and response actions (i.e., corrective actions). Documentation includes, at minimum, identification of the sampling/field measurement site, sampling/measurement date and time, sampler's name, description of the non-conforming issue, corrective action taken to remedy the situation, follow-up actions (if applicable), final decision, and approval by the QA Officer. Data verification and validation reports (if issues are identified) or acknowledgment of data verification and validation (if no issues are identified), signed by the QA Officer and PM must be incorporated into all reports submitted to HI-DOH.

6. Data Quality Assessment

The data quality assessment process will use standardized forms to summarize each sample.

6.1. Data validation and verification methods

Once the data have been entered into the Hui o Ka Wai Ola database, the QA Officer will print out the data and proofread it against the original data sheets. Errors in data entry will be corrected. Outliers and inconsistencies will be flagged for further review, or discarded. Problems with data quality will be discussed in the interim and final reports to data users. The data management system will be designed to ensure archival and retrieval of analytical results with all their metadata.

6.1.1. Field Parameters Verification

If a result does not pass QA/QC, the Monitoring Team Leaders will make the initial identification of procedure that did not conform to the SOPs or QAPP protocol, and take corrective action to ensure that protocols are followed.

As part of standard field protocols, any sample readings out of the expected range (Table 4-5) will be reported to the Monitoring Team Leaders and to the QA Officer. A second sample or reading will be taken as soon as possible to verify the initial reading. If the data is outside the normal range, then the data will be noted (flagged) on the data sheet. We will take further actions to trace any sources of error, and to correct those problems. Outliers that result from errors found during data verification will be identified and corrected; outliers that cannot be attributed to errors in sampling, measurement, transcription, or calculation will be clearly identified in project reports.

Samples or field measurements that do not pass QA/QC will be documented with the following information: sample/measurement identification, sample location, sampling date, name of sampler, reason for QA/QC failure, and corrective action taken.

6.1.2. Laboratory Data Verification

For water samples, if an error is detected in the collection, storage or shipping of the samples, the QA Officer and Monitoring Team Leader will be notified. Upon receiving the data sheets and results from the laboratory, the QA Officer will identify any results where holding times have been exceeded, sample identification information is incorrect, samples were inappropriately handled, or calibration information is missing or inadequate. Such data will be marked as unacceptable by the QA Officer and will be coded to include this information in the electronic database.

6.2. Reconciliation with data quality assurance objectives

As soon as possible after each sampling event, calculations and determinations for precision, completeness, and accuracy will be made and corrective action implemented if needed. If data quality indicators do not meet the project's specifications, data may be discarded and resampling may occur. The cause of failure will be evaluated. If the cause is found to be equipment failure, calibration/ maintenance techniques will be reassessed and improved. If the problem is found to be monitoring team error, team members will be retrained.

For analytical samples, the QA officer will document each of the QC samples and the QC purpose (controlling bias, accuracy, etc). If the data quality objectives are not met, additional QC samples will be used to identify where in the process there is room for improvement or changes.

Any limitations on data use will be detailed in both interim and final reports, and other documentation as needed. If failure to meet project specifications is found to be unrelated to

equipment, methods, or sample error, specifications may be revised for the next sampling season. Revisions will be submitted to the state quality assurance officers for approval

7. References

ASTM (American Society for Testing and Materials). 1997. Standard test methods for determining sediment concentration in water samples (ASTM Designation: D-3977-97). ASTM, West Conshohocken, Pennsylvania.

HI-DOH-CWB (State of Hawai'i Department of Health Clean Water Branch). 2014. State of Hawaii water quality monitoring and assessment report. http://health.hawaii.gov/cwb/files/2014/11/Final-2014-State-of-Hawaii-Water-Quality-Monitoring-and-Assessment-Report.pdf

U.S. Environmental Protection Agency (2001). EPA Requirements for Quality Assurance Project Plans. EPA QA/R5; EPA/240/B-01/003; EPA, Office of Environmental Information: Washington, DC, 2001. http://www.epa.gov/quality/qs-docs/r5-final.pdf.

Environmental Protection Agency; Volunteer Stream Monitoring: A Methods Manual; **http://www.epa.gov/owow/monitoring/volunteer/stream/**

South Yuba River Citizens League. Water Quality Monitoring Field Procedures Manual. Feb 2012. 7th Edition.

U.S. Geological Survey, 1999, Sediment laboratory quality assurance project: U.S. Geological Survey, Office of Water Quality, Branch of Quality Systems, accessed from https://bqs.usgs.gov/slqa/ on March 18, 2016.

Appendix List

Appendix A- Standard Operating Procedures

- Appendix A-1 Preparation
- Appendix A-2 Calibration of field instruments
- Appendix A-3 Field measurements with hand-held instruments
- Appendix A-4 Nutrient sample processing
- Appendix A-5 Suspended-sediment sample collection and measurement
- Appendix A-6 *Enterococcus* sample collection and measurement using the IDEXX Enterolert and Quanti-tray system
- Appendix A-7 Shipping and handling
- Appendix A-8 QA/QC assessment

Appendix B – Site List

Appendix C – Forms for sampling and analysis

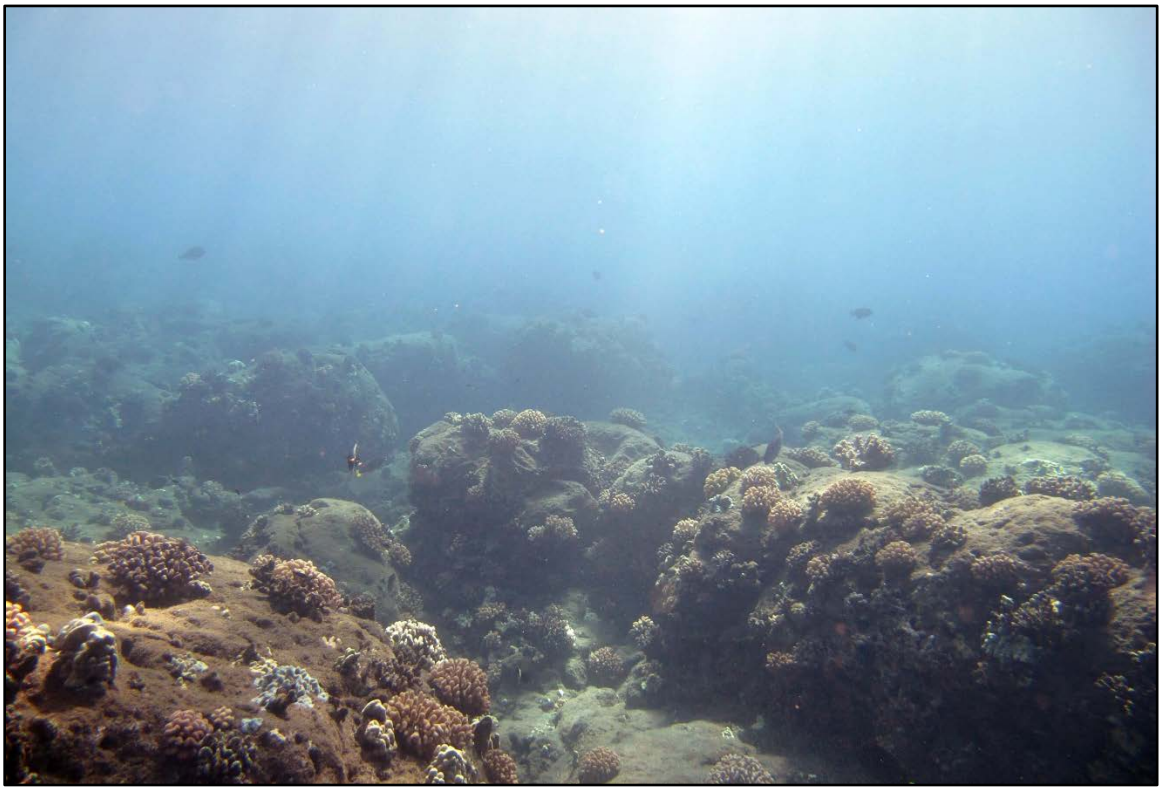
Kahoʻolawe Island Reserve
Technical Assistance to Support Tracking CAP Implementation and Fundraising

We supported the implementation of the Kahoʻolawe CAP by conducting coral reef surveys in June 2015. We conducted reef surveys in June 2015 around the entire island of Kahoʻolawe, redoing the baseline surveys we led five years ago. In collaboration with University of Hawaiʻi's Fisheries Ecology Research Lab, the Kahoʻolawe Island Reserve Commission (KIRC) and NOAA, our team of divers conducted one week of fish transect surveys, coral sizing, benthic habitat photos, and rugosity measurements. This is an important reef to study because, as the largest no-take area in the main Hawaiian Islands, it is the best baseline for comparison of reef fish communities at other sites.

Kahoʻolawe coral reef. Photo credit: KIRC

Marine science director Dr. Eric Conklin presented to the Kahoʻolawe Island Reserve Commission (KIRC) the results of the coral and fish surveys conducted by TNC and partners in 2009 and 2015. Our surveys found that while invasive fish biomass has significantly increased over the past five years, native fish populations have also increased slightly and the Reserve still has some of the highest native fish biomass in the main Hawaiian Islands. See the Kahoʻolawe Monitoring Report below. See the Baseline Biological Surveys of the Coral Reefs of Kahoʻolawe, Hawaiʻi report below.

Baseline Biological Surveys of the Coral Reefs of Kahoʻolawe, Hawaiʻi 1981-2015



Coral reef at Kahoʻolawe. Photo © TNC.

This report was prepared by The Nature Conservancy under cooperative agreement award #NA13NOS4820145 from the NOAA Coral Reef Conservation Program, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of NOAA, the NOAA Coral Reef Conservation Program, or the U.S. Department of Commerce.

The Nature Conservancy
Protecting nature. Preserving life.

NOAA CORAL REEF CONSERVATION PROGRAM

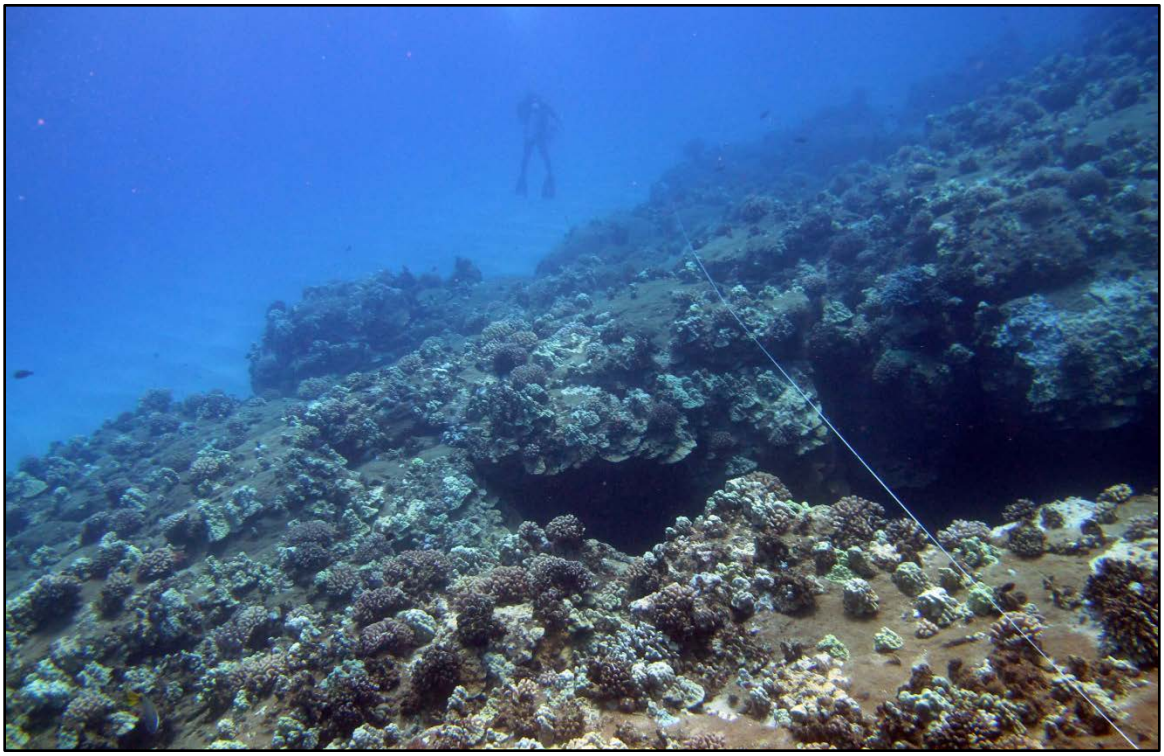
Baseline Biological Surveys of the Coral Reefs of Kahoʻolawe, Hawai'i 1981-2015

Dwayne Minton[1], Zach Caldwell[1], Ryan Carr[1], Eric Conklin[1], Alan Friedlander[2], Hank Lynch[1], Kaylyn McCoy[2], Rebecca Most[1], Kydd Pollock[1], Kostantinos Stamoulis[2], Dean Tokishi[3], and Chad Wiggins[1]

[1]The Nature Conservancy
923 Nuʻuanu Ave.
Honolulu, HI 96817

[2]Fisheries Ecology Research Lab, Department of Biology
University of Hawaiʻi at Mānoa
Honolulu, HI 96822

[3]Kahoolawe Island Reserve Commission
811 Kolu St., Suite 201
Wailuku, HI 96793



April 22, 2016

List of Acronyms

CAP	Conservation Action Plan
CCA	Crustose Coralline Algae
CPCe	Coral Point Count with Excel Extension
CRAMP	Coral Reef Assessment and Monitoring Program
FERL	University of Hawai‘i’s Fisheries Ecology Research Lab
FHUS	Fish Habitat Utilization Study
FMA	Fisheries Management Area
HIMB	Hawai‘i Institute of Marine Biology
KIRC	Kaho‘olawe Island Reserve Commission
MLCD	Marine Life Conservation District
MOP	University of Hawai‘i’s Marine Option Program
TNC	The Nature Conservancy

List of
English Common, Hawaiian, and Scientific Names
of Species Included in this Report

Common Name	Hawaiian Name	Scientific Name
Ocellated coral	-	*Cyphastrea ocellina*
Oval mushroom coral	ʻĀkoʻakoʻa	*Fungia scutaria*
Bewick coral	-	*Leptastrea bewickensis*
Crust coral	Koʻa	*Leptastrea purpurea*
Transverse coral	-	*Leptastrea transversa*
Rice coral	ʻĀkoʻakoʻa	*Montipora capitata* (=*verrucosa*)
Blue rice coral		*Montipora flabellata*
Branching rice coral		*Montipora incrassata*
Sandpaper rice coral	Koʻa	*Montipora patula*
Porkchop coral	-	*Pavona duedeni*
Maldive coral	-	*Pavona maldivensis*
Corrugated coral	ʻĀkoʻakoʻa	*Pavona varians*
Antler coral	-	*Pocillopora eydouxi*
Cauliflower coral	Koʻa	*Pocillopora meandrina*
False lichen coral	-	*Porites c.f. bernardi*
Finger coral	Pōhaku puna	*Porites compressa*
Lobe coral	Pōhaku puna	*Porites lobata*
Hump coral	-	*Porites lutea*
Plate-and-pillar coral	-	*Porites rus*

Common Name	Hawaiian Name	Scientific Name
Hawaiian sergeant	Mamo	*Abudefduf abdominalis*
Achilles tang	Pākuʻikuʻi	*Acanthurus achilles*
Ringtail surgeonfish	Pualu	*Acanthurus blochii*
Eyestripe surgeonfish	Palani	*Acanthurus dussumieri*
Whitebar surgeonfish	Māikoiko	*Acanthurus leucopareius*
Brown Surgeonfish	Māʻiʻiʻi	*Acanthurus nigrofuscus*
Bluelined surgeonfish	Maiko	*Acanthurus nigroris*
Orangeband surgeonfish	Naʻenaʻe	*Acanthurus olivaceus*
Thompson's surgeonfish	-	*Acanthurus thompsoni*
Convict tang	Manini	*Acanthurus triostegus*
Smalltoothed jobfish	Wahani	*Aphareus furca*
Green jobfish	Uku	*Aprion virescens*

Common Name	Hawaiian Name	Scientific Name
Stareye parrotfish	Pōnuhunuhu	*Calotomus carolinus*
Hawaiian whitespotted toby	-	*Canthigaster jactator*
Barred jack	Ulua	*Carangoides ferdau*
Island jack	Ulua	*Carangoides orthogrammus*
Giant trevally	Ulua aukea	*Caranx ignobili*
Bluefin trevally	Ōmilu	*Caranx melampygus*
Potter's angelfish	-	*Centropyge potteri*
Peacock grouper	Roi	*Cephalopholis argus*
Multiband butterflyfish	-	*Chaetodon multicinctus*
Hawaiian morwong	Kīkākapu	*Cheilodactylus vittatus*
Spectacled parrotfish	Uhu ʻahuʻula	*Chlorurus perspicillatus*
Bullethead parrotfish	Uhu	*Chlorurus spilurus*
Agile chromis	-	*Chromis agili*
Chocolate-dip chromis	-	*Chromis hanui*
Oval chromis	-	*Chromis ovalis*
Blackfin chromis	-	*Chromis vanderbilti*
Threespot chromis	-	*Chromis verater*
Goldring bristletooth	Kole	*Ctenochaetus strigosus*
Mackerel scad	ʻōpelu	*Decapterus macarellus*
Bird wrasse	Hinālea iʻiwi	*Gomphosus varius*
Ornate wrasse	Lāʻō	*Halichoeres ornatissimus*
Blacktail snapper	Toʻau	*Lutjanus fulvus*
Bluestriped snapper	Taʻape	*Lutjanus kasmira*
Black durgon	Humuhumu ʻeleʻele	*Melichthys niger*
Bigeye emperor	Mū	*Monotaxis grandoculis*
Yellowstripe goatfish	*Wekeʻā*	*Mulloidichthys flavolineatus*
Yellowfin goatfish	Weke ʻula	*Mulloidichthys vanicolensis*
Paletail unicornfish	Kala lōlō	*Naso brevirostris*
Sleek unicornfish	Kala lōlō	*Naso hexacanthus*
Orangespine unicornfish	Umaumalei	*Naso literatus*
Arc-eye hawkfish	Pilikoʻa	*Paracirrhites arcatus*
Goldsaddle goatfish	Moāno ukali	*Parupeneus cyclostomus*
Island goatfish	Munu	*Parupeneus insularis*
Manybar goatfish	Moāno	*Parupeneus multifasciatus*
Sidespot goatfish	Malu	*Parupeneus pleurostigma*
Whitesaddle goatfish	Kūmū	*Parupeneus porphyreus*
Bright-eye damselfish	-	*Plectroglyphidodon imparipennis*
Blue-eye damselfish	-	*Plectroglyphidodon johnstonianus*
Regal parrotfish	Lauia	*Scarus dubius*

Common Name	Hawaiian Name	Scientific Name
Palenose parrotfish	Uhu	*Scarus psittacus*
Ember parrotfish	Uhu ʻeleʻele	*Scarus rubroviolaceus*
Pacific gregory	-	*Stegastes fasciolatus*
Hawaiian gregory	-	*Stegastes marginatus*
Old woman wrasse	Hinālea luahine	*Thalassoma ballieui*
Saddleback wrasse	Hinālea	*Thalassoma duperrey*
Yellow tang	Lauʻipala	*Zebrasoma falvescens*

Note on names:
This report uses English common names to allow for easier reading for those not familiar with scientific names. English common names were selected for use over Hawaiian names to avoid confusion since a single Hawaiian name can often apply to multiple species. Hawaiian names were obtained primarily from three sources: Randall (2007) for fish, and Hoover (1998) and Bernice P. Bishop Museum for invertebrates.

Table of Contents

1.0 Summary 1
2.0 Introduction 2
3.0 Survey Methods 4
3.1 Survey Sites 4
3.2 Data Collection Methods 5
3.3 Previous Kahoʻolawe Coral Reef Surveys 7
3.4 Data Analysis 9
4.0 Results and Discussion 9
4.1 Benthic Assemblage 9
4.2 Fish Assemblage 20
4.4 Fish Species of Interest 38
5.0 Management Recommendations 44
6.0 Acknowledgements 49
7.0 References 49
Appendix A. Kahoʻolawe Survey Site Data (2009 & 2015) 54
Appendix B. TNC Survey Methods and Data Analysis 58
Appendix C. Glossary of Scientific Terms 64

Cover Image: A survey diver hangs in the water above a reef inside the Kahoʻolawe Island Reserve.

1.0 Summary

The Island of Kahoʻolawe has a complex history that has resulted in a century of sparse human occupation and light exploitation of its coral reef resources. For much of its modern history, the island has been off-limits to most fishing, making it a *de facto* marine reserve, and therefore less impacted by overharvest than other more populated areas of Hawaiʻi. In 1990, the Kahoʻolawe Island Reserve (hereafter, the Reserve) was established for the preservation of Kahoʻolawe's archaeological, historical and environmental resources, rehabilitation, re-vegetation, habitat restoration and education.

At the invitation of the Kahoʻolawe Island Reserve Commission (KIRC), The Nature Conservancy's marine monitoring team joined its partners at UH's Fisheries Ecology Research Lab and the KIRC to conduct surveys of Kahoʻolawe's marine resources in 2015. These surveys were intended to update and extend the existing body of coral reef information and provide a current baseline condition from which the effectiveness of management actions could be assessed. Data on benthic and fish assemblages were collected at 50 randomly-selected sites around Kahoʻolawe and compiled with historical data dating back to 1981.

The benthic assemblage significantly varied with wave exposure. Exposed reefs were dominated by robust and encrusting corals whereas sheltered reef areas had higher coral species diversity and higher diversity of colony morphology. Sheltered reefs tended to be more heavily affected by terrestrial-derived sediment, although the impact of sediment on the assemblage structure was complex. Over the past three decades, coral cover appears to have increased on sheltered reefs, while remaining relatively stable on exposed reefs.

The fish assemblage was dominated by surgeonfishes, snappers, parrotfishes and groupers. Invasive fishes were abundant, and while the effect of these invasive fish on native species inside the Reserve is currently unknown, growing scientific evidence suggests the negative impacts of these species in Hawaiʻi are likely small. The fish assemblage showed a strong spatial pattern: biomass was highest on the west side of the Reserve (farthest from Maui) and decreased to the east (nearest to Maui). The drop in biomass was associated primarily with a disproportionally large decrease in the biomass of target fishes, or those species most prized by fishers. Spatial variability in habitat and water quality, preferential selection of the Reserve's western reefs by large fish, depressed regional fish stocks, and legal fishing along the Reserve boundary were investigated and found to be inadequate explanations, while fishing within the Reserve, and most likely illegal poaching, was determined to be the most likely cause of the observed spatial pattern.

Climate change is likely the most significant long-term threat facing Kahoʻolawe's nearshore reefs. Reducing local stressors such sediment erosion and potential damage from human use, as well as ensuring fishery harvests are sustainably managed both within the Reserve and at the county or state scale, would likely increase the resilience of the Reserve's reefs to the effects of climate change.

2.0 Introduction

Hawaiian reefs provide culture, food, commerce, and recreation to residents and visitors alike, yet despite their importance, Hawai‘i’s nearshore marine environment suffers from pollution, overfishing, invasive species, and over-development, particularly around the more populated areas of the state (Friedlander *et al.* 2008, Williams *et al.* 2008, Friedlander *et al.* 2013).

The island of Kaho‘olawe has a complex history that has resulted in a century of sparse human occupation and light exploitation of its coral reef resources. Archeological evidence suggests that Hawaiians came to Kaho‘olawe as early as 400 A.D., settling in small fishing villages along the island’s coast (King 1993). Following western contact, the island was briefly used as a penal colony and, for nearly a century, for sheep and cattle grazing (1858-1941). In 1942, the island was used as a bombing range by the U.S. Navy, an activity that continued until 1990 (KIRC 2014). Overgrazing and aerial bombing destroyed vegetation, promoting erosion which continues to be a threat to Kaho‘olawe’s nearshore marine ecosystems. During the military bombing era and until it was turned over to the Kaho‘olawe Island Reserve Commission (KIRC), the island was off-limits to fishing, making it a *de facto* marine reserve (Dames & Moore 1997)[1].

In 1993, the Kaho‘olawe Island Reserve (hereafter, the Reserve) was placed under the administration of the KIRC, which was established for the preservation of Kaho‘olawe’s archaeological, historical and environmental resources, rehabilitation, re-vegetation, habitat restoration, and education (Dames & Moore 1997). Currently only limited take of marine life is permitted for cultural, spiritual, and subsistence purposes and all other fishing (including bottom fishing), ocean recreation, commercial and/or any other activities are strictly prohibited (or highly regulated[1]) within the Reserve. Access to the Reserve is highly restricted because of the continued presence of unexploded ordnance, as well as for the protection of marine resources. As a result of this history of intensive restrictions on fishing, the fisheries resources around Kaho‘olawe are less impacted by overharvest than those of other more populated areas of the state.

This is not to say that the reefs are in pristine condition, however. In many areas, sediment from the eroded landscape is a significant threat to the Reserve’s nearshore reefs. Other potential threats include existing and potential introductions of marine invasive species, runoff of pollutants, and illegal harvest (poaching). In locations where human access and use is permitted, there are also concerns regarding the effect of authorized resource extraction.

A number of previous marine resource surveys conducted around Kaho‘olawe have documented a diverse coral reef ecosystem (Kawamoto *et al.* 1981, Cox *et al.* 1995, Stanton 2005, 2006, 2007, 2008, Friedlander *et al.* 2010), including a higher standing stock of reef fishes compared to other locations in Hawai‘i.

[1] Limited trolling (2 days a month) was permitted starting in 1968 (Dames & Moore 1997), and limited fishing activity is still permitted by the KIRC with appropriate approvals and permits.

In 2009 and again in 2015, The Nature Conservancy's (TNC) marine monitoring team and its partner at UH's Fisheries Ecology Research Lab (FERL, Dr. Alan Friedlander) were invited to conduct surveys of Kaho'olawe's marine resources to provide information on their status and condition. Results from the 2009 surveys have been published elsewhere (Friedlander *et al.* 2010).

This report focuses on the findings of the 2015 surveys, and is intended to update and extend the existing body of coral reef information available for the island of Kaho'olawe. This information will also provide a current baseline condition from which the effectiveness of management actions implemented in accordance with the Reserve's Ocean Management Plan can be assessed.

2.1 Description of Kaho'olawe

Kaho'olawe is a heavily eroded basalt island located approximately 11 km (7 mi) southwest of Maui across the 'Alalākeiki Channel. At 116.5 km² (45 mi^2), it's the smallest of the eight main Hawaiian Islands. The Reserve is protected from northern swells by Moloka'i and Maui Islands, but is exposed to southern swells.

The southern coast of Kaho'olawe consists of steep cliffs with two large bays, Kamohio and Waikahalulu (Figure 1). Although this coastline receives the impact of strong waves, some protected habitats with high coral cover are found within these two large bays (Friedlander *et al.* 2010). Due to the often hazardous sea conditions, the Reserve's south-facing reefs are poorly studied. The surveys conducted by TNC and partners in 2009 (Figure 1, red circles) are currently the most comprehensive assessments available.

The western end of the island has two large beaches, Honokanai'a (Smuggler's Cove) and Keana a ke Keiki (Twin Sands). A wide, relatively shallow shelf with the remnants of Black Rock and Kuia Shoal extends offshore. This portion of the island experiences strong southern swell, and previous surveys have found low coral cover (Kawamoto *et al.* 1981, Cox *et al.* 1995, Stanton 2005, 2006, 2007, 2008, Friedlander *et al.* 2010).

The northern coast is characterized by low rocky cliffs, interspersed with numerous, small, silty pocket beaches. Numerous gulches incised along the coast funnel eroded soil onto a relatively shallow shelf that extends offshore. Turbidity is often high after periods of rain and when wave events disturb the sediment on the bottom. Normal trade winds can mobilize inshore sediment deposits moving them out of the bays and along the coast. Previous surveys have found diverse reefs with high coral cover (Kawamoto *et al.* 1981, Cox *et al.* 1995, Stanton 2005, 2006, 2007, 2008, Friedlander *et al.* 2010).

The eastern end of Kaho'olawe includes a large bay, Kanapou Bay, that is often exposed to waves through the 'Alenuihāhā Channel, which separates Maui from Hawai'i Island. Although wave disturbance can be high, coral communities in deeper water have been found to be relatively diverse with moderate coral cover (Cox *et al.* 1995, Stanton 2005, 2006, 2007, 2008, Friedlander *et al.* 2010).

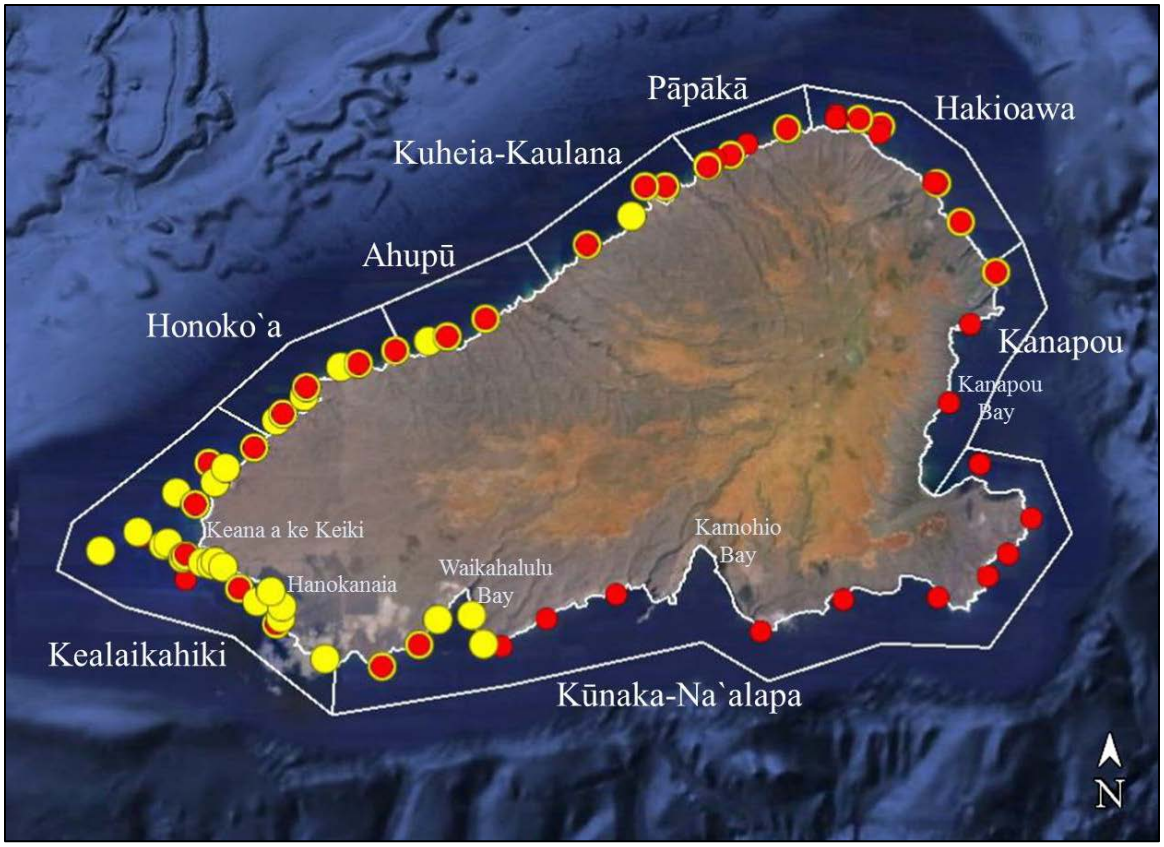


Figure 1. Locations of coral reef survey sites on Kahoʻolawe for 2009 (red) and 2015 (yellow). The white lines and names represent Kahoʻolawe's *ʻili* (subdivision of an ahupuaʻa).

3.0 Survey Methods

3.1 Survey Sites

The survey area encompassed the entire shallow water reefs around the island of Kahoʻolawe, extending from approximately 3 m to 20 m (~10-60-ft) deep and fringing approximately 47 km (27.2 mi) of coastline.

From June 15-19, 2015 TNC's marine monitoring team and FERL partners surveyed 50 randomly-selected[2] sites within the survey area (Figure 1). Due to hazardous sea conditions during the time of the surveys, surveys along the south and southeast coastline (within the *ʻili* of Kunaka/Naʻalapa and Kanapou) were limited in number and restricted primarily to the western end of the Kunaka/Naʻalapa *ʻili* (Figure 1). Twenty of the 2015 surveys sites were conducted at the same GPS coordinates as sites surveyed by teams in 2009, and while no permanent transect markers were installed in 2009, for the purposes

[2] Random sites were selected in order to get an unbiased measure of the community across the survey area. Using a non-random site selection method, such as selecting sites known to have high fish abundance, would provide a skewed or biased assessment of the Reserve's coral reef community.

of this report, it was assumed these were the same sites as those previously surveyed. Due to the restricted spatial extent of the 2015 surveys compared to the 2009 surveys, the re-surveyed sites were used to examine potential changes in the reef community between 2009 and 2015. The distribution of sites by *ʻili*, is provided in Table 1. Appendix A contains the positional information and available site metadata (e.g., depth, rugosity, date surveyed etc.) for all 50 survey sites in both 2009 and 2015.

Several sites of specific interest were identified by KIRC natural resource staff, including two sites where human access is permitted (Honokanaiʻa and Hakioawa) and three sites with similar reef structure where access is not permitted (Honokoa, Kuikui and Pāpākāiki). Additionally, Stanton (2005, 2006, 2007, 2008) identified five "access" (Hakioawa, Kuheia, Makaʻalae, Honokoa, and Honokanaiʻa) and five closely paired "control" sites (Lae ʻO Kuikui, Pāpākāiki, ʻOawapalua Laepaki and Honukanaenae) where access was not permitted. These ten sites were re-visited as part of the 2009 and 2015 survey efforts, and were used to assess the potential effects of human access on the reef community using a paired design (Table 2).

3.2 Data Collection Methods

Sites were surveyed by divers deployed from small boats. The survey teams navigated to each predetermined site using a Garmin GPS unit. Once on site, the survey team descended directly to the bottom, where divers established two transect start-points approximately 10 m apart. From each start-point, divers deployed a separate 25 m transect line along a predetermined compass bearing, with the two transect lines running parallel to the other. If the bearing resulted in a large change in depth, the transects were altered to follow the depth contour. Specific survey methods are briefly discussed below. For a full description of the fish and benthic survey methods used, see Appendix B.

Table 1. Number of survey sites in 2009 and 2015 by *ʻili*. The designation of sheltered/exposed *ʻili* were determined based Hawaiʻi's dominant swell regime and supported by analysis of the 2015 benthic cover data (see section 4.1)

	2009	**2015**
Sheltered	26	22
Ahupū	2	3
Hakioawa	9	4
Honokoʻa	4	7
Kanapou	3	1
Kuheia-Kaulana	3	4
Pāpākā	5	3
Exposed	20	28
Kealaikahiki	8	23
Kūnaka-Naʻalapa	12	5
Total Surveys	**46**	**50**

Table 2. Ten paired sites used to examine potential effects of human access on the Reserve's coral reefs. These sites were originally surveyed by Stanton (2005).

Access	Control
Honokanai'a	Honukanaenae
Honokoa	Laepaki
Maka'alae	'Oawapalua
Kuheia	Pāpākāiki
Hakioawa	Lae 'O Kuikui

Benthic Cover

Photographs of the bottom were taken every meter along one 25 m transect line at each survey site using a Canon G12 or S110 camera mounted on a 0.8 m long PVC monopod. This generated 25 images for each survey site, with each photo covering approximately 0.8 x 0.6 m of the bottom. A 5 cm scale bar marked in 1 cm increments was included in all photographs. Twenty randomly-selected photographs from each transect were later analyzed to estimate the percent cover of coral, algae, and other benthic organisms present.

Each selected photograph was imported into Adobe Photoshop CS5 where its color, contrast, and tone were auto-balanced to improve photo quality prior to analysis. Photos were analyzed using the Coral Point Count program with Excel extension (CPCe) developed by the National Coral Reef Institute (Kohler and Gill 2006). Using CPCe, 30 random points[3] were overlaid on each digital photograph, and the benthic component under each point was identified to the lowest possible taxonomic level. Additionally, if a random point fell on a coral showing obvious paling or bleaching, the condition was noted. Bleached corals can be difficult to identify in photographs, so the estimate of bleaching from this analysis represents a conservative estimate of the actual level of coral bleaching that was occurring during the surveys. All photographs were processed by the same person to reduce potential observer variability. Once completed, the raw point data from each photograph was combined to calculate the percent cover of each benthic component for the survey site.

Rugosity

To estimate the topographic complexity of the bottom at each site, an index of rugosity was calculated along the first 10 meters of one 25 m transect by dividing the length of brass chain required to contour the bottom by the 10 m transect length (McCormick 1994). For this index, a value of one represents a flat surface with no relief, and

[3] The number of points analyzed on each photograph (30 points) and the number of photographs at each site (20 photographs) were selected after determining that these values represented the optimal effort to achieve the greatest power to detect statistical differences.

increasing values represent more topographically complex substratum. Rugosity was collected at nearly all survey sites in 2015 (Appendix A).

Fish

All fish surveys were conducted by trained and calibrated divers. Divers slowly deployed the parallel 25 m transect lines while identifying to species and sizing into 5 cm bins (*i.e.*, 0-5 cm, >5-10 cm, >10-15 cm, etc.) all fish within or passing through a 5 m wide belt along each of the two 25 m transects. Divers took between 10 and 15 minutes to complete each fish survey. Using fish length and published size-to-weight conversions, fish biomass (i.e., weight of fish) was calculated for each size class of fish for each species and summed to obtain total fish biomass.

This method closely corresponds with that used by Friedlander and colleagues for the "Fish Habitat Utilization Study" (FHUS) as well as other work in Hawai'i, and therefore provides comparable data. Details of Friedlander and colleagues' method are available in a number of publications (Friedlander *et al.* 2006, 2007a, 2007b). The FHUS was conducted in the early 2000s and represents a comprehensive view of sites across a range of management areas in Hawai'i. In addition to the FHUS data, additional comparisons can be made with other sites at which TNC's marine monitoring team has collected fish information. Data from these additional TNC sites were collected between 2009 and 2015, and often include multiple annual survey events at a location. Together, these data comprise a formidable spatial and temporal comparative data set for fish assemblages.

Following the completion of the transect surveys, a 5-minute timed swim was conducted at a subset of survey sites (30 sites) during which the two fish surveyors swam approximately 5 m apart, identifying to species and sizing into 5 cm bins all target[4] fish larger than 15 cm within or passing through a 5 m wide belt (centered on the surveyor) that extended from the ocean bottom to the surface. During the timed swim, surveyors communicated with each other to ensure that each fish was recorded by only one surveyor (*i.e.*, fishes were not double counted), effectively creating a single 10 m wide belt transect.

Timed swims were initiated along the same compass bearing as the 25 m transects and shifted as necessary to maintain a constant water depth. If short stretches of increased water depth or soft bottom habitat were encountered, surveyors quickly traversed them and continued to survey. If longer stretches of soft bottom or a significant change in depth were encountered, divers altered course to maintain a relatively constant depth and to avoid swimming into extensive areas of soft bottom habitat.

3.3 Previous Kaho'olawe Coral Reef Surveys

In 2009, TNC, the Hawai'i Cooperative Fishery Research Unit, and KIRC, conducted resource surveys at 46 sites around the island of Kaho'olawe (Table 3). The results of these surveys have been published elsewhere (Friedlander *et al.* 2010), but the data have

[4] For a list of species that comprise "target fish" for this report, see table B.1 in Appendix B.

been incorporated into this report to examine temporal trends and improve the spatial resolution of the analysis. Many of the surveyors involved in the 2015 surveys were also involved in 2009, and all divers involved in both surveys were calibrated amongst themselves to reduce observer variability, making the 2009 and 2015 datasets directly and easily comparable.

Between 2004 and 2008, the University of Hawai‘i’s Marine Option Program (MOP) conducted twice-annual surveys (generally March and August) at 10 sites in the Reserve (Stanton 2005, 2006, 2007, 2008). In both 2009 and 2015, these locations were resurveyed, but due to differences in the survey methods used, the fish datasets were not easily comparable. However, the MOP benthic data were comparable after some data reconciliation (see below).

Between 1998 and 2003 (exact date unknown), the Coral Reef Assessment and Monitoring Program (CRAMP) established and surveyed a monitoring site at Hakioawa (Friedlander *et al.* 2003). With some data reconciliation (see below), the CRAMP surveys produced both fish and benthic data that are comparable with TNC and partner’s 2009 and 2015 surveys.

In 1993, researchers form the Hawai‘i Institute of Marine (HIMB) and the National Marine Fisheries Service conducted fish and benthic surveys at 10 sites primarily along the leeward coast of the island (Cox *et al.* 1995). The methods used in the 1993 surveys did not collect comparable fish data, but with some data reconciliation, the benthic data collected during those surveys was comparable with the 2009 and 2015 surveys.

In 1981, 27 transects spread over six sites were surveyed as part of a project to examine the effects of sedimentation (Kawamoto *et al.* 1981). Again, due to differences in methods, fish data were not directly comparable with TNC and partner’s 2009 and 2015 datasets, but coral cover data were comparable.

Table 3. The number of sites surveyed (sheltered/exposed *‘ili*) by TNC and partners (2009 and 2015) and others (1981-2008) around Kaho‘olawe from 1981 to 2015.

Site Location	**1981**[a]	**1993**[b]	**2003**[c]	**2005-2008**[d]	**2009**[e]	**2015**[f]
Benthic	6 (5/1)	18 (10/8)	1 (1/0)	10 (8/2)	28 (14/14)	50 (22/28)
Fish	6 (5/1)	18 (10/8)	1 (1/0)	10 (8/2)	46 (26/20)	50 (22/28)
TOTAL	**6**	**18**	**1**	**10**	**46**	**50**

[a]Kawamoto *et al.* 1981
[b]Cox *et al.* 1995
[c]Friedlander *et al.* 2003
[d]Stanton 2005, 2006, 2007, 2008
[e]Friedlander *et al.* 2010
[f]This report

3.4 Data Analysis

All data from the 2015 surveys were entered into a custom Access database and checked for errors. In this report, all means are presented as the average ± the standard error of the mean (SEM). Standard parametric and non-parametric statistical approaches, as appropriate, were used to test for differences between years and location (exposed versus sheltered *ʻili*). In most cases, a multifactor ANOVA including sample year (2009 and 2015) and location (leeward/windward) was used to examine summary-level variables (*e.g.*, total fish biomass, total fish abundance, etc.). As necessary, fish biomass and abundance were log-transformed to correct skewness and heteroscedasticity. Tukey multiple comparisons were used to identify differences within significant factors. Multivariate analysis on the benthic and fish assemblages was conducted using the suite of non-parametric multivariate procedures included in the PRIMER statistical software package (Plymouth Routines In Multivariate Ecological Research). For a full description of the statistical methods, see Appendix B.

Data Reconciliation

During the 2009 surveys, fish data were collected using the same methods and in many cases the same dive teams, so no reconciliation was necessary prior to making comparisons with the 2015 survey data. However, the 2009 benthic data needed to be reconciled because some benthic categories were defined differently by the photo-analysts. While lower taxonomic categories (*e.g.*, species, genera) for benthic organisms were often not directly comparable, higher taxonomic groups (e.g., coral, turf algae, crustose coralline algae [CCA], etc.) were. Therefore, temporal comparisons were restricted to broad taxonomic groups for benthic organisms. One notable exception was corals, for which comparable species-level data were available.

In most cases, fish data from the pre-2009 surveys could not be reconciled sufficiently for quantitative analysis, but qualitative comparisons were possible. While benthic methods varied between the pre-2009 and 2009-2015 surveys, the resulting data were sufficiently comparable at higher taxonomic levels. Qualitative species level comparisons were also possible within some benthic groups, notably corals. To improve the analysis, sites were grouped by sheltered and exposed *ʻili* (Table 1). For exposed *ʻili*, only sites within the *ʻili* of Kealaikahiki were used in the analysis because pre-2009 surveys did not have sites in the Kūnaka-Naʻalapa *ʻili*.

4.0 Results and Discussion

4.1 Benthic Assemblage

2015 Survey

Nineteen species of coral were observed within the survey area with the lobe coral (*Porites lobata*) and sandpaper rice coral (*Montipora patula*) comprising more than half

of all coral cover (Table 4). Together, coral, turf algae (turf), and CCA accounted for >80% of Kahoʻolawe's benthic cover.

The benthic assemblage significantly differed among the *ʻili* (ANOSIM; R=0.526; p=0.001). Two groups were identified, with the south and west facing *ʻili* of Kunaka/Naʻalapa and Kealaikahiki having a benthic assemblage typical of wave-exposed reefs and the remaining *ʻili* having benthic assemblage typical of less-exposed or sheltered reefs (Figure 2), which is consistent with expectations givens Hawaiʻi's dominant swell regimes and the shelter provided to Kahoolawe from northern swells by other islands (Figure 3).

Reef structure in Hawaiʻi is strongly influenced by wave exposure (Storlazzi *et al.* 2005, Jokiel 2006). For most of the Hawaiian Islands, the largest and most frequent wave energy comes out of the north (Vitousek and Fletcher 2008), but due to shelter provided by Maui, Molokaʻi and Lānaʻi, wave exposure on Kahoʻolawe is primarily from the south (Figure 3), with secondary exposure from the east through the ʻAlenuihāhā Channel.

Wave-exposed reefs tend to be dominated by coral species with robust or low relief growth forms, such as lobe corals and various encrusting species, while more delicate growth forms are found with higher frequency on wave-sheltered reefs (Jokiel 2006). On

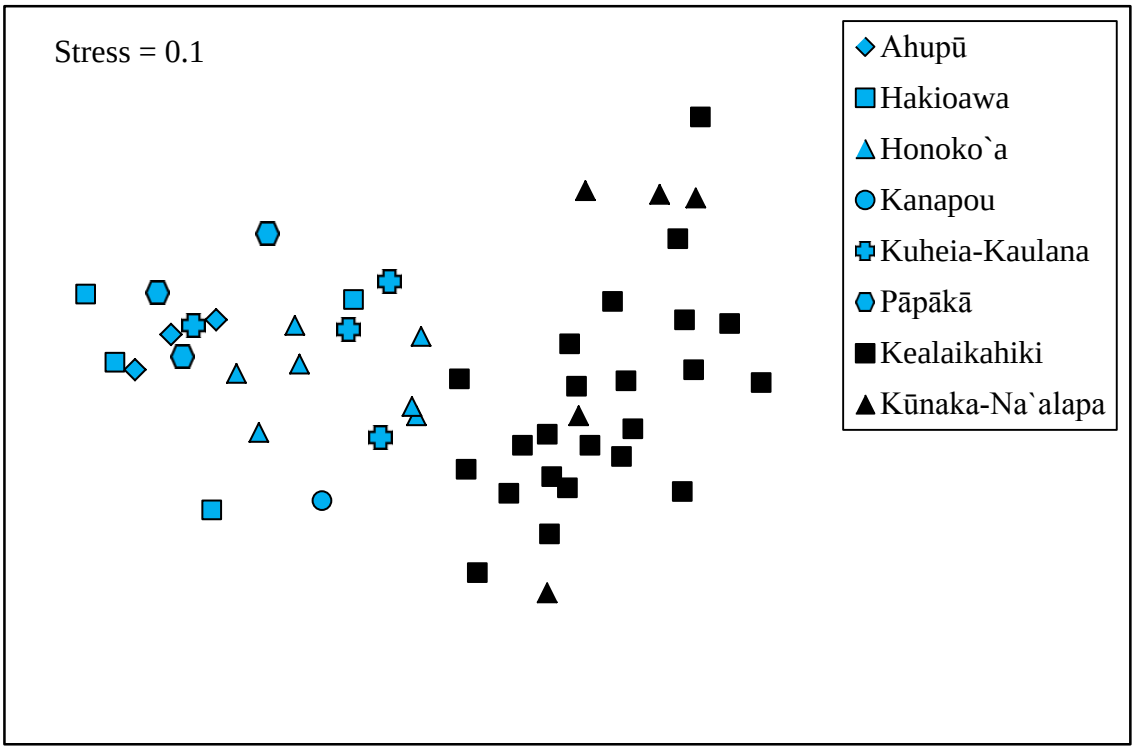


Figure 2. nMDS plot of 2015 survey sites by *ʻili*. Blue symbols represent sites in *ʻili* designated as sheltered, and black symbols represent sites in *ʻili* considered exposed, based on the composition of the benthic assemblage (see text). Plots were generated using benthic cover data for all organisms.

Table 4. Mean (± SEM) cover of benthic organisms at sheltered and exposed sites on Kahoʻolawe in 2015. Scientific names appear at the front of this report.

	Kahoʻolawe	**Exposed**	**Sheltered**
Coral	28.4 ± 3.5	10.2 ± 1.4	51.7 ± 3.7
Sandpaper rice coral	9.0 ± 1.1	5.6 ± 0.8	13.3 ± 1.9
Lobe coral	6.2 ± 1.4	0.3 ± 0.2	13.9 ± 2.4
Rice coral	4.3 ± 1.0	0.1 ± 0.1	9.7 ± 1.8
Finger coral	4.1 ± 1.0	0.1 ± 0.1	9.2 ± 1.7
Cauliflower coral	3.2 ± 0.4	3.8 ± 0.7	2.4 ± 0.4
Corrugated coral	0.6 ± 0.2	0	1.3 ± 0.4
Plate-and-pillar coral	0.4 ± 0.4	0	1.0 ± 1.0
Hump coral	0.2 ± 0.1	0	0.4 ± 0.3
Porkchop coral	0.2 ± 0.1	0.1 ± 0.1	0.2 ± 0.1
False lichen coral	0.1 ± 0.1	0.1 ± 0.1	<0.1
Maldive coral	0.1 ± 0.1	0	0.1 ± 0.1
Antler coral	<0.1	<0.1	0
Ocellated coral	<0.1	<0.1	<0.1
Blue rice coral	<0.1	0	<0.1
Bewick coral	<0.1	<0.1	<0.1
Crust coral	<0.1	<0.1	0
Oval mushroom coral	<0.1	0	<0.1
Transverse coral	<0.1	0	<0.1
Branching rice coral	<0.1	0	<0.1
Turf	51.8 ± 3.2	66.6 ± 3.0	33.0 ± 3.3
Macroalgae	0.3 ± 0.1	0.4 ± 0.2	0.2 ± 0.1
Dictyota spp.	0.1 ± 0.1	0.2 ± 0.2	0
Halimeda sp.	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Red Macroalgae	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Other Macroalgae	<0.1	<0.1	0
CCA	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Other	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Bluegreen algae	<0.1	<0.1	<0.1
Abiotic	15.4 ± 2.2	20.1 ± 3.3	9.5 ± 2.2
Sand	11.9 ± 2.0	14.6 ± 3.1	8.5 ± 2.1
Rubble	3.4 ± 1.1	5.3 ± 1.7	1.0 ± 0.3
Recently Dead Coral	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Pavement	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1
Depth (ft.)	30.3 ± 1.4	32.9 ± 1.9	27.1 ± 2.0
Rugosity	13.9 ± 1.0	12.3 ± 0.7	15.8 ± 1.9

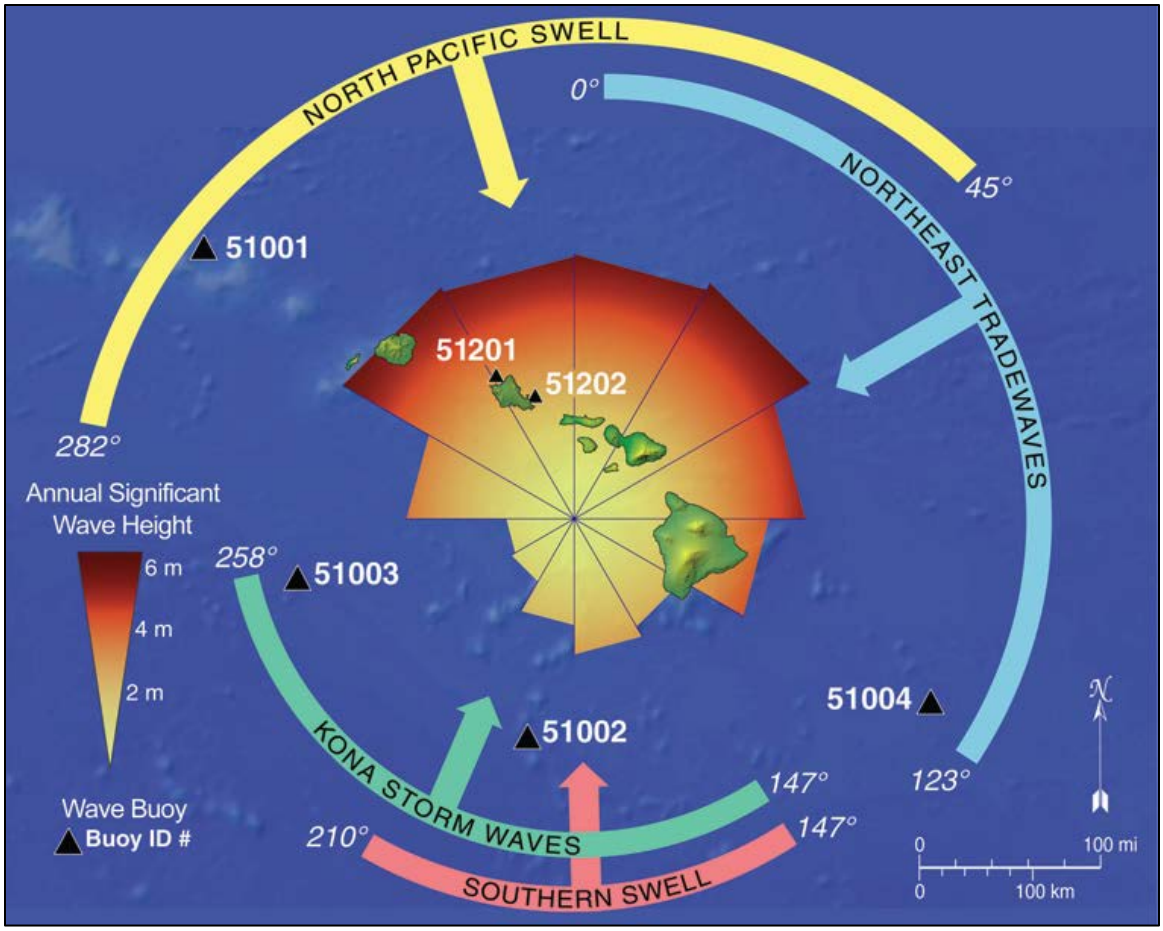


Figure 3. Hawai‘i’s dominant swell regimes (figure from Vitousek & Fletcher [2008]).

Kaho‘olawe, differences in the cover of four species of coral—sandpaper rice coral, finger coral (*Porites compressa*), rice coral (*Montipora capitata*), and lobe coral—explained nearly 60% of the difference observed between exposed and sheltered benthic assemblages (via SIMPER analysis). Sandpaper rice coral, lobe coral, and rice coral were more common and finger coral less common on exposed compared to sheltered reefs (Table 4), which is consistent with differences in wave exposure.

Coral cover on sheltered reefs (51.7 ± 3.7%) was five-times higher than on exposed reefs (10.2 ± 1.4%), and species diversity was 1.5 times greater at sheltered (17 species) compared to exposed (11 species) sites. Two wave resistant species, sandpaper rice coral and cauliflower corals (*Pocillopora meandrina*), were the dominant species on exposed reefs, while lobe coral and other encrusting species were present but not necessarily abundant. Rice coral has two wave-dependent growth forms in Hawai‘i; only the robust, encrusting form was found at exposed sites, whereas both the encrusting and more delicate branching forms were found on sheltered reefs (Plate 1). Exposed reefs also had higher cover of turf and abiotic substratum, especially rubble (Table 4).

The *ʻili* identified here as sheltered and exposed (Table 1) differ somewhat from previous researchers (Friedlander *et al.* 2010) in that reefs in Kanapou *ʻili* are consistent with a wave-sheltered reef. It should also be noted that in 2015, only one site was surveyed in the Kanapou *ʻili*, but examination of the 2009 sites surveyed in Kanapou support its designation as a sheltered *ʻili*. However, KIRC staff have noted that Hakioawa and Pāpākā *ʻili* experience significant wave action as a result of "wrap around" swell coming through the ʻAlenuihāhā Channel. While these reefs undoubtedly receive periodic high wave events, benthic assemblage structure suggests these wave events are either not frequent and/or severe enough to result in a shift in species composition to one more consistent with a wave-exposed reef.

No significant difference in coral cover was found between the "access" and "control" sites (Paired t-test, t=1.07, p=0.363). While the paired sites had a wide range of coral cover, ranging from ~1% to ~75%, the difference between the pairs was not significant. Assemblage structure also did not differ (ANOSIM; R=-0.229; p=0.971), suggesting little effect of human access on the benthic assemblage. It should be noted, however, that potential effects of human access may be obscured by larger "regional" impacts (e.g., island-wide sedimentation), and access areas should continue to be closely monitored, especially as restoration actions continue to reduce other significant stressors.

Terrestrial-derived sedimentation was not directly monitored as part of this project, but it could be detected in benthic photos via its red-to-dark brown color (Plate 1). Of the fifty sites surveyed in 2015, twenty sites (40%) showed evidence (presence/absence) of terrestrial-derived sediment on the reef (Figure 4). These sites were more common on the wave-sheltered (north and east) sides of the island, which is not surprising considering waves are capable of suspending sediment off the bottom and facilitating transport off the reef. Additionally, vegetation on the east side of the island is less intact than on the west side, likely promoting more erosion along this sheltered coastline.

The potential effect of terrestrial sediment on coral has been well documented in the scientific literature (see Rogers 1990 and Fabricious 2005 for reviews), but findings on Kahoʻolawe appear to run counter to general expectations. On the exposed side of Kahoʻolawe, no difference in coral cover was found between sites with and without photographic evidence of terrestrial-derived sediment (Figure 5). In contrast, sites on sheltered reefs with terrestrial-derived sediment had higher coral cover on average than sites without (ANOVA; $F_{3,46}$=60.86; p<0.001).

Coral cover alone does not tell the entire story, however. Examining the entire benthic assemblage using a multivariate analysis finds significant differences between sites with and without terrestrial-derived sediment only for exposed reef (ANOSIM; R=0.701; p=0.001) and not for sheltered ones (ANOSIM; R=0.136; p=0.117). This seeming paradox arises from:

1) On exposed reefs, a shift occurs in the coral species composition from lobe and cauliflower corals to finger coral (almost perfectly offsetting each other) along with a large, concurrent increase in abiotic substratum, especially sand, at sites

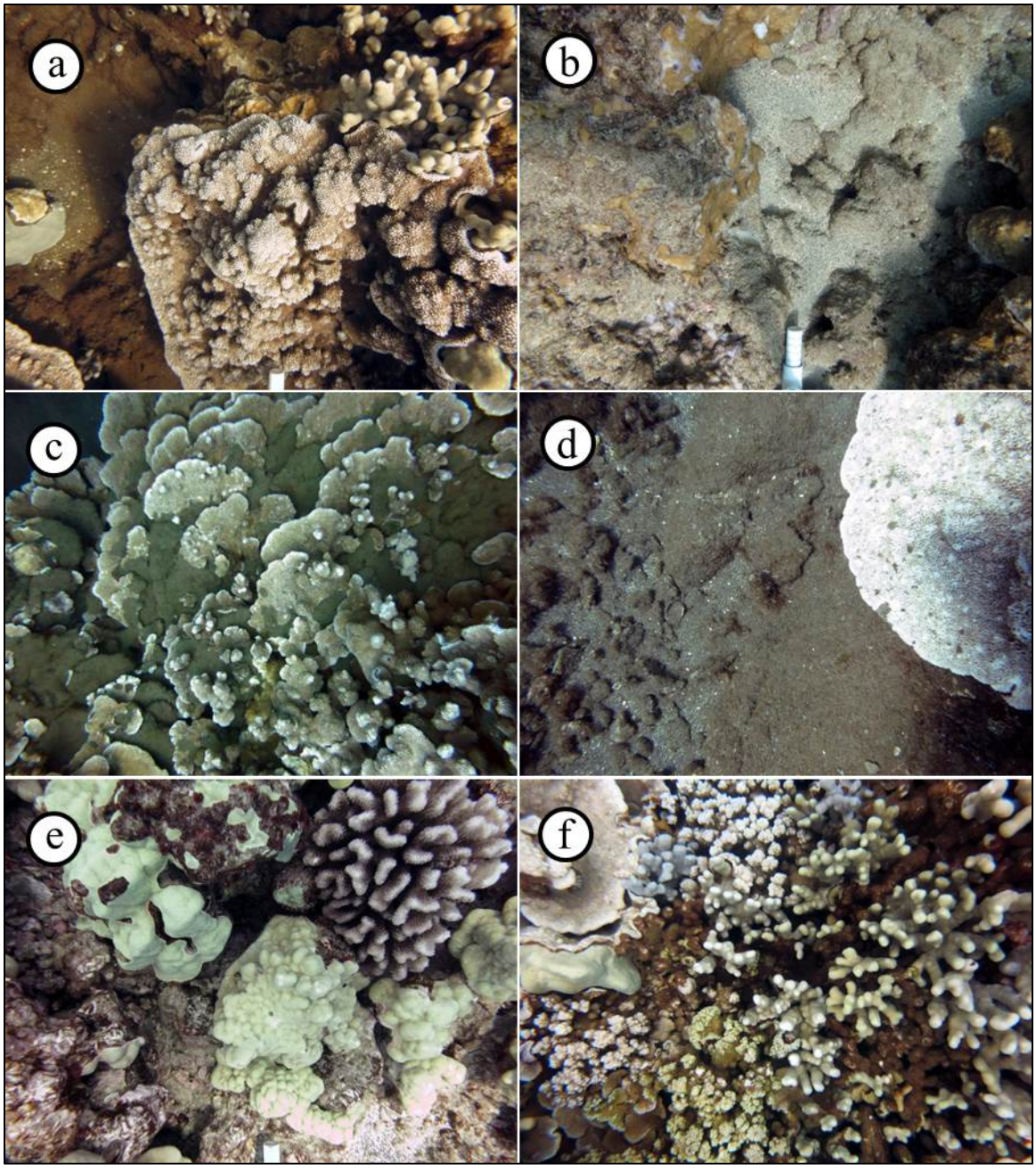


Plate 1. a) Brown-colored terrestrial-derived sediment on and around a rice coral colony (survey site: 2015-KIRC119). b) Marine sand near a sandpaper rice coral colony (2015-KIRC054). c) Terrestrial-derived sediment atop a rice coral colony (2015-KIRCHakioawa) d) A bleached rice coral colony surrounded by terrestrial derived sediment (2015-KIRC116a). e) Coral species typical on an exposed reef include low growing lobe corals and robust branching cauliflower corals (2015-KIRC068). f) Corals such as finger coral and the branching morphology of rice coral typically found on wave-sheltered reefs (2015-KIRC121).

with terrestrial-derived sediment. This results in no significant change in total coral cover (Figure 5), but a shift in both species composition and the amount of abiotic substratum.

2) At sheltered sites, small changes occur in the cover of numerous coral species, but there were notable increases in finger coral, the branching form of rice coral, and other rarer coral species. These small increases are not offset by concurrent decreases in lobe coral and cauliflower corals at sites with terrestrial-derived sediment (as was seen in the exposed sites with terrestrial sediments). Additionally, there is no significant change in non-coral taxa. This results in an increase in total coral cover (Figure 5) without significantly changing the species composition or the amount of abiotic substratum.

Examining these findings as a whole, it appears that sediment is not the primary stressor shaping the benthic assemblage structure on the Reserve's reefs. Sheltered sites without terrestrial-derived sediment were found primarily on the eastern and western edges of the island, abutting the dividing line between sheltered and exposed *ʻili* (Figure 4). These reef areas likely represent transition zones from sheltered to exposed reefs, and they likely receive periodic high wave events that may be sufficient to partially reduce coral

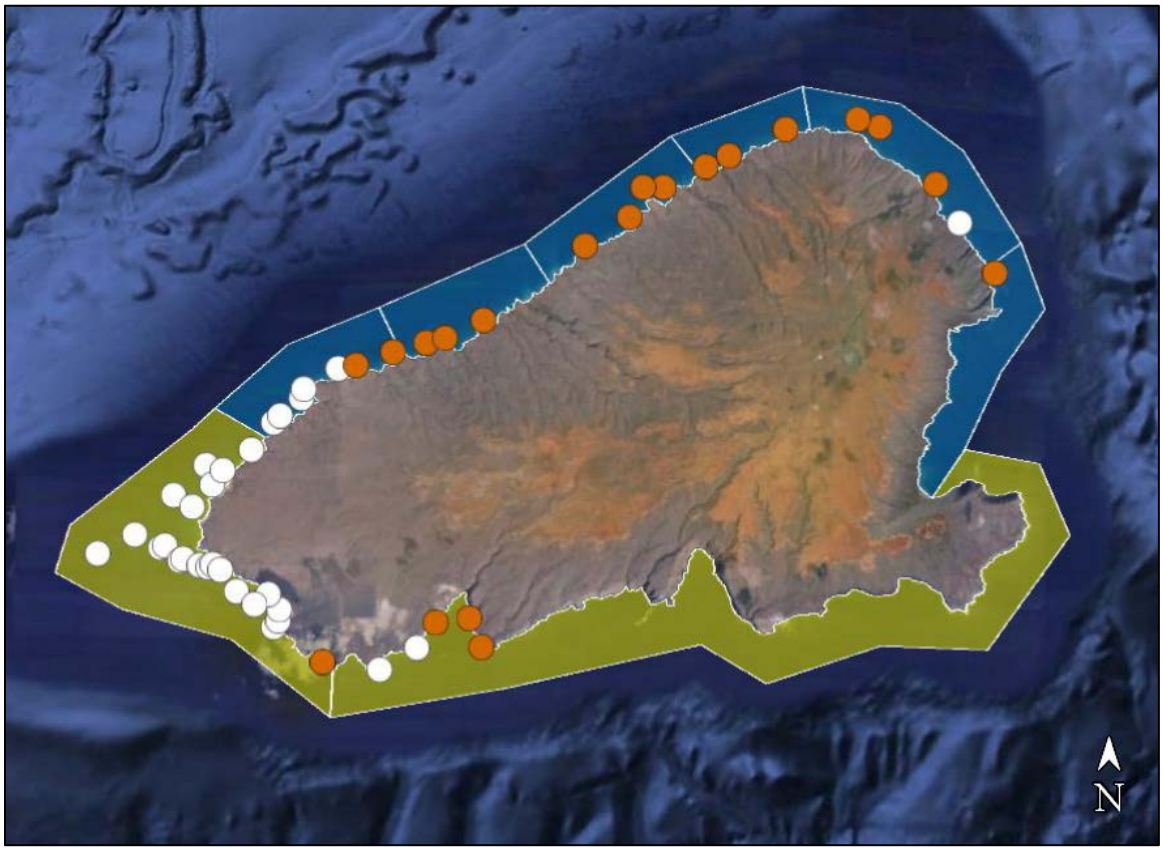


Figure 4. The presence (brown circles) or absence (white circles) of terrestrial-derived sediment at the 2015 Kahoʻolawe survey sites. Exposed *ʻili* are shaded green; sheltered *ʻili* are shaded blue.

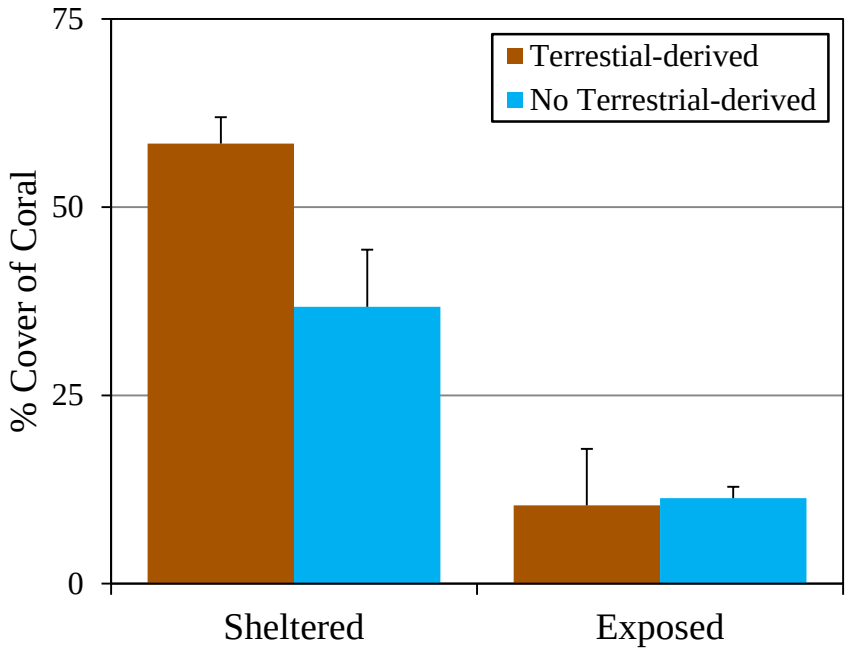


Figure 5. Coral cover on sheltered and exposed reefs with and without evidence of terrestrial-derived sediment.

cover. This explanation is supported by the site at the eastern edge of the sheltered "zone" which doesn't have terrestrial-derived sediment and clusters near the exposed sites in the nMDS plot, suggesting it has a high similarity with sites characterized by the exposed reef assemblage. Coral species expected on wave-sheltered reefs were more common at sites with terrestrial-derived sediment compared to those without. While terrestrial sediment could appear to be a "benefit" to the Reserve's reefs, this is likely not the case, and the higher coral cover and species diversity is more likely the result of a reduction in wave exposure than the presence of terrestrial-derived sediment. Wave action appears to be a primary structuring agent on the Reserve's reefs, which would be consistent with other findings in Hawai'i (Dollar 1982, Storlazzi *et al.* 2002, Jokiel *et al.* 2004).

Even so, these findings do not indicate that sediment is having *no* impact on Kaho'olawe's reefs. Sediment effects on coral and other benthic organisms are well documented and cannot be dismissed within the Reserve, and it may indeed be the case that coral cover and diversity could be higher at these sheltered sites if they were not affected by sediments. While sediment effects appear smaller than wave action effects on the Reserve's benthic assemblage, this survey was not designed to directly examine these relationships and lacks the sensitivity to effectively do so. Additional, targeted research would be needed to separate wave action and sediment effects on Kaho'olawe's benthic assemblage.

In 2014 and 2015, Hawai'i experienced two significant bleaching events. The 2014 event, which lasted from approximately July-December 2014, did not significantly effect

Table 5. Percent of coral tissue bleached (±SEM) by species for Kahoʻolawe and exposed/ sheltered reefs. For plate-and-pillar coral (*Porites rus*) and oval mushroom coral (*Fungia scutaria*), an insufficient number of observations did not allow an estimate of the tissue bleaching rate to be made, but bleached colonies were observed in photographs.

	Kahoʻolawe	**Exposed**	**Sheltered**
Rice coral	33.0 ± 6.4	51.5 ± 14.6	23.7 ± 5.5
Cauliflower coral	28.6 ± 5	20.7 ± 6.4	38 ± 7.6
Sandpaper rice coral	9.9 ± 4.6	28.9 ± 14.5	2.2 ± 0.8
Corrugated coral	6.3 ± 6.3	-	6.3 ± 6.3
Finger coral	3.1 ± 2.1	-	3.8 ± 2.5
Lobe coral	2.1 ± 0.6	1.7 ± 0.7	2.5 ± 1.1
Plate-and-pillar coral	Yes	-	-
Oval mushroom coral	Yes	-	-
% Coral Bleached	**8.3 ± 1.9**	**9.4 ± 3.1**	**6.8 ± 1.5**

corals on Maui (and presumably Kahoʻolawe). The second bleaching event occurred in the latter half of 2015 (approximately August-December 2015), and affected Maui more severely than the 2014 event. The State Department of Land and Natural Resources, Division of Aquatic Resources, estimated that over 50% of the corals at many sites around Maui bleached during the 2015 event, including at Makena, a location across the ʻAlalākeiki Channel from Kahoʻolawe.

Bleaching was observed in seven coral species during the 2015 surveys of Kahoʻolawe (Table 5). These survey were conducted in June 2015, between the peaks of the 2014 and 2015 bleaching events, when bleaching rates were presumably at their lowest. The overall bleaching rate oberved was low, and did not significantly vary with exposure (ANOVA; $F_{1,49}$=0.06; p=0.808) or sediment (ANOVA; $F_{1,49}$=0.07; p=0.792). Bleaching also did not significantly vary with human access (Paired t-test, t_4=0.79, p=0.472), but the sample size is small and given the high variability in the data, the power to detect a difference is low. Species-specific bleaching rates varied, with bleaching tolerant species (Marshall and Schuttenberg 2006), such as lobe coral, showing low rates of tissue bleaching, and more susceptible species, such as rice coral exhibiting up to 50% bleaching (Table 5). It is reasonable to believe that bleaching rates were significantly higher on Kahoʻolawe in the months following these surveys, however, which is supported by observations from the KIRC natural resources staff. Follow-up surveys to assess the potential impact of the 2015 bleaching event should be conducted to determine the current status of the coral assemblage.

Bleaching information was not collected as part of the 2009 surveys, but Stanton (2006, 2007, 2008) documented high incidence of bleaching from 2005-2007, especially for rice coral and cauliflower coral. Comparison of bleaching rates through time, however, is not possible because Stanton collected information on percent of colonies bleached

(incidence), whereas the present surveys collected information on the percent of coral tissue bleached from benthic photos; these two data types are not comparable. However, qualitative comparisons find a similar pattern of bleaching with rice and cauliflower coral displaying the greatest amount of bleaching.

Temporal Trends (1981-2015)

Due to differences in photo-interpretation between the 2009 and 2015 surveys, we determined that direct comparisons could only reliably be made for higher taxonomic groups (*e.g.*, coral, macroalgae, turf, etc.) and for individual coral species. The 2009 survey effort used slightly different criteria for distinguishing other non-coral species, so their direct comparability with the 2015 dataset was uncertain. For surveys prior to 2009, we determined that only coral cover could be confidently compared with the 2009 and 2015 surveys.

At the 20 sites surveyed in 2009 and re-surveyed in 2015, there was no significant change in coral cover between survey years for sites on sheltered (t-test, t=1.23, p=0.245) or exposed (t-test, t=0.75, p=0.48) reefs within the Reserve (Figure 6).

Looking at the coral assemblage, no difference was found for exposed sites (ANOSIM; R=0.076; p=0.154), but a significant difference was found for sheltered ones (ANOSIM;

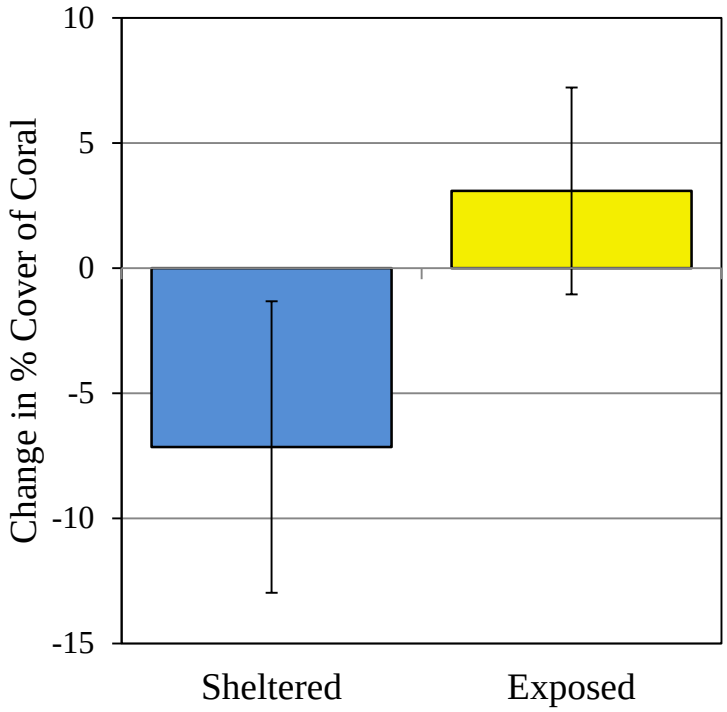


Figure 6. Average change in coral cover at 20 sites surveyed in 2009 and 2015. Change is not significantly different from zero for either sheltered or exposed reefs.

R=0.214.; p=0.006). However, the difference among the sheltered reef sites was driven primarily by a single site (Figure 7)[5], and the associated R-statistic is fairly low, suggesting the difference between the 2009 and 2015 communities are likely small and not ecologically meaningful. This conclusion is further supported when examining the contribution of the various benthic groups to the observed difference. No single species drives the change between years; instead, small changes across many coral species contribute equally to the observed shift in assemblage structure.

Looking back to 1981, the coral cover in exposed *'ili* showed no discernable trend (Pearson Correlation, r=0.239, p=0.569), but coral cover in sheltered *'ili* showed a significant increase (Pearson Correlation, r=0.851, p=0.004) over the same time period (Figure 8). The reason(s) for increased coral cover on sheltered reefs is not known, but possible explanations include:

(1) Improved water quality conditions, especially regarding sediment, have improved the habitat leading to better coral recruitment and growth. This explanation is

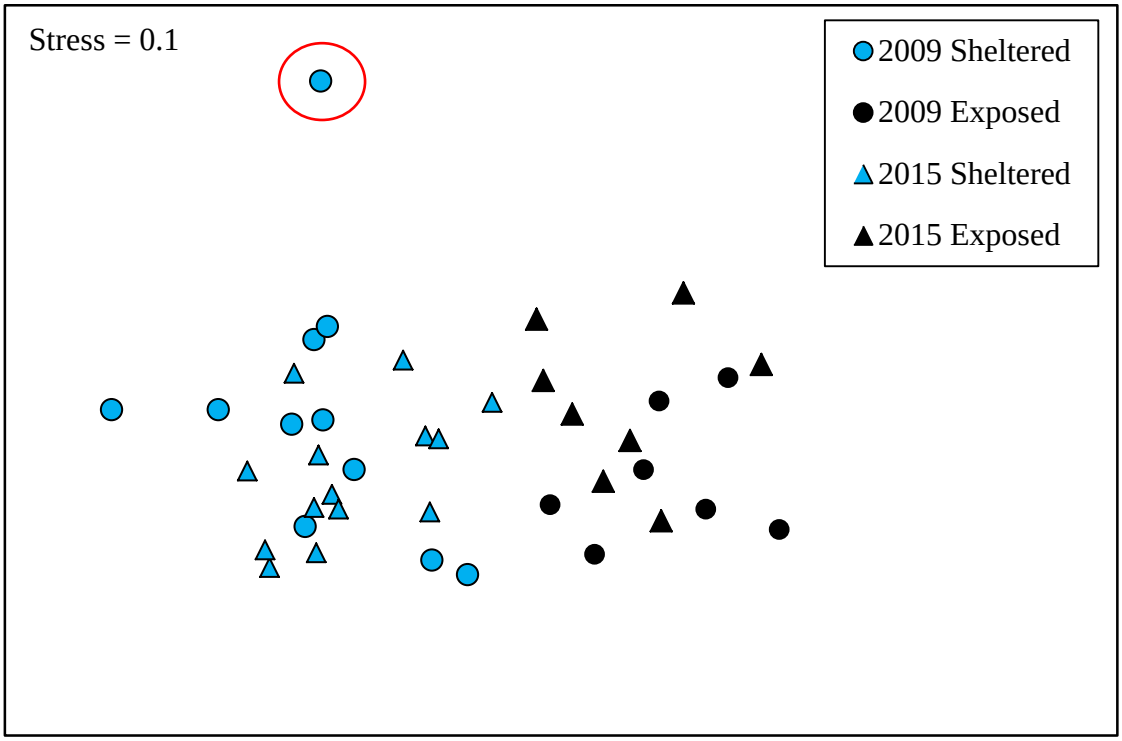


Figure 7. nMDS plot of the 20 sites surveyed in both 2009 (circles) and 2015 (triangles). Assemblage structure did not signfifcantly differ for exposed reef sites (black symbols), and a single site (circled in red) created a significant result for the sheltered sites (blue symbols). Deeper investigation showed no meaningful ecological difference between the 2009 and 2015 survey sites.

[5] Unlike other survey sites, this "unusual" site (2009-KIRC048) was primarily "silt" (82%) with coral heads interspersed. Removing it from the analysis results in R=0.194, p=0.029

consistent with the observed increase in coral cover on sheltered reefs, where the majority of sites with terrestrial-derived sediment occur.

(2) A series of "good" coral recruitment years. This explanation would potentially improve conditions island-wide, but the cover on the sheltered reefs appears to consistently increase, which is likely inconsistent with periodic “good” recruitment years. However, data on coral recruitment is not available at Kahoʻolawe so it is not possible to adequately assess coral recruitment over this time period.

(3) Potential methodological "errors" in the survey work. All survey approaches have "method-associated" error that can increase the variability of the data. While this type of "error" can result in what appears to be an increasing trend in the data—especially data conducted by different researchers at different times with different methods—given the length of the time series and the consistent trend, it is unlikely that this type of "error" adequately explains the increasing trend.

(4) Different surveyors and methods may have produced different results. This explanation is not consistent with the data because the same surveyors conducted the surveys from 2005-2008, during which the increasing trend continued.

While coral cover has increased on the north (sheltered) side of the Reserve, the lack of historical data for the south (exposed) side of the Reserve makes it difficult to draw a solid conclusion about these reefs. It appears that coral cover on the Reserve’s exposed reefs has not significantly changed over the past 35 years, which is itself a significant finding given that data from elsewhere in Hawaiʻi has documented large, significant declines in coral cover at many sites, including Puakō (Minton *et al.* 2012), Kaʻūpūlehu, (Minton *et al.* 2015) and several other west Hawaiʻi Island sites (Walsh *et al.* 2013), as well as numerous sites on Maui and Oʻahu (Rodgers *et al*. 2014). Overall, the reefs of Kahoʻolawe appear to have been stable or improving between 1993 and 2015.

4.2 Fish Assemblage

2015 Surveys

A total of 135 species representing 30 families of fishes were observed during the 2015 Kahoʻolawe surveys (Tables 6 and 7). More fish species were observed on exposed than sheltered reefs, 122 compared to 101 species, but the average number of species per survey site did not vary by exposure (t-test; T=0.49; df=38; p=0.625): 24.5 ± 0.7 and 25.5 ± 1.8 species/site for sheltered and exposed, respectively.

Five fish families contributed over 60% of the total fish biomass, with surgeonfish contributing the most on both exposed and sheltered reefs (Table 6). Surgeonfishes (Acanthuridae), parrotfishes (Scaridae) and wrasses (Labridae), three of the top five

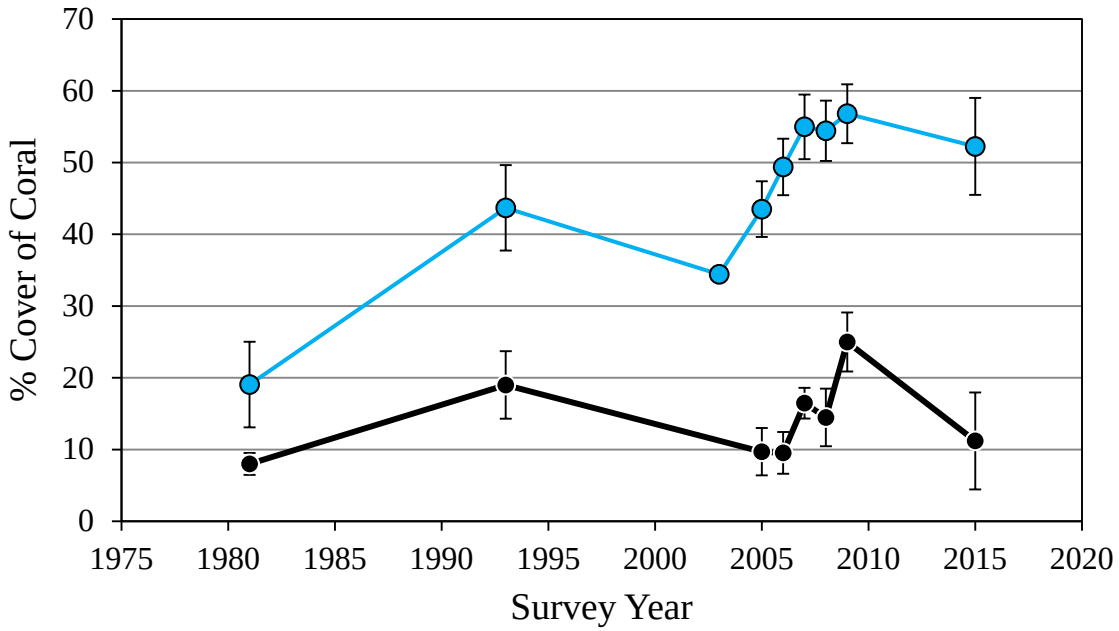


Figure 8. Change in coral cover at Kahoʻolawe from 1981-2015 for sheltered (blue) and exposed (black) *ʻili*. For reefs in sheltered *ʻili*, the increase was significant (Pearson Correlation, r=0.851, p=0.004), but no trend was found for exposed *ʻili* (Pearson Correlation, r=0.239, p=0.569). Data are from Kawamoto *et al.* (1981), Jokiel *et al.* (1995), Friedlander *et al.* (2003), Stanton (2005, 2006, 2007, 2008), Friedlander *et al.* (2010).

species by biomass, tend to be among the most common fish families on Hawaiian reefs. In contrast, the other two families, snappers (Lutjanidae) and groupers (Serranidae), tend to comprise a relatively small percentage of the total fish biomass on other Hawaiian reefs. High snapper biomass on Kahoʻolawe was associated with the smalltoothed jobfish (*Aphareus furca*), which accounted for 55% of all snapper biomass. Grouper biomass was comprised exclusively of the invasive peacock grouper or roi (*Cephalopholis argus*).

Families generally comprised of small bodied fish were most abundant on Kahoʻolawe's reefs, with damselfish (Pomacentridae), surgeonfish, and wrasses (Labridae) being numerically dominant (Table 7). These three families dominated sheltered reefs, accounting for nearly 95% of all fish individuals observed, whereas they accounted for approximately 75% of the observed fish on exposed reefs.

Total fish biomass was significantly higher on Kahoʻolawe's exposed (170.9 ± 30.3 g/m^2) compared to sheltered (100.6 ± 17.5 g/m^2) reefs (ANOVA; $F_{1,95}$=9.71; p=0.002). Fish abundance, however, did not significantly vary with exposure (ANOVA; $F_{1,95}$=2.95; p=0.089). Fish assemblage structure also significantly varied with exposure (ANOSIM; R=0.244; p=0.001), but the relatively small R-statistic suggests only a small, and likely not ecologically meaningful difference. A follow up SIMPER analysis identified no key

Table 6. Biomass (g/m^2) of fish by family on the sheltered and exposed coasts of Kahoʻolawe. Families are ordered by decreasing biomass for the entire island.

	Kahoʻolawe	**Sheltered**	**Exposed**
Surgeonfishes (Acanthuridae)	43.7 ± 7.3	35.5 ± 11.3	50.2 ± 9.6
Snappers (Lutjanidae)	23.8 ± 7.3	9.0 ± 3.7	35.5 ± 12.3
Parrotfishes (Scaridae)	12.5 ± 2.0	9.7 ± 2.5	14.7 ± 3.0
Groupers (Serranidae)	10.9 ± 1.7	13.7 ± 2.4	8.7 ± 2.2
Triggerfishes (Balistidae)	9.7 ± 2.0	5.5 ± 1.9	13 ± 3.1
Wrasses (Labridae)	7.0 ± 1.1	5.2 ± 1.5	8.4 ± 1.6
Emperors (Lethrinidae)	6.6 ± 1.8	4.8 ± 2.6	7.9 ± 2.4
Jacks (Carangidae)	4.6 ± 2.1	1.6 ± 0.8	6.8 ± 3.6
Squirrel/Soldierfishes (Holocentridae)	4.3 ± 1.4	1.4 ± 0.4	6.6 ± 2.3
Goatfishes (Mullidae)	3.8 ± 1.6	0.8 ± 0.3	6.1 ± 2.7
Butterflyfishes (Chaetodontidae)	3.2 ± 0.4	3.4 ± 0.4	3.2 ± 0.7
Damselfishes (Pomacentridae)	2.7 ± 0.8	2.2 ± 0.5	3.2 ± 1.3
Filefishes (Monacanthidae)	2.4 ± 0.8	3.4 ± 1.5	1.6 ± 0.7
Chubs (Kyphosidae)	2.0 ± 1.3	3.6 ± 2.9	0.7 ± 0.4
Requiem sharks (Carcharhinidae)	1.6 ± 1.6	0	2.9 ± 2.9
Hawkfishes (Cirrhitidae)	0.6 ± 0.1	0.4 ± 0.1	0.7 ± 0.1
Moorish Idol (Zanclidae)	0.3 ± 0.1	0.2 ± 0.1	0.4 ± 0.1
Trumpetfishes (Aulostomidae)	0.1 ± 0.1	0.2 ± 0.2	0.1 ± 0.1
Barracudas (Sphyraenidae)	0.1 ± 0.1	0	0.2 ± 0.2
Angelfishes (Pomacanthidae)	0.1 ± 0.1	<0.1	0.1 ± 0.1
Puffers (Tetraodontidae)	0.1 ± 0.1	0.1 ± 0	0.1 ± 0.1
Morwongs (Cheilodactylidae)	<0.1	0	0.1 ± 0.1
Porcupinefishes (Diodontidae)	<0.1	0	0.1 ± 0.1
Blennies (Blenniidae)	<0.1	<0.1	<0.1
Cardinalfishes (Apogonidae)	<0.1	<0.1	0
Boxfishes (Ostraciidae)	<0.1	0	<0.1
Coral crouchers (Caracanthidae)	<0.1	0	<0.1
Moray eels (Muraenidae)	<0.1	<0.1	<0.1
Eagle rays (Myliobatidae)	<0.1	0	<0.1
Milkfish (Chanidae)	<0.1	<0.1	0
Total Biomass	140.0 ± 19.1	100.6 ± 17.5	170.9 ± 30.3

Table 7. Abundance (individuals/125 m^2) of fish by family on the leeward and windward coasts of Kahoʻolawe. Families are ordered by decreasing biomass for the entire island

	Kahoʻolawe	**Sheltered**	**Exposed**
Damselfishes (Pomacentridae)	115.1 ± 10.9	117.6 ± 13.7	113.1 ± 16.5
Surgeonfishes (Acanthuridae)	60.3 ± 5.6	61.6 ± 8.4	59.4 ± 7.6
Wrasses (Labridae)	14.0 ± 0.9	10.8 ± 0.8	16.5 ± 1.4
Butterflyfishes (Chaetodontidae)	9.1 ± 1.1	9.3 ± 0.7	8.8 ± 2.0
Triggerfishes (Balistidae)	8.0 ± 1.5	4.1 ± 1.1	11 ± 2.3
Snappers (Lutjanidae)	7.3 ± 3.9	1.9 ± 0.5	11.5 ± 7
Parrotfishes (Scaridae)	6.5 ± 1.8	5.9 ± 1.2	6.9 ± 3.0
Morwongs (Cheilodactylidae)	4.4 ± 3.2	0	7.9 ± 5.7
Hawkfishes (Cirrhitidae)	3.7 ± 0.4	2.3 ± 0.3	4.8 ± 0.5
Goatfishes (Mullidae)	3.7 ± 1.5	1.1 ± 0.4	5.7 ± 2.6
Groupers (Serranidae)	2.4 ± 0.5	2.8 ± 0.4	2.1 ± 0.9
Squirrel/Soldierfishes (Holocentridae)	1.7 ± 0.5	1.0 ± 0.6	2.3 ± 0.7
Emperors (Lethrinidae)	1.6 ± 0.4	1.5 ± 0.4	1.6 ± 0.6
Jacks (Carangidae)	1.4 ± 0.8	0.3 ± 0.1	2.2 ± 1.4
Puffers (Tetraodontidae)	0.9 ± 0.1	1.1 ± 0.2	0.7 ± 0.1
Chubs (Kyphosidae)	0.6 ± 0.3	1.0 ± 0.7	0.2 ± 0.1
Filefishes (Monacanthidae)	0.5 ± 0.2	0.4 ± 0.2	0.6 ± 0.2
Moorish Idol (Zanclidae)	0.4 ± 0.1	0.2 ± 0.1	0.6 ± 0.2
Angelfishes (Pomacanthidae)	0.3 ± 0.1	0.2 ± 0.1	0.4 ± 0.2
Trumpetfishes (Aulostomidae)	0.2 ± 0.1	0.3 ± 0.2	0.1 ± 0.1
Blennies (Blenniidae)	0.1 ± 0.1	<0.1	0.1 ± 0.1
Moray eels (Muraenidae)	<0.1	<0.1	0.1 ± 0.1
Cardinalfishes (Apogonidae)	<0.1	<0.1	0
Coral crouchers (Caracanthidae)	<0.1	0	<0.1
Requiem sharks (Carcharhinidae)	<0.1	0	<0.1
Milkfish (Chanidae)	<0.1	<0.1	0
Porcupinefishes (Diodontidae)	<0.1	0	<0.1
Eagle rays (Myliobatidae)	<0.1	0	<0.1
Boxfishes (Ostraciidae)	<0.1	0	<0.1
Barracudas (Sphyraenidae)	<0.1	0	<0.1
Total Abundance	222.4 ± 12.5	197.8 ± 14.8	254.5 ± 19.5

species responsible for the observed difference between exposed and sheltered fish assemblages; instead, the difference was the result of small shifts in the relative biomass of many species (50+ species). This suggests that the observed difference in total fish biomass between exposed and sheltered reefs may be primarily the result of larger average size for individuals within a species rather than a shift in the assemblage structure from small- to large-bodied species. Comparing the average size of individuals for the nine species with highest biomass (for the tenth species, giant trevally or *ulua aukea* [*Caranx ignobili*], too few individuals were observed to make meaningful comparisons), individuals on exposed reefs were an average of 5% larger than those on sheltered reefs (Table 8). The only exceptions were green jobfish or *uku* (*Aprion virescens*) and blacktailed snapper or *to'au* (*Lutjanus fulvus*), which tended to have a smaller average size on exposed reefs.

Total fish biomass also did not differ between sites with and without terrestrial sediment for either exposed or sheltered reefs (ANOVA; $F_{3,46}$=1.29; p=0.287). No effect of "access" was found (Paired t-test, t=1.65, p=0.198), suggesting potential impacts from the allowed human access were not detectable, but given the small sample size and the variability of fish populations, this analysis likely had low power to detect differences. Access areas should continue to be closely monitored to detect any emerging effects.

Target fishes[6] refer to fish desirable for food, commercial activity, and/or cultural practices that reside in the habitats and depth ranges surveyed by TNC's marine monitoring team and its partners. Target fish biomass was highly variable (92.0 ± 13.7 g/m^2) and did not significantly vary with wave exposure (ANOVA; $F_{1,95}$=0.03; p=0.854). Surgeonfish were the most common target fish group (Figure 9), accounting for 41% of

Table 8. Average fish size (cm) for the ten species with greatest biomass on sheltered and exposed reefs.

	Sheltered		Exposed			
	n	**Size**	**n**	**Size**	**Δ (cm)**	**Δ (%)**
Green jobfish	12	60.4	31	47.7	-12.7	-21
Peacock grouper	148	29.5	74	32.2	2.7	9.2
Eyestripe surgeonfish	15	28	51	30.3	2.3	8.2
Ember parrotfish	78	29.3	104	36	6.7	22.9
Ringtail surgeonfish	45	25.1	54	25.6	0.5	2
Sleek unicornfish	9	22.2	23	25.7	3.5	15.8
Bigeye emperor	50	25.8	65	30.2	4.4	17.1
Bullethead parrotfish	78	22.5	40	23	0.5	2.2
Blacktail snapper	48	26.8	37	23.5	-3.3	-12.3
Giant trevally	2	35	5	102	67	191.4

[6] See Appendix B for a list of species that comprise the target fish for this report.

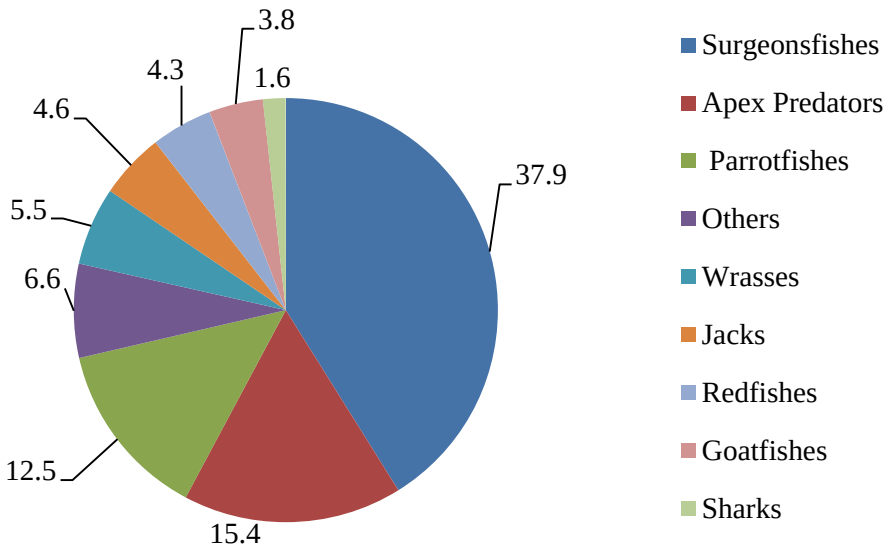


Figure 9. Target fish biomass (g/m^2) by target group for Kaho‘olawe in 2015. See Appendix B for a complete list of species in each target fish group.

the total target fish biomass. Apex predators, rare on most Hawaiian reefs, contributed the next most to total target fish biomass (17%), and together with jacks and sharks, accounted for 23% of the target fish biomass. The absence of these three groups on many of Hawai‘i’s reefs has been attributed to high fishing pressure.

As with total fish biomass, target fish biomass showed no effect from terrestrial-derived sediment on both exposed and sheltered reefs (ANOVA; $F_{3,46}$=1.68; p=0.185) or those with human access (Paired t-test, t=2.21, p=0.114).

Prime spawners are large target fishes (>70% their maximum size) which are generally prized by fishers and tend to contribute disproportionately more to the total reproductive potential of the population than smaller individuals due to their greater egg and sperm production (*i.e.*, higher fecundity) and the higher survivorship of their larvae (Williams *et al.* 2008). Therefore, prime spawner biomass is a good indicator of fishing impacts (*e.g.*, as fishing pressure increases, the biomass of prime spawners is likely the first thing to decrease), and represents an important component of ecological function (*i.e.*, population breeding potential).

Prime spawner biomass in the Reserve was 37.7 ± 7.7 g/m^2, with a diverse assemblage contributing: 467 individual prime spawners were observed along survey transects, encompassing 37 species in nine fish families. Prime spawner biomass on exposed reefs was significantly higher than on sheltered ones (ANOVA; $F_{1,95}$=9.87; p=0.002), which is consistent with the finding that fish individuals were, on average, larger on the exposed compared to sheltered reefs (Table 8).

Prime spawner biomass showed no relationship with terrestrial-derived sediment (ANOVA; $F_{3,46}$=2.09; p=0.115), but did show a significant effect of human “access”

(Paired t-test, t=3.91, p=0.030). The effect, however, was not consistent with human access causing a negative impact; prime spawner biomass was significantly higher at "access" compared to "control" sites, a result that is difficult to interpret and should be viewed with caution given the small sample size.

Spatial Patterns within the Reserve

Total fish biomass, target fish biomass and prime spawner biomass were all highest on the west end of Kaho'olawe, but also more variable (Figure 10), a finding consistent with that observed in 2009 (Friedlander *et al.* 2010). In 2015, <20% of the sites along the north and east coast of the Reserve had above average total fish (>140.0 g/m^2), resource fish (>92.0 ± 13.7 g/m^2), and prime spawner (>37.7 ± 7.7 g/m^2) biomass, compared to 50% of the sites in the westernmost *'ili*. This pattern did not hold for non-target fish, where roughly half of all sites in all areas of the Reserve had above average non-target fish biomass, as would be expected.

While interesting, these patterns alone are not sufficient to understand the factors that may be responsible for them. Plotting the average ratio of target fish to total fish biomass and prime spawner to total fish biomass can be more informative (Figure 11). These ratios adjust for differences in total fish biomass, and represent the proportion of the total fish biomass comprised of target fish and prime spawners. All stressors and reef

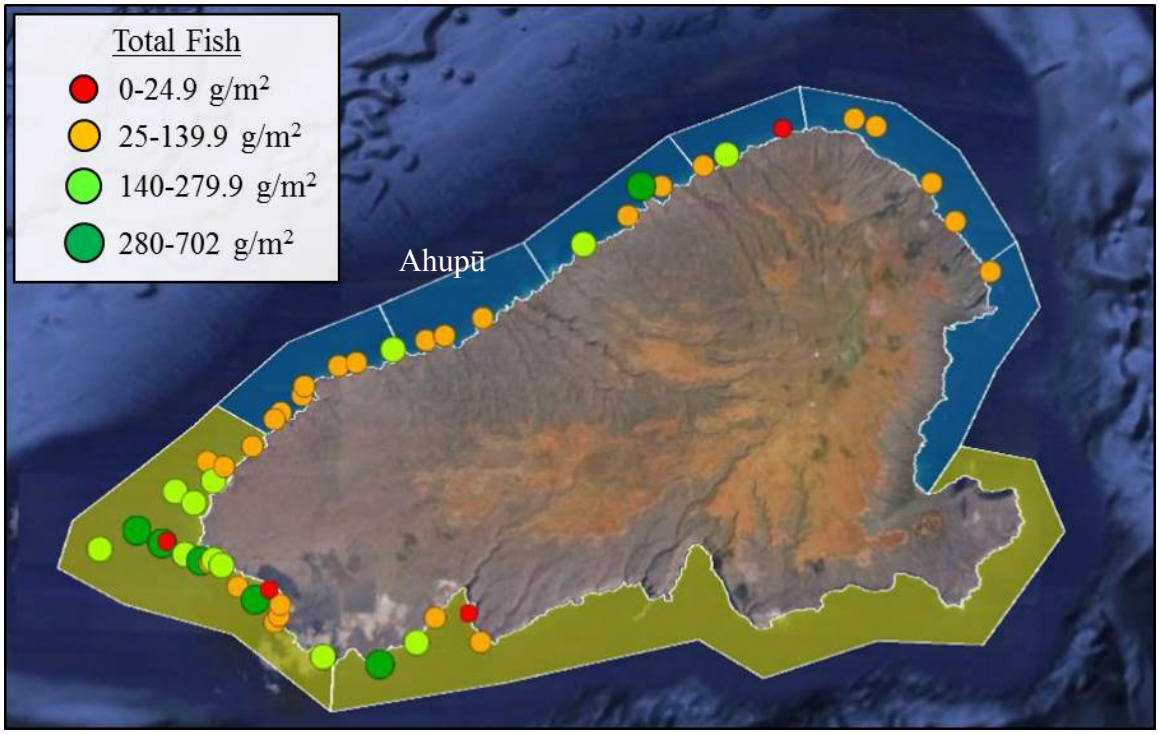


Figure 10. Total fish, target fish and prime spawner (both next page) biomass at survey sites in 2015. Red and orange circles are below the average biomass for each group, whereas light and dark green circles are sites with above average biomass. Exposed *'ili* are shaded green; sheltered *'ili* are shaded blue.

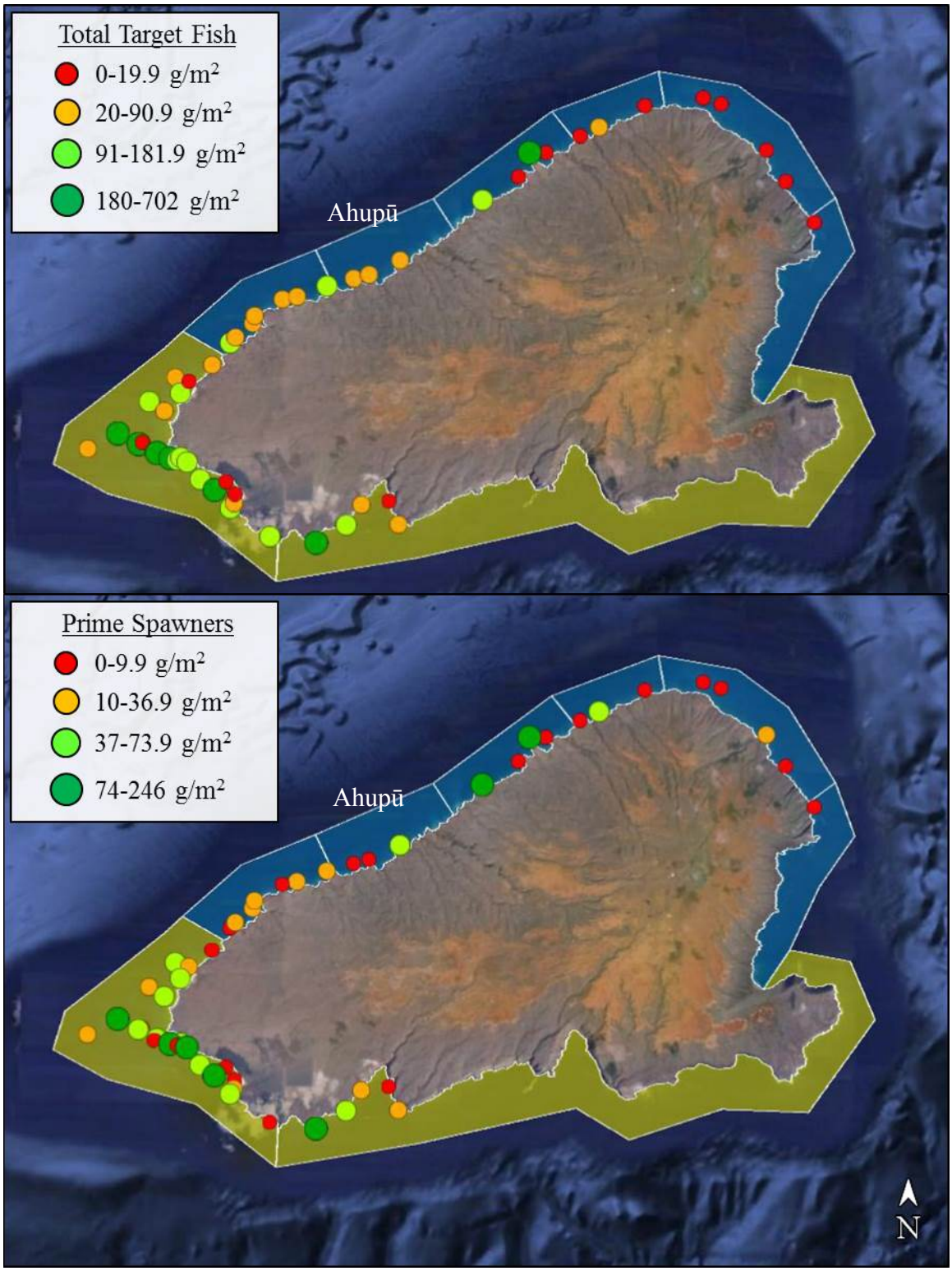


Figure 10 (continued). Total fish (previous page), target fish and prime spawner biomass at survey sites in 2015. Red and orange circles are below the average biomass for each group, whereas light and dark green circles are sites with above average biomass. Exposed *ʻili* are shaded green; sheltered *ʻili* are shaded blue.

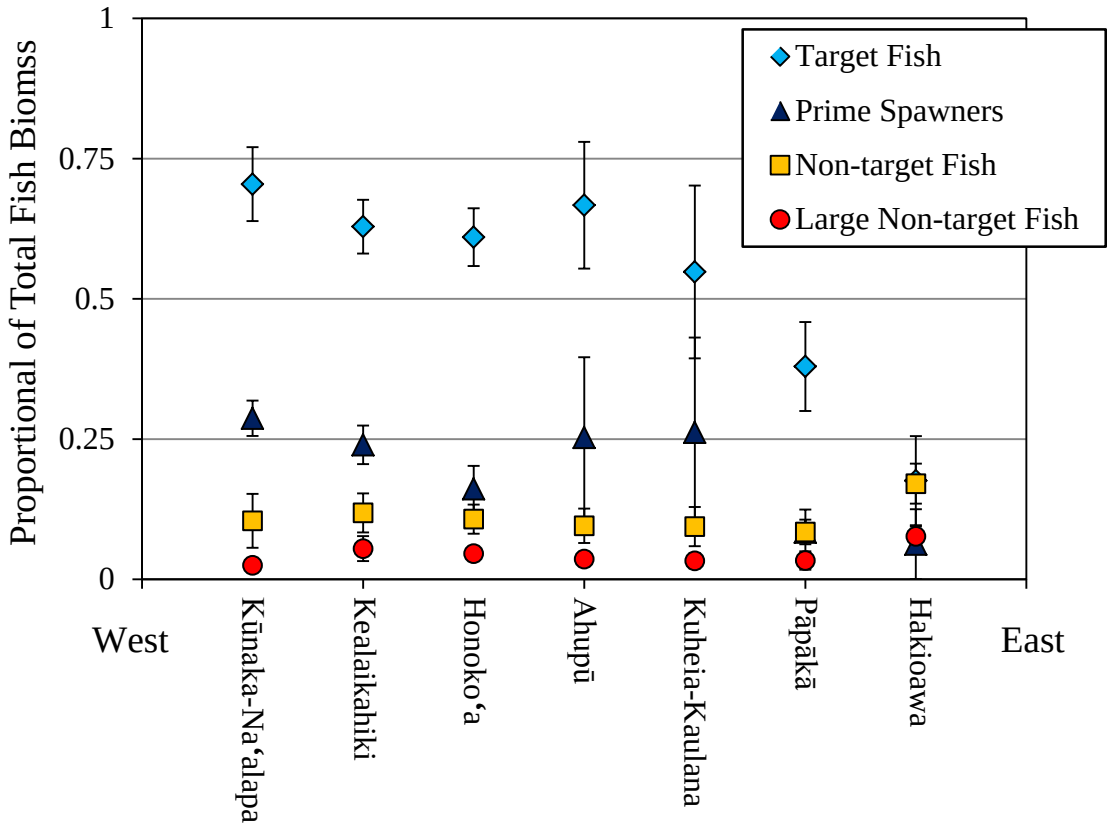


Figure 11. The proportion of the total fish biomass comprised of target fish, prime spawners, non-target fish, and large non-target fish by *'ili*. *'Ili* are arranged by their approximate position on Kaho'olawe, from west (farthest from Maui) to east (closest to Maui).

conditions being equal, we would expect these proportions to be roughly the same across the Reserve. However, eastern *'ili* have proportionally fewer target fish (Pearson Correlation, r=-0.877, p=0.009) and prime spawners (Pearson Correlation, r=-0.753, p=0.050) than western *'ili*, indicating these groups are being disproportionately (*i.e.*, more strongly) acted upon by whatever factors are causing the reduction in total fish biomass in the eastern *'ili*. In contrast, non-target fish (Pearson Correlation, r=0.317, p=0.489) and non-target fish >70% their maximum size[7] (Pearson Correlation, r=0.440, p=0.323) showed no change in the relative contribution, suggesting they are not differentially affected by these same factors. Therefore, the drop in total fish biomass moving east across the Reserve is primarily associated with a disproportionate decrease in target fish, including prime spawners.

[7] Non-target fish >70% of the species maximum size are analogous to prime spawners, which are target fish >70% of the species' maximum size.

There exist several possible explanations for this observed spatial pattern:

1) *Differences in benthic habitat quality*. Fish respond to the physical structure of their habitat, and features such as bottom topography (*e.g.*, rugosity) and small-scale heterogeneity of hardbottom (*e.g.*, local patchiness) can have significant effects on the amount of fish biomass present (Friedlander and Parrish 1998, Minton *et al.* 2011). On most coral reefs, a positive correlation in general exists between fish biomass and three-dimensional relief. However, reefs on exposed shores, including the westernmost *ʻili*, had lower rugosity (and lower coral cover and species diversity) than those in sheltered areas, but more fish. Additionally, all fish species, regardless of their fishery status, should be affected by the physical structure of benthic habitat, yet the ratio of non-target species was not spatially correlated. The available data suggests little difference in benthic quality across the Reserve; therefore this explanation does not adequately explain the observed spatial distribution of fish.

2) *Difference in water quality*. Locations with terrestrial-derived sediment inputs are likely areas with high runoff, the primary transport mechanism for land-based pollutants such as chemicals from unexploded ordinance (few other pollution sources likely exist on the island). No relationship was found between the fish assemblage and the presence or absence of terrestrial-derived sediment, suggesting differences in water quality within the Reserve do not adequately explain the observed spatial pattern.

3) *Western point of the Reserve is preferred by large fish*. Projections of reef into deep water and off points of land often seem to attract or to be preferred by large fish. The western end of Kahoʻolawe forms a shelf that extends out toward open ocean, and could be attractive habitat to large fish. If this were the case, it could explain the observed spatial pattern. However, the relative distribution of prime spawners and large non-target fish species (Figure 11) do not support this explanation: while the proportion of prime spawners decreases in the eastern *ʻili*, the proportion of larger non-target fish shows little spatial relationship. Large fish in general do appear to favor the western side of the Reserve.

4) *Depressed regional fishery stocks.* Oceanographic data suggest that at least some of the Reserve's larval supply originates from Maui (Storlazzi *et al.* 2006), and low fishery stocks on Maui could adversely impact fish populations within the Reserve. Without additional information, it is difficult to examine this hypothesis, but the distribution of fish from Kahoʻolawe appears to run counter to what would be expected: locations closer to the potential source (*i.e.*, Maui) should receive more larvae and thus have more fish. More likely, however, the relatively small size of Kahoʻolawe would promote fairly uniform larval import. While regionally depressed fishery stocks may be adversely affecting the Reserve's target species populations; it likely does not adequately explain the observed spatial patterns within the Reserve.

5) *Fishing outside the Reserve boundary*. External fishing pressure, directly along the boundary of the Reserve which is 3.2 km (2 mi) offshore of Kahoʻolawe, could account for the observed spatial patterns. The eastern most *ʻili* are closest to Maui, the primary source of most fishing pressure in the Maui Nui region and legal fishing conducted along the Reserve's boundary could be lowering target fish and prime spawner biomass in the *ʻili* closest to Maui. This would require target fish to be highly mobile because they would need to leave shallow water reefs near Kahoʻolawe in order to be legally harvested. While this is a possibility with some species, notably jacks, apex predators, and some other highly mobile species, the relative contribution of these mobile species shows what might be a slightly decreasing trend (Pearson Correlation, r=-0.551, p=0.2), but one that is not strong enough to adequately explain the lower fish biomass in the eastern *ʻili* (Figure 12). The proportion of non-mobile, more reef-associated target species (e.g., parrotfishes, target surgeonfishes, etc.) shows a stronger decreasing trend (Pearson Correlation, r= -0.676, p=0.095) than that of mobile target fish, suggesting the observed spatial pattern is being driven primarily by these reef-associated target fish species which would not be caught in deeper water. Therefore, direct effects from fishing outside the boundary do not adequately explain the observed spatial pattern within the Reserve.

6) *Proximity to Maui, fishing inside the Reserve, and poaching*. The eastern side of the Reserve is closest to Maui and could therefore be subject to greater impacts from Maui-based activities such as fishing or pollution from land runoff. Target fish, including prime spawners, are affected by this proximity while non-target fish are not, suggesting fishing, and likely poaching as the primary cause of the observed spatial pattern for fish in the Reserve. While it is difficult to cleanly separate permitted from illegal fishing inside the Reserve, no effect on the fish assemblage was found associated with permitted access points in the Reserve, suggesting a broader effect, such as illegal fishing, is occurring. Data suggest that poaching, if it is occurring, is most prevalent east of Ahupū *ʻili*.

Comparisons with other Hawaiian Reefs

Compared to other reefs on Maui and around the state (Figure 13), Kahoʻolawe had the highest total fish biomass of all areas in 2015 (and fourth highest in 2009), regardless of management status (*e.g.*, Marine Life Conservation District [MLCD], Fisheries Management Areas [FMA], etc.). In 2015, Kahoʻolawe's total fish biomass was over three times greater than the average total fish biomass on Maui reefs open to fishing (n=9), and 1.5 times greater than Maui's MLCDs (n=3).

The Reserve's highly diverse target fish assemblage, with 51 species in 12 families and no target fish group accounting for more than 42% of the total target fish biomass (Figure 9), stands in contrast to other reefs around the state. For example, at Polanui, Maui, surgeonfish account for approximately 70% of the target fish biomass while jacks, apex predators, redfish, and other target fishes were nearly absent (Minton *et al.* 2014).

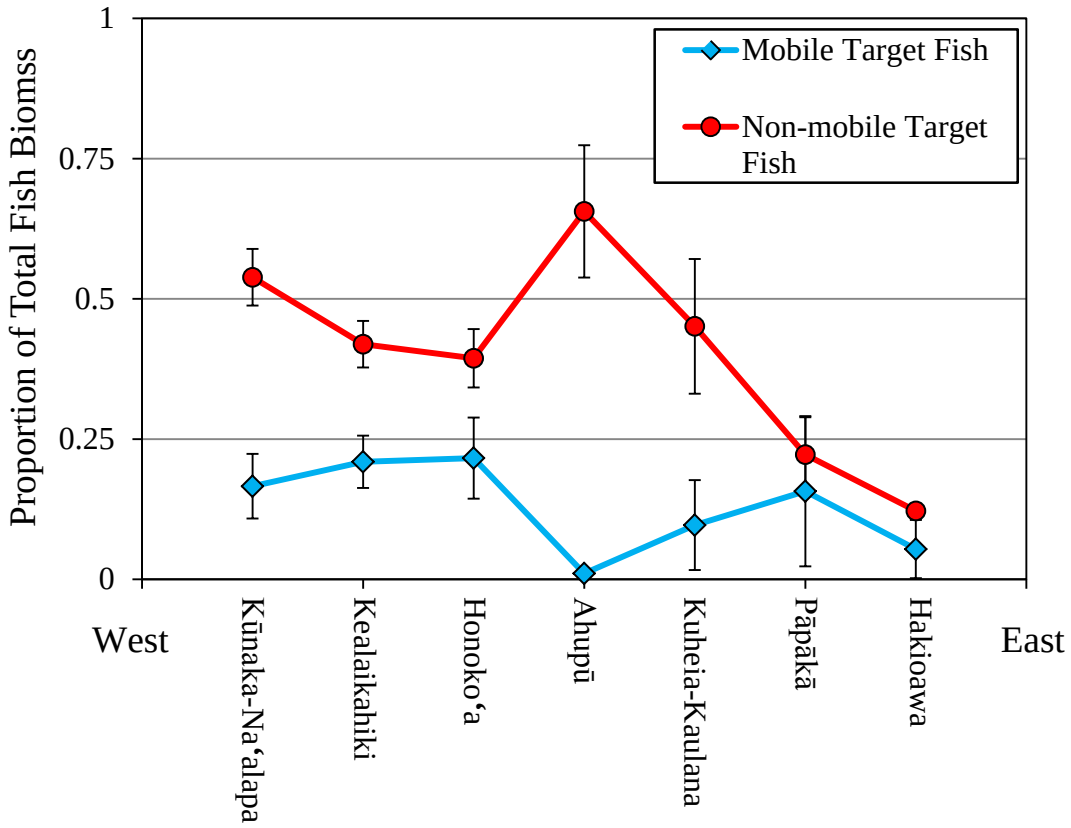


Figure 12. The proportion of the total fish biomass comprised of "mobile" and "non-mobile" target fish by *'ili*. *'Ili* are arranged by their approximate position on Kaho'olawe, from west (farthest from Maui) to east (closest to Maui). See text for a description of mobile vs. non-mobile target fish (page 29).

Similar patterns have been documented at Wailuku, Maui, where surgeonfish and small parrotfish comprised over 75% of the target fish biomass while jacks, redfish, apex predators, and other target fish were nearly absent (TNC, unpublished data).

As with total fish biomass, when compared to other reefs on Maui and across the state, Kaho'olawe had the highest target fish biomass of any area surveyed, regardless of management status (Figure 14). Compared to other reefs in the state, fishing pressure does not appear to be severely affecting Kaho'olawe's fish assemblage. This is further supported when comparing Kaho'olawe's target and non-target fish biomass to state averages by management category (Figure 15). On heavily fished reefs, target fish biomass is significantly lower than in areas protected from fishing (*i.e.*, MLCDs), whereas non-target fish biomass is similar regardless of management status. In the Reserve, target fish biomass is twice that of areas closed to fishing making its nearshore fishing stocks among the best in the state.

In 2015, the Reserve also had among the highest prime spawner (37.7 ± 7.7 g/m^2) biomass of any area surveyed in the main Hawaiian Islands regardless of management

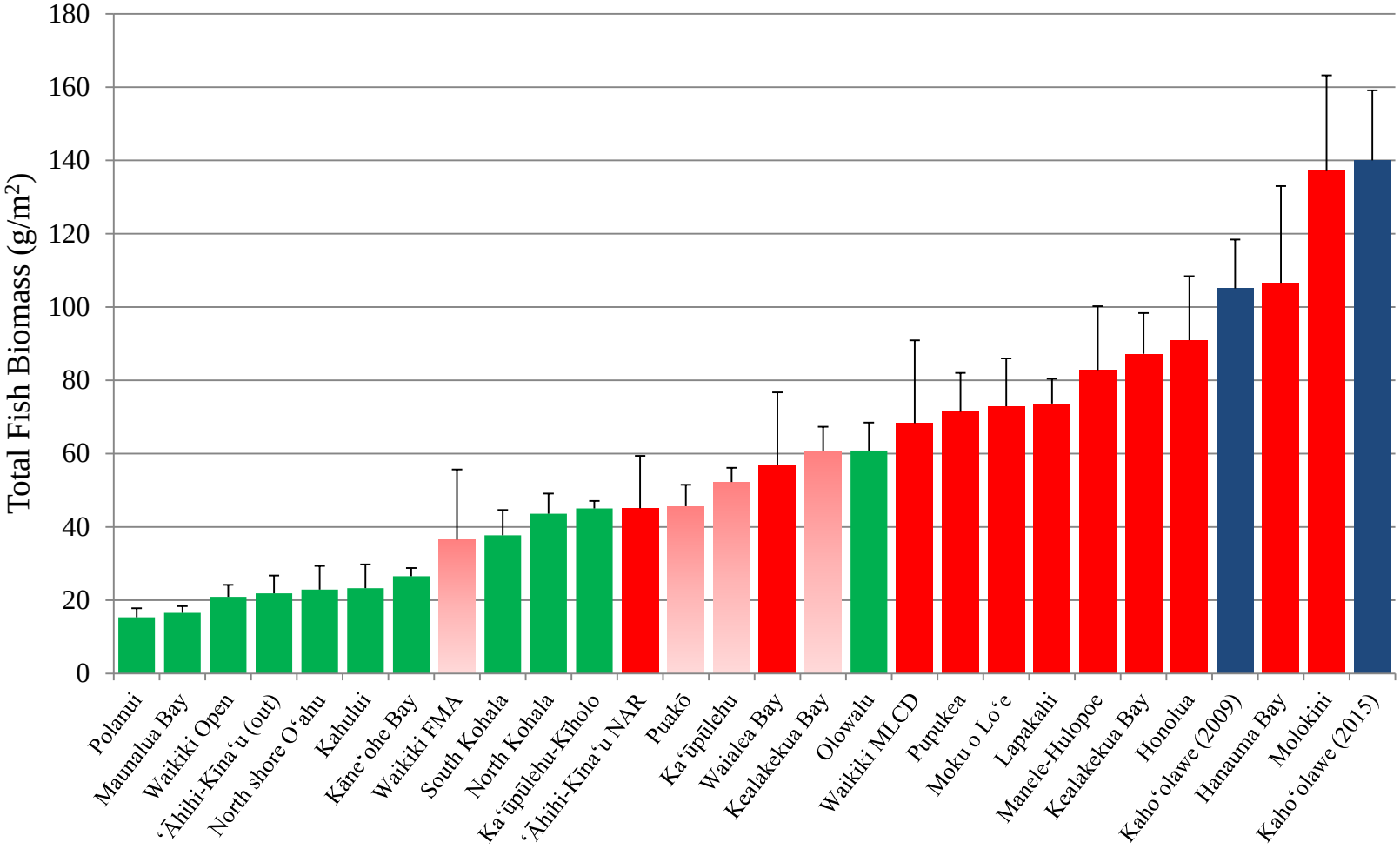


Figure 13. Total fish biomass on the reefs surrounding Kahoʻolawe (solid blue bar). Color of bars represents level of fisheries management occurring at the site: green=no additional fishing regulations; red=no take allowed; gradated red=limited take allowed. Data for other sites are from Friedlander (UH) and TNC.

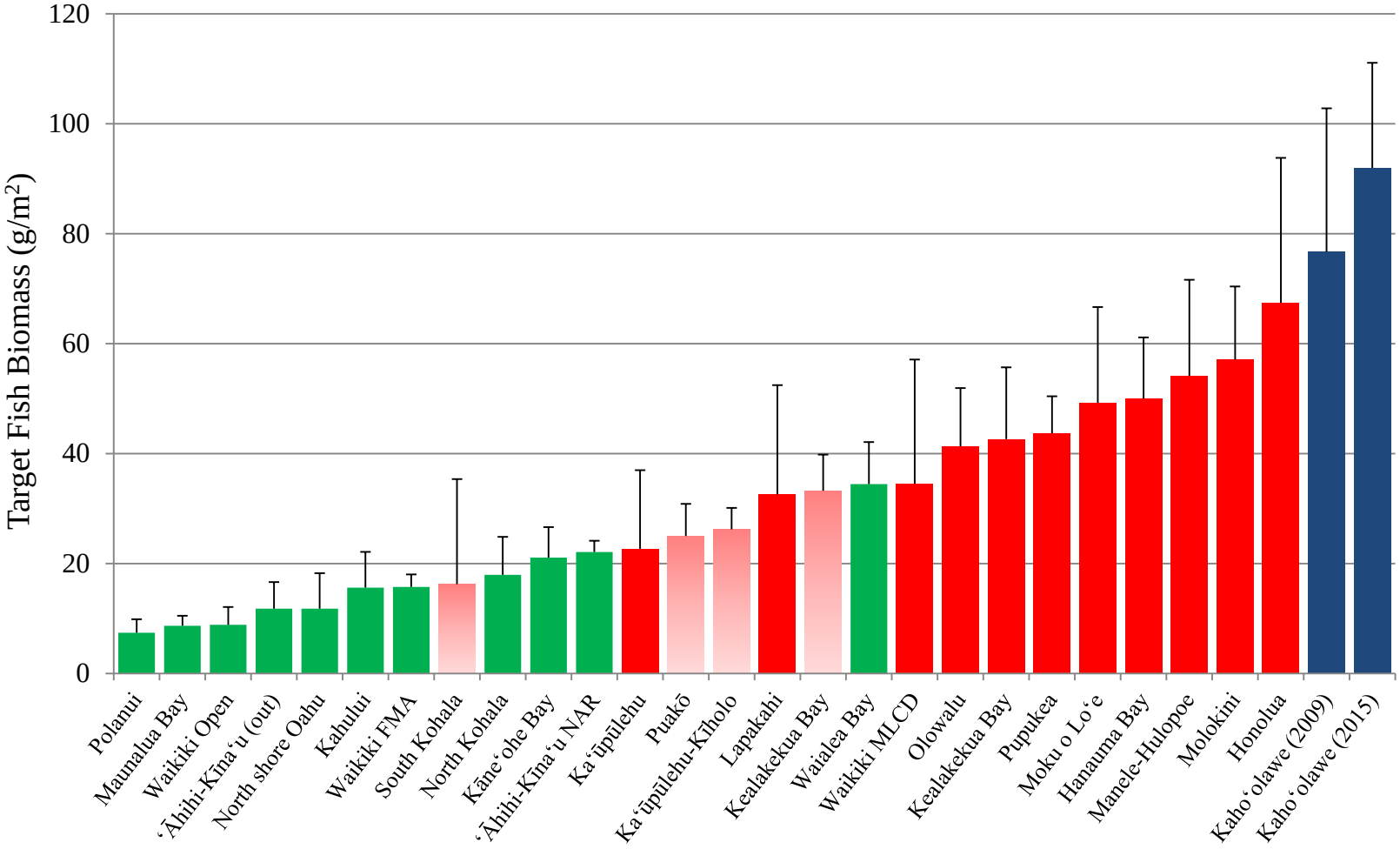


Figure 14. Target fish biomass on the reefs around Kahoʻolawe (solid blue bar). Color of bars represents level of fisheries management occurring at the site: green=no additional fishing regulations; red=no take allowed; gradated red=limited take allowed. Data for other sites are from Friedlander (UH) and TNC.

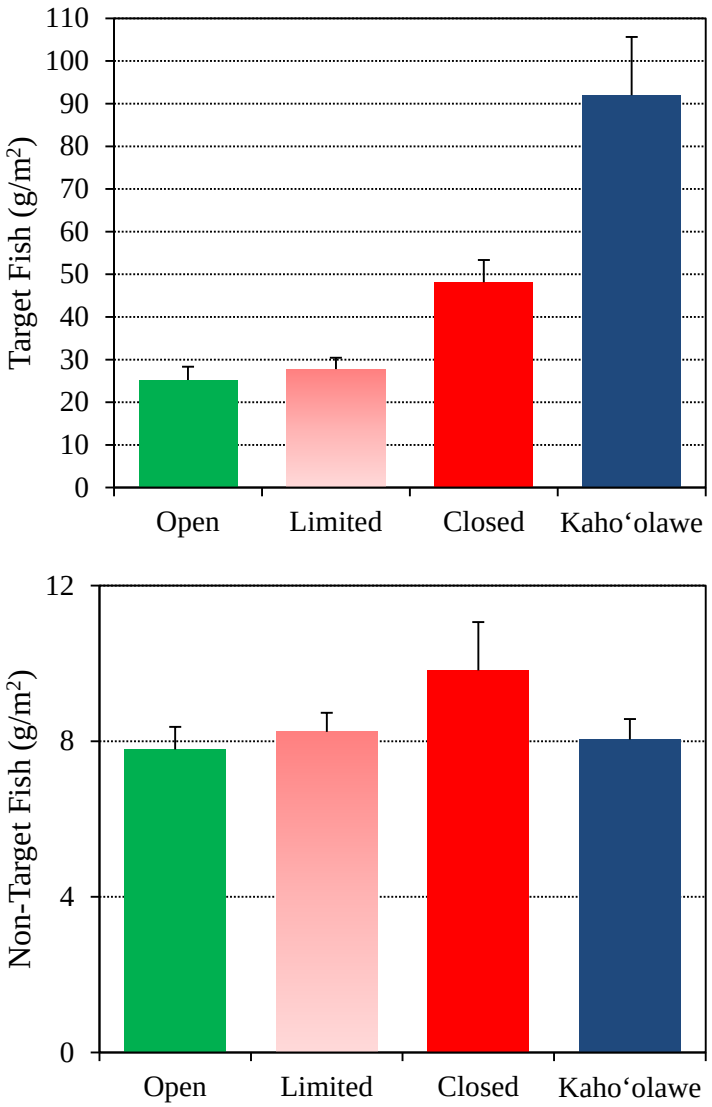


Figure 15. Comparison of Kaho‘olawe target and non-target fish biomass in areas open to fishing, with limited fishing regulations (e.g., inside an FMA) or closed to all or most fishing (e.g., MLCDs). Values represent statewide averages.

status (Figure 16). While prime spawner biomass was lower in 2009 (17.6 ± 5.4 g/m^2), it was still similar to the statewide average for MLCDs (19.1 ± 3.3 g/m^2), further supporting relatively healthy fish stocks within the Reserve compared to the rest of the main Hawaiian Islands.

Temporal Trends

Total fish biomass did not significantly change between the 2009 and 2015 surveys on both exposed (t-test, t_7=0.88, p=0.411) and sheltered (t-test, t_{17}=1.88, p=0.079) reefs. Additionally, there was no change in target fish or prime spawner biomass. While fish

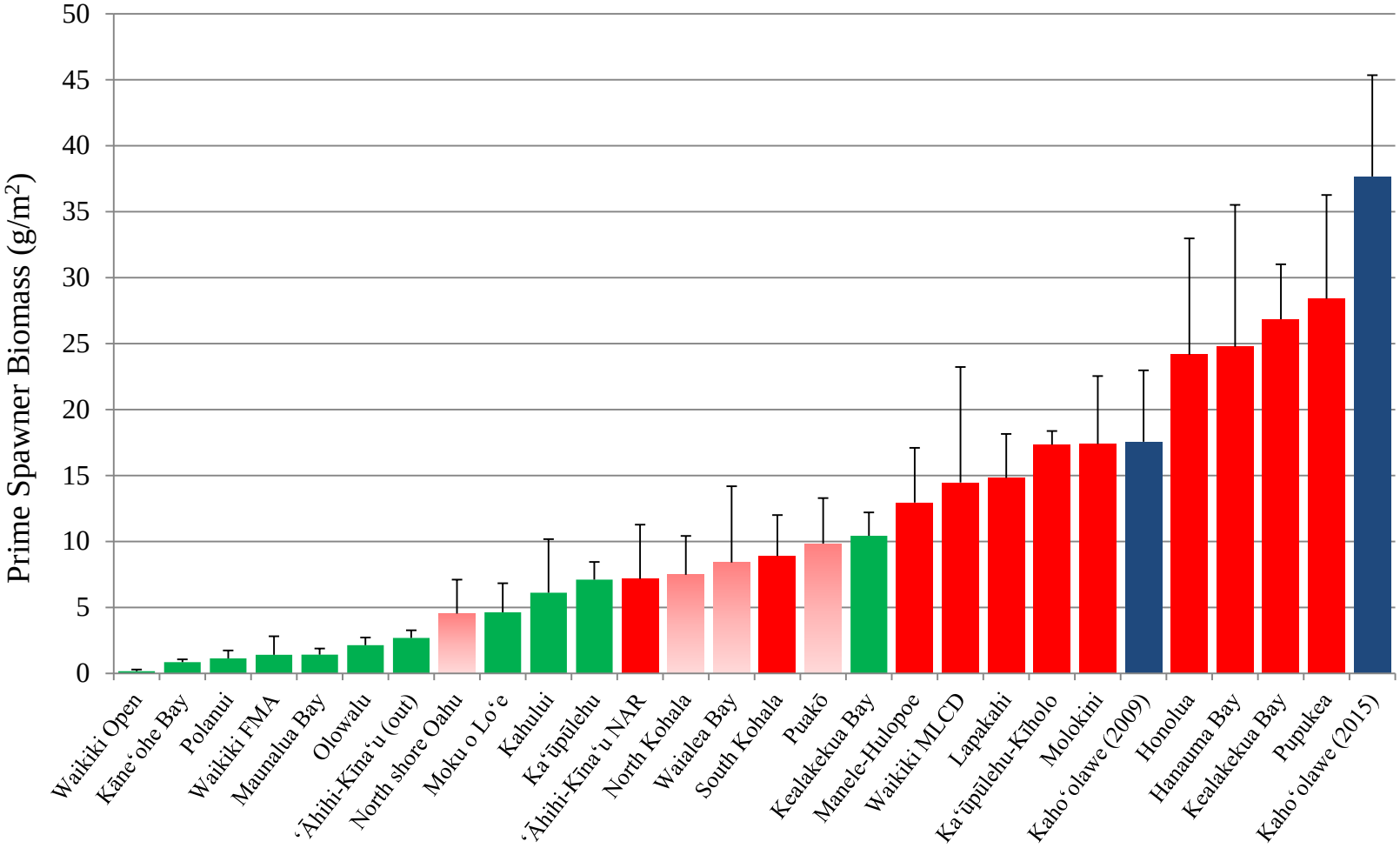


Figure 16. Prime spawner biomass on the reefs around Kahoʻolawe (solid blue bar). Color of bars represents level of fisheries management occurring at the site: green=no additional fishing regulations; red=no take allowed; gradated red=limited take allowed. Data for other sites are from Friedlander (UH) and TNC.

assemblages on exposed reefs did not change over time (ANOSIM; R=0.072; p=0.208), a significant difference was found for fish assemblages on sheltered reefs (ANOSIM; R=0.16; p=0.004), but given the low R-statistic, this difference is likely not ecologically meaningful, which was supported by a follow-up SIMPER analysis that identified no key species that explained a large amount of the difference. Examining all available information, it appears the fish assemblage has remained stable between 2009 and 2015.

Comparing the surveys conducted in 2009 and 2015 to older surveys is problematic. Differences in data collection methods and the lack of biomass information create significant challenges for direct comparisons. Qualitative comparisons, however, are possible. The top twenty species by abundance can be ranked and compared to examine potential shifts in assemblage structure over time. Compiled species rankings (Table 9) suggest there has been little change in the structure of Kaho‘olawe’s fish assemblage over the past three decades. Little change has occurred in the five most abundant species. It appears that yellow tangs (*Zebrosoma flavescens*) may have increased in abundance since 1981. Unranked in 1981, yellow tangs became mid-ranked in the early 2000s and highly ranked in 2009 and 2015, suggesting an increase in their numbers over time.

4.3 Invasive Fishes

Recently, many communities across Hawai‘i have raised concerns about the abundance of invasive fish on Hawaiian reefs, particularly the peacock grouper or *roi* (*Cephalopholis argus*). While growing scientific evidence suggests invasive fish species have minimal impacts on native Hawaiian reef fish populations (Schumacher and Parrish 2005, Dierking *et al.* 2009, TNC unpub. data), there is the perception among some stakeholders that invasive fishes are significantly impacting native species through direct competition and/or predation.

Three species of invasive fishes were observed in the Reserve in 2015: peacock groupers, bluestriped snapper (*Lutjanus kasmira*), and blacktail snapper (*L. fulvus*) (Table 10). Invasive fish biomass was among the highest recorded in the state and nearly seven-times higher than the statewide average for MLCDs (3.2 ± 1.0 g/m^2).

The total biomass of invasive fish did not differ by exposure (ANOVA; $F_{1,95}=2.92$; p=0.091), although invasive fish biomass on exposed reefs was highly variable with many exposed reef sites having no invasive fish. However, peacock grouper biomass on sheltered reefs (13.4 ± 2.4 g/m^2) was almost twice that found on exposed reefs (8.7 ± 2.2 g/m^2), whereas bluestriped snapper were significantly more common on exposed (6.4 ± 4.1 g/m^2) compared to sheltered (<0.1 g/m^2) reefs. These distributions are likely habitat related. Peacock groupers are a dominant fore reef and lagoon predator in their native home range (Randall and Brock 1960), and can be significant components of the shallow water reef and lagoon ecosystems where they are introduced (Shpigel and Fishelson 1985), including some areas of Hawai‘i. While sometimes found in high energy locations (Shpigel and Fishelson 1985), peacock groupers seem to prefer less exposed areas. In contrast, blueline snappers can be abundant in high energy environments in Hawai‘i (Friedlander *et al.* 2002) and elsewhere (Newman and Williams 1996).

Table 9. Top 20 fish species by abundance. Ranks go from 1 (most abundant) to 20 as identified in surveys from 1981 to 2015.

Species	1981	2005	2006	2007	2009	2015
Blackfin chromis	1	1	1	1	1	1
Agile chromis	5	3	4	2	4	2
Brown Surgeonfish	3	2	2	3	2	3
Goldring bristletooth	4	6	5	6	5	4
Saddleback wrasse	2	4	3	4	6	5
Yellow tang		16	10	10	3	6
Black durgon		9	14	7	11	7
Sleek unicornfish					7	8
Hawaiian morwong						9
Whitebar surgeonfish	10	5	6	5		10
Arc-eye hawkfish	20	12	8	11	12	11
Bluestriped snapper	16	8			13	12
Blacktail snapper						13
Orangespine unicornfish		15	18	16		14
Multiband butterflyfish	8	14	16	20		15
Bullethead parrotfish		11	15	12	18	16
Thompson's surgeonfish					19	17
Peacock grouper		10		19	16	18
Hawaiian sergeant						19
Orangeband surgeonfish		18				20
Achilles tang	19					
Bluelined surgeonfish	13					
Convict tang		13				
Hawaiian whitespotted toby	17	20	11	13	17	
Potter's angelfish	18					
Chocolate-dip chromis	9	19		18	14	
Oval chromis	6				15	
Threespot chromis	15					
Bird wrasse		7	7	8		
Ornate wrasse			13			
Yellowfin goatfish					8	
Paletail unicornfish				15	9	
Manybar goatfish	12	17	19	14	10	
Bright-eye damselfish	14		12			
Blue-eye damselfish	11		9	9	20	
Palenose parrotfish			17			
Hawaiian gregory			20			
Pacific gregory	7					

Table 10. Mean (± SEM) biomass (g/m^2) of three invasive fish on exposed and sheltered reefs on Kaho‘olawe and the statewide average for MLCD. Data for Kaho‘olawe are from 2015 surveys. MLCD data are from Friedlander (UH) and TNC.

	Kaho‘olawe	Exposed	Sheltered	MLCD
Peacock grouper	10.9 ± 1.7	8.7 ± 2.2	13.4 ± 2.4	1.8 ± 1.7
Blacktail snapper	4.9 ± 3.2	6.8 ± 5.8	2.4 ± 0.8	0.2 ± 0.1
Bluestriped snapper	3.7 ± 2.3	6.4 ± 4.1	<0.1	1.3 ± 0.9
Total	19.5 ± 5.7	22.1 ± 10.0	16.2 ± 2.9	3.2 ± 1.0

4.4 Fish Species of Interest

KIRC has requested information on specific species of interest, including convict tangs or *manini* (*Acanthurus triostegus*), goldring bristletooth or *kole* (*Ctenochaetus strigosus*), goatfishes, parrotfishes or *uhu*, and jacks.

Convict tangs

In 2015, convict tangs or *manini* were relatively rare at Kaho‘olawe (Figure 17), appearing at only 9 of 50 survey sites and comprising 0.2 ± 0.1 g/m^2 of the total fish biomass at Kaho‘olawe. A total of 58 convict tangs were observed, with an average length of 11.0 ± 0.7 cm.

Convict tangs reach reproductive maturity at 9.4 cm[8] for males and 17.3 cm for females (Longenecker *et al.* 2008). It is not possible to determine the sex of convict tangs observed during visual surveys, so it is problematic to calculate the percentage of the population greater than the size at maturity. Longenecker *et al.* (2008) found a male:female sex ratio of 43:57 in their population (collected on O‘ahu and Hawai‘i Island). Assuming a similar sex ratio in the Reserve, 75% of observed males but only 7% of females were likely above the minimum size at maturity.

In Hawai‘i, the legal harvest size for convict tangs is 12.7 cm (5 in), which is significantly smaller than the size at maturity for females. The average size of convict tangs at Kaho‘olawe was under the legal harvest size; only 42% of the observed individuals on transects were greater than 12.7 cm.

Goldring bristletooth

Goldring bristletooth or *kole* are often the most abundant and conspicuous surgeonfish on Hawaiian reefs, and were the fourth most abundant fish observed in 2015 (Table 9). They comprised 2.2 ± 0.4 g/m^2 of the total fish biomass and had a density of 21.3 ± 3.1

[8] Longenecker *et al.* (2008) give sizes in fork length, but provides a conversion to obtain total length. Total lengths are used in this report.

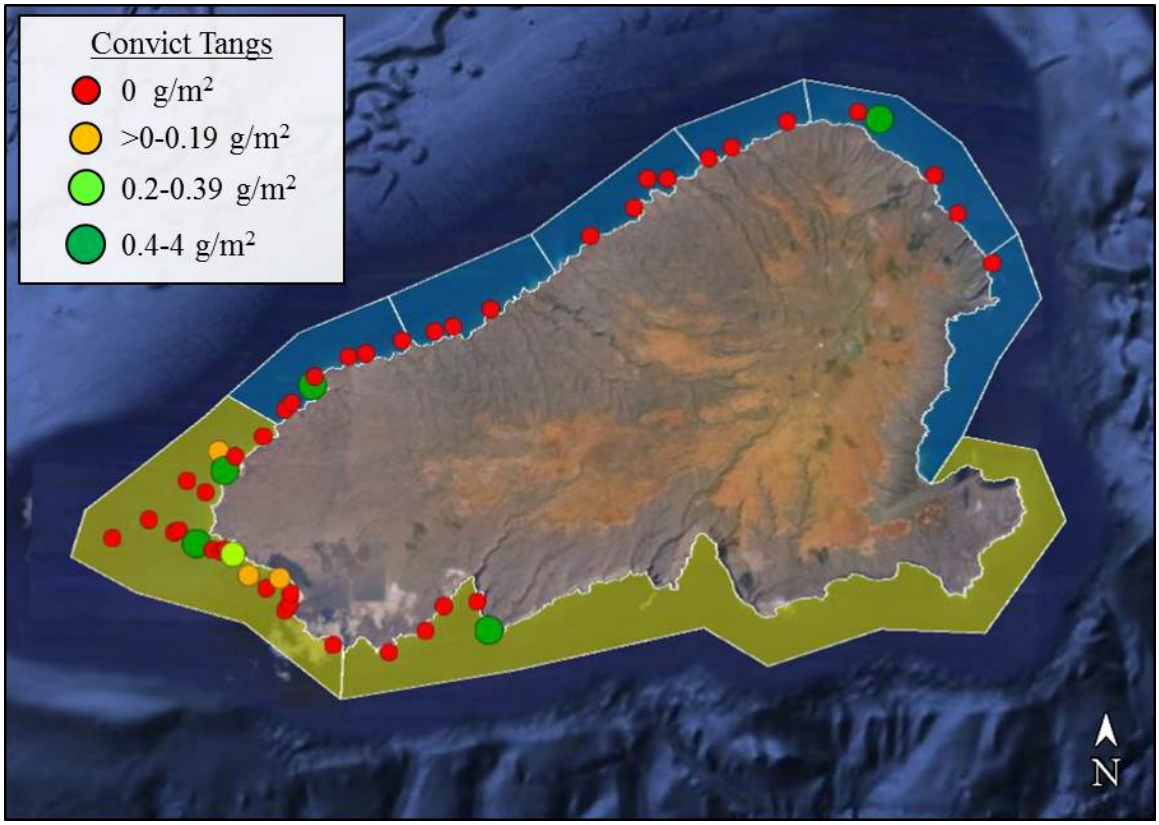


Figure 17. Biomass of convict tangs at survey sites in 2015. Red and orange circles are below the average species biomass, whereas light and dark green circles are sites with above average biomass. Exposed *ʻili* are shaded green; sheltered *ʻili* are shaded blue.

fish/125m^2 (Figure 18). Goldring bristletooth were more common on Kahoʻolawe than on many other Maui reefs (range of four Maui sites: 0.3-6.6 fish/125m^2).

The average size of goldring bristletooth in the Reserve in 2015 was 9.5 ± 0.1 cm. Goldring bristletooth reach reproductive maturity at 11.0 cm[9] for males and 9.1 cm for females (Langston *et al.* 2009). While it is not possible to determine the sex of individual fish during visual surveys, approximately 30% of the population was larger than 11 cm, the size at sexual maturity for females.

Goatfishes (family Mullidae)

Seven species of goatfish were observed at Kahoʻolawe in 2015, with two species, the manybar goatfish or *moāno* (*Parupeneus multifasciatus*) and the yellowstripe goatfish or *wekeʻā* (*Mulloidichthys flavolineatus*), being the most common on transects (Table 11). Of the remaining species, the sidespot goatfish or *malu* (*Parupeneus pleurostigma*) and the whitesaddle goatfish or *kūmū* (*Parupeneus porphyreus*), were relatively rare in the survey area.

[9] Langston *et al.* (2009) give sizes in fork length, but provides a conversion to obtain total length. Total lengths are used in this report.

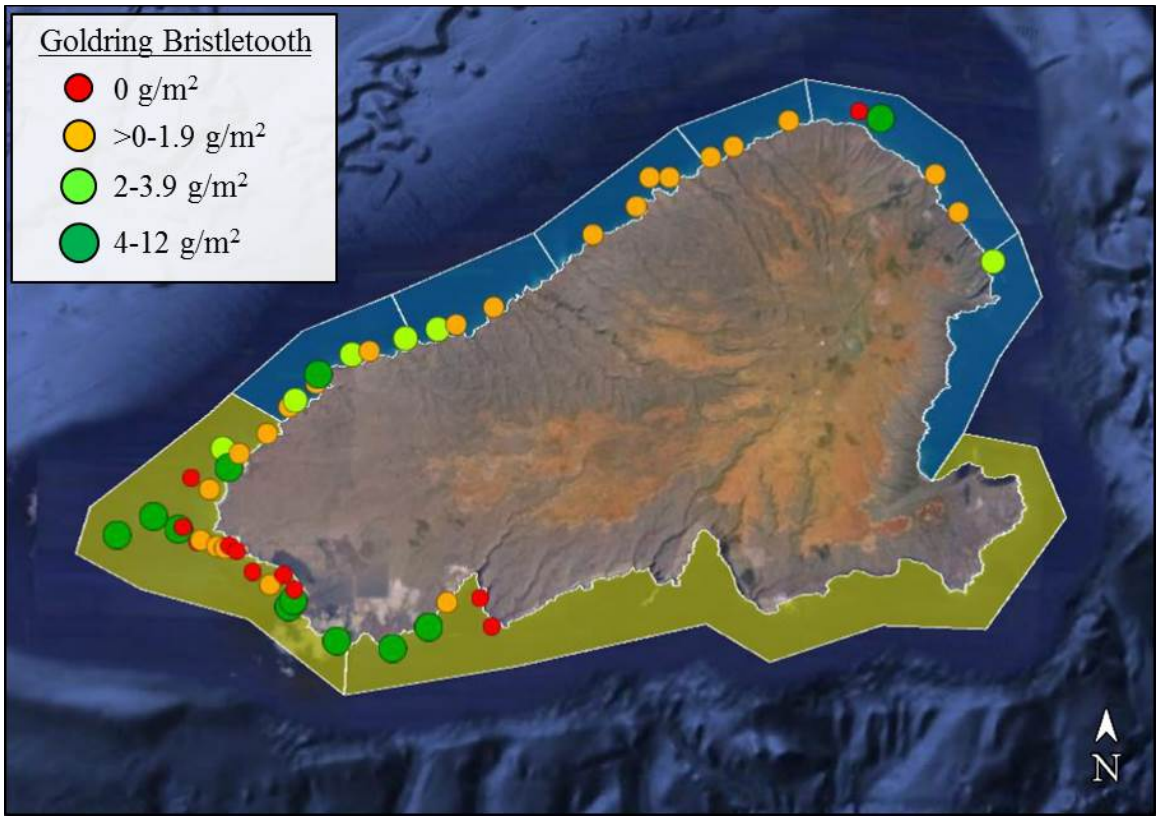


Figure 18. Biomass of goldring bristletooth at survey sites in 2015. Red and orange circles are below the average species biomass, whereas light and dark green circles are sites with above average biomass. Exposed *ʻili* are shaded green; sheltered *ʻili* are shaded blue.

Total goatfish biomass did not change between the 2009 and 2015 surveys (ANOVA; $F_{1,92}$=2.25; p<0.137), but was significantly lower on the sheltered (0.8 ± 0.3 g/m^2) compared to exposed (6.1 ± 2.7 g/m^2) reefs (ANOVA; $F_{1,95}$=20.42; p<0.001) (Figure 19). Further analysis suggests the near absence of goatfish from sheltered reefs was associated with presence of terrestrial-derived sediment on the reef, which is not surprising considering sand flats are important foraging grounds for many of these fishes. When the presence of terrestrial-derived sediment was included in the analysis, reef exposure became non-significant, and the presence of terrestrial-derived sediment was important (p=0.063). Sites with terrestrial-derived sediment had lower goatfish biomass (0.6 ± 0.3 g/m^2) than sites without (5.9 ± 2.5 g/m^2), suggesting goatfish favor "clean" sediment for foraging and may benefit from activities that reduce terrestrial erosion onto Kahoʻolawe's nearshore reefs.

Average fish size was larger at Kahoʻolawe than other Maui reefs. For example, at Polanui, Maui, manybar goatfish averaged only 11.8 ± 1.8 cm (Minton *et al*. 2014) compared to 15. 9 ± 0.6 cm on Kahoʻolawe, suggesting fishing pressure on the species may be lower in the Reserve than elsewhere. Under new fishing rules enacted (DAR

Table 11. The number of goatfish individuals observed (N) on transects (5-minute timed swims), average biomass (g/m^2), average size, maximum size, size at maturity, and percent of the fish observed larger than the size at maturity for the six goatfish species observed at Kaho‘olawe in 2015. All sizes are in centimeters. Maximum size is for the species in Hawai’i.

Goatfish	N	Average Biomass	Average size[1]	Max. Size[2]	Size at Maturity[3]	Percent Mature
Yellowstripe	183 (2)	1.7 ± 1.3	22.3 ± 0.2	36.5	F:20.2[4] M: ?	>90%
Manybar	97 (40)	0.6 ± 0.2	15.9 ± 0.6	30	F: 15.2[5] M: 14.5	~40%
Island	38 (20)	0.7 ± 0.2	21.3 ± 1.6	40.6	?	-
Yellowfin	30 (6)	0.3 ± 0.3	21.3 ± 0.8	38	F:19.8[4] M: ?	~50%
Goldsaddle	13 (11)	0.3 ± 0.2	24.3 ± 3.3	50	?	-
Sidespot	3 (3)	<0.1	-	33	?	-
Whitesaddle	2 (0)	0.1 ± 0.1	-	51	26	-

[1]Average size calculated from individuals on transects only
[2]From Randall (2007)
[3]From Fishbase (Froese & Pauly 2011), unless otherwise noted
[4]From Cole (2009), converted from standard length using coefficients from Fishbase.com
[5]From Longenecker and Langston (2008)

2015), the legal harvest size is 12.7 cm for “small” goatfish species (manybar, sidespot, yellowfin, yellowstripe, and island) and 30.5 cm for large species (whitesaddle and goldsaddle). The average size for all small goatfish species exceeds the new minimum harvest size by at least 2 cm (Table 11), providing further support that fishing pressure on these species is likely low in the Reserve.

Parrotfish

Six species of parrotfish were observed at Kaho‘olawe in 2015, with the bullethead parrotfish (*Chlorurus spilurus*) being the most common on both transects and along timed swims (Table 12). Parrotfish contributed 12.5 ± 2.1 g/m^2 to the total fish biomass at Kaho‘olawe (Figure 20).

A sufficient number of individuals for four species were observed during the 2015 surveys to calculate species-specific average length (Table 12). The average size for each species was below the current legal harvest size for Maui County (DAR 2015): 25.4 cm (10 in) for small parrotfish species (stareye [*Calotomus carolinus*], bullethead, regal

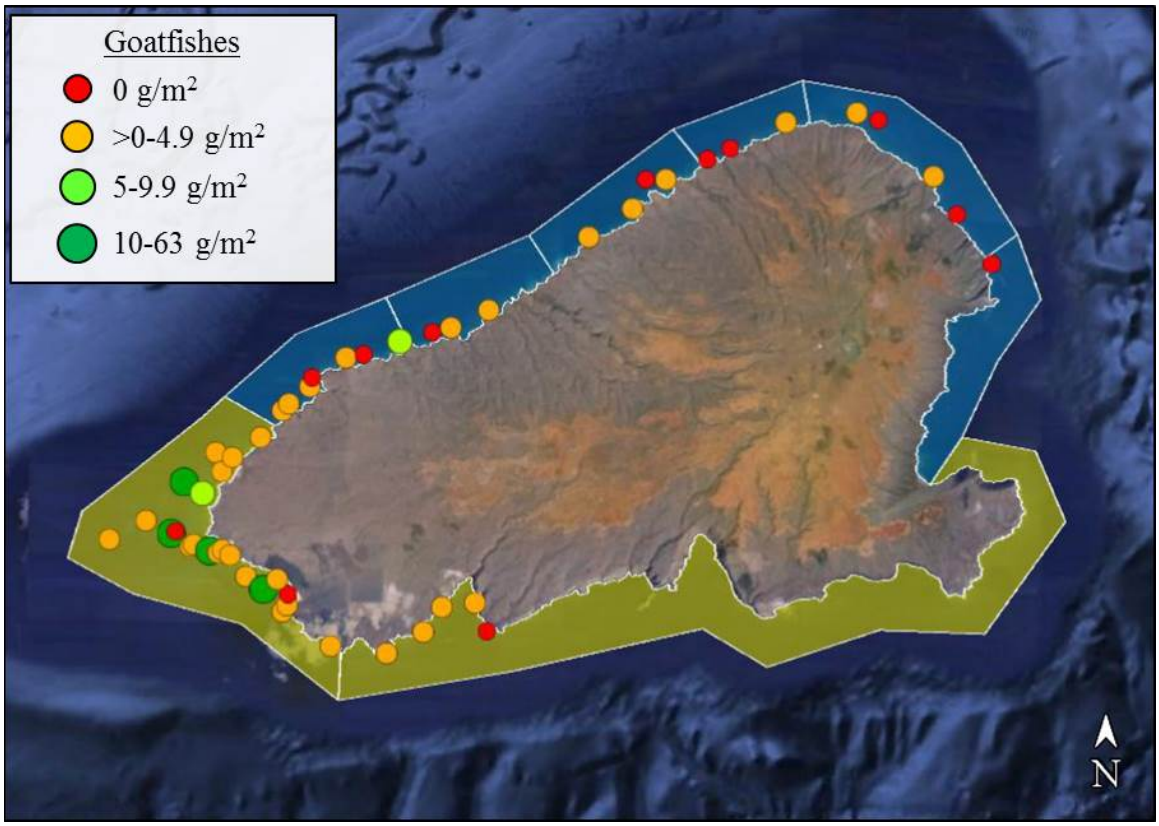


Figure 19. Biomass of all goatfishes at survey sites in 2015. Red and orange circles are below the average goatfish biomass, whereas light and dark green circles are sites with above average biomass. Exposed *ʻili* are shaded green; sheltered *ʻili* are shaded blue.

[*Scarus dubius*], and palenose [*S. psittacus*]) and 35.6 cm (14 in) for large species (spectacled [*Chlorurus perspicillatus*] and ember [*S. rubroviolaceus*]). While average size may have been under the legal take limit, individuals greater than legal harvest size were observed for all species.

Sexual maturity in parrotfish is complicated by their reproductive mode as protogynous sequential hermaphrodites (female-first, sex-changers). Most "small" sexually mature individuals are female and undergo sex change to male at a larger body size. For the four species for which an average size could be calculated, the proportion of the population above the size at maturity for females ranged from 17-56% and for males from 6-11% (Table 12).

On other reefs around the state parrotfish individuals tend to be smaller in size, with populations that have a lower percentage of individuals at or above the size at maturity. For example, at Polanui, no parrotfish were observed above the legal harvest size (30.5 cm at the time of the survey) and only 8% of palenose parrotfish exceeded the size at maturity for females (Minton *et al.* 2014).

Table 5. The number of parrotfish individuals observed (N) on transects (5-minute timed swims), average biomass (g/m^2), average size, maximum size, size at maturity, and percent of the fish observed larger than the size at maturity for the four parrotfish species observed at Kahoʻolawe in 2015. Biomass is in g/m^2 and all sizes are in centimeters. Maximum size is for the species in Hawaiʻi. No average size was calculated for species with <5 individuals.

Parrotfish	N	Average Biomass	Average size	Max. Size[1]	Size at Maturity[2]	Percent Mature[3]
Bullethead	253 (214)	3.2 ± 1.3	14.7 ± 0.5	40	F: 17 M: 27	38/6%
Ember	196 (141)	6.4 ± 1.1	22.3 ± 0.9	71	F: 35 M: 47	17/6%
Palenose	166 (46)	1.5 ± 0.3	15.9 ± 0.5	30	F: 14 M: 23	56/11%
Stareye	16 (3)	0.4 ± 0.1	23.8 ± 2.2	50	F: 24 M: 37	38/6%
Regal	2 (8)	0.1 ± 0.1	-		?	-
Spectacled	2 (6)	0.9 ± 0.6	-		F: 34 M: 46	-

[1]From Randall (2007)
[2]From DeMartini and Howard (2016)
[3]First number equals the percent of fish exceeding size at maturity for female and second number is percent above size at maturity for males.

Jacks

Five species of jacks were observed at Kahoʻolawe in 2015, but three were relatively rare (Table 13). Only single individuals of both barred (*Carangoides ferdau*) and island (*Carangoides orthogrammus*) jacks, both known locally as *ulua*, and seven giant trevally were observed in the project area. Mackerel scad or *ʻōpelu* (*Decapterus macarellus*) are schooling fish occasionally found over deeper reef areas. While they were the most abundant in terms of individuals (~150 fish), they occurred primarily in two large schools of greater than 50 individuals.

In total, jacks contributed 4.6 ± 2.1 g/m^2 to the total fish biomass (Figure 21). The bluefin trevally or *ʻōmilu* (*Caranx melampygus*), for which enough fish were observed to estimate average size, had an average length of 34.9 ± 1.7 cm in the Reserve, including four individuals greater than 50 cm in length (the max. size in Hawaiʻi is 83 cm). Approximately half of the bluefin trevally were larger than the size at maturity (Table 13).

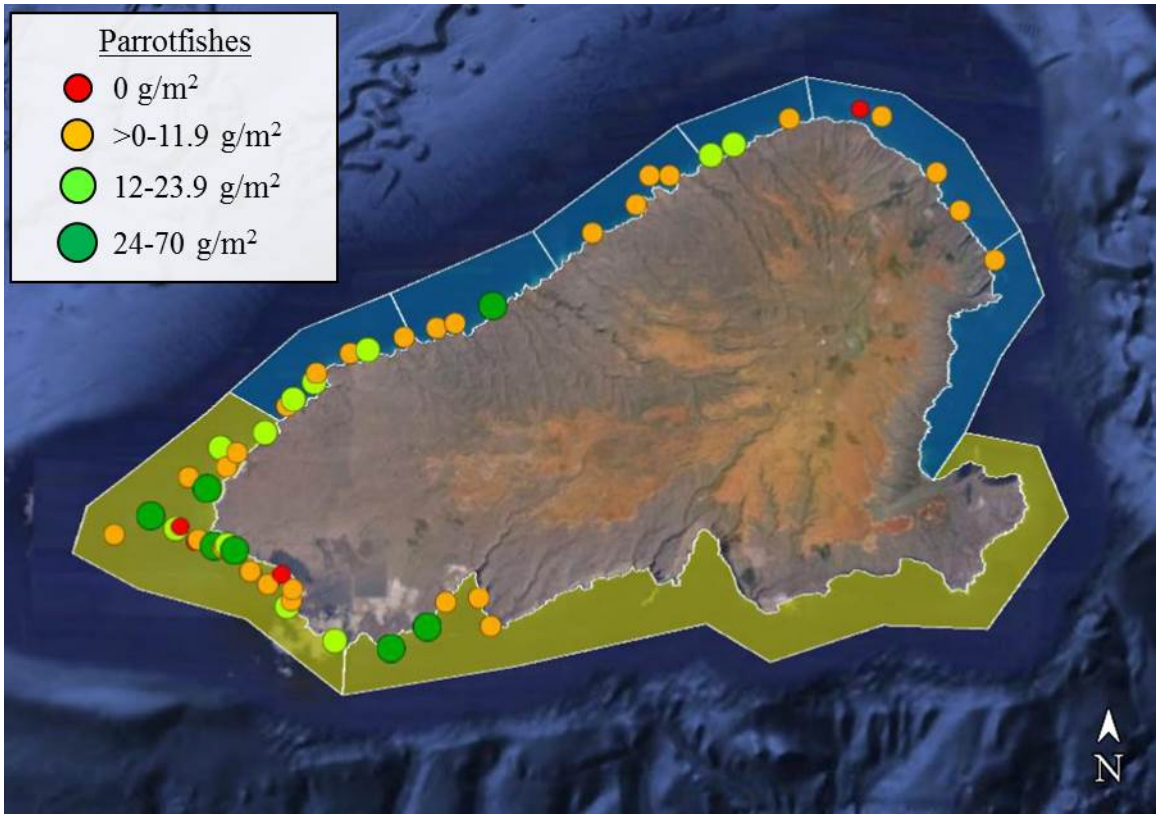


Figure 20. Biomass of all parrotfishes at survey sites in 2015. Red and orange circles are below the average parrotfish biomass, whereas light and dark green circles are sites with above average biomass. Exposed *ʻili* are shaded green; sheltered *ʻili* are shaded blue.

Minimum legal harvest size for jacks in Hawaiʻi is 25.4 cm (10 in). Eighty-one percent of the bluefin trevally were above the minimum legal harvest size in the Reserve, suggesting fishing pressure is low. Bluefin trevally are capable of traveling large distances (>3 km) over open water, but these long distance forays are relatively rare, with individuals showing high site fidelity, especially at night, and with active daytime foraging along reefs within one kilometer (Holland *et al.* 1996). Given the distance of open water between Kahoʻolawe and Maui (~11 km), the rate of movement of the bluefin trevally between the two islands is likely low.

5.0 Management Recommendations

The Kahoʻolawe Island Reserve: ʻIli O Kealaikahiki Conservation Action Plan (CAP) (KIRC 2014) and the Kahoʻolawe Ocean Management Plan (Dames & Moore 1997) identify several threats to Kahoʻolawe's coral reef resources, including three classified as high threats (Table 14). The effects of several of these threats on the Reserve's marine resources can be further examined in relation to the findings in this report:

Table 13. The number of jackss (N) observed on transects (5-minute timed swims), average biomass, average size, maximum size, size at maturity, and percent of the fish observed larger than the size at maturity for the jack species observed at Kaho‘olawe in 2015. Biomass is in g/m^2 and all sizes are in centimeters. Maximum size is for the species in Hawai‘i. No average size was calculated for species with <5 individuals.

Jacks	N	Average Biomass	Average size	Max. Size[1]	Size at Maturity[2]	Percent Mature
Mackerel scad	95 (50)	NA[3]	school[3]	32	24.5	-
Bluefin trevally	37 (13)	2.1 ± 0.7	34.9 ± 1.7	83	35	50%
Giant trevally	2 (5)	4.2 ± 1.9	-	165	60	-
Barred jack	1 (0)	0.1 ± 0.1	-	55	?	-
Island jack	1 (0)	0.1 ± 0.1	-	79	?	-

[1]From Randall (2007)
[2]From Honebrink (2001)
[3]This species usually occurs in large schools, making sizing individuals and estimating biomass difficult.

- Erosion and sedimentation (High Threat): At many of the 2015 survey sites, evidence of terrestrial-derived sediment was observed on the reef, sometimes completely smothering coral. Terrestrial-derived sediment was more common in sheltered *‘ili* than exposed ones. However, there was no relationship with the presence of sediment and decreased coral cover or diversity. Coral diversity and cover was correlated with exposure, suggesting the effects of sediment on the benthic assemblage are secondary to exposure, a finding consistent with other research in Hawai‘i. Sediment effects were detected for goatfish, which appeared to favor sites with marine sediment over those with evidence of terrestrial-derived sediment. Sediment has been an issue on Kaho‘olawe’s reefs for over a century, and it is likely that the coral reef community has become generally acclimatized to it. There is evidence, however, that coral cover has increased since the 1980s, following the implementation of erosion control measures, so benefits from continued erosion control may be realized.

- Lack of knowledge about resources (Medium Threat): Over the past three decades, numerous marine surveys have been conducted at Kaho‘olawe, documenting benthic and fish diversity and abundance. These efforts, taken as a whole, have likely documented a large percentage of the fish and coral diversity within the Reserve. Prior to 2009, surveys were conducted at a limited number of sites, providing poor spatial resolution on species distributions. Data collected in 2009 and 2015, however, had high spatial coverage and provide a significantly improved view of species distributions. Additional surveys are unlikely to

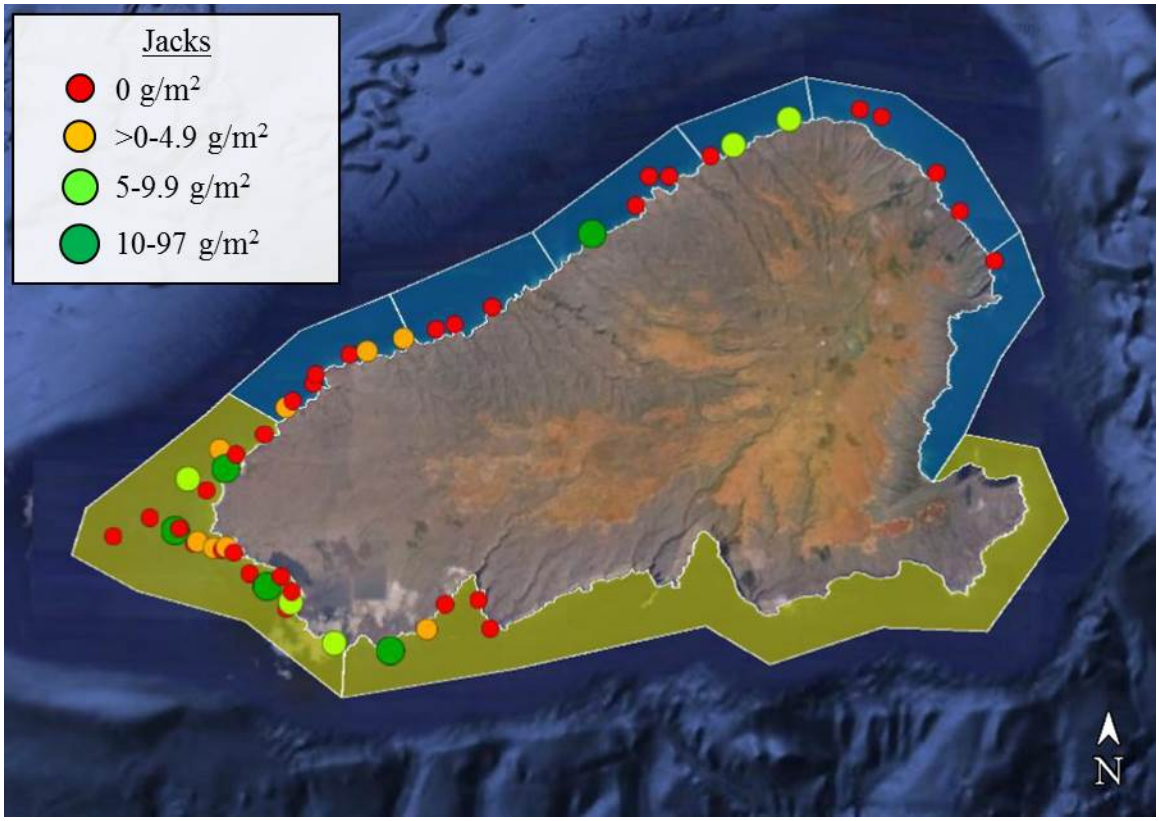


Figure 21. Biomass of all jacks at survey sites in 2015. Red and orange circles are below the average jack biomass, whereas light and dark green circles are sites with above average biomass. Exposed *ʻili* are shaded green; sheltered *ʻili* are shaded blue.

identify a large number of new records for fish or coral. However, mobile invertebrates, the very shallow-water reef community (<3 m), and the intertidal zone, appear to be inadequately surveyed at this time.

- Human access and impacts (Medium Threat): No differences were found between benthic or fish assemblages at "access" and "control" sites, but the sample sizes were small and the power to detect differences was likely low. Given the low level of human access, impacts are likely very small to insignificant, but a targeted investigation could be warranted.

- Harvest/Overharvest (Medium Threat): For the Reserve as a whole, little evidence of adverse impacts resulting from the current harvest of marine resources (legal and/or illegal) was found. The biomass of resource fish and prime spawners (two measures that are good indicators of overharvest) in the Reserve were the highest found in the main Hawaiian Islands, suggesting relatively healthy fish stocks. Mean fish size for species often exceeded the legal harvest size, and a large proportion of the fish populations examined were above the species' size at maturity. The composition of the fish assemblage appears to have been stable for several decades. However, within the Reserve, the likely effects of

fishing/poaching were detected from the spatial distribution of fish biomass; eastern *ʻili*—those closest to Maui—had lower biomass of target fish than western *ʻili*, in contrast to equivalent non-target fish biomas.

- Introduced fish species (Low Threat): Three introduced fish species were commonly observed on Kahoʻolawe's reefs, raising concerns about their potential impact on the native community. Current scientific research conducted in Hawaiʻi has found few negative impacts from these invasive fish on native populations (Schumacher and Parrish 2005, Dierking *et al.* 2009, TNC unpub. data). But the invasive fish biomass on Kahoʻolawe exceeds that found on most reefs in Hawaiʻi, increasing the potential for adverse impacts, and thus may warrant further investigation to determine their effect, if any, on the Reserve's coral reefs (e.g., a fish removal experiment might be useful). In all likelihood, the removal of these invasive fish would have little impact on the Reserve's native fish assemblage; however, there may be reasons other than direct ecological benefits to justify their removal from the Reserve.

Climate change was not identified as a threat in the Reserve's management plans, but is likely the most significant long-term threat facing Kahoʻolawe's nearshore reefs. Climate change is expected to result in elevated sea water temperature, which is a primary cause of coral bleaching. Bleaching was observed in the 2015 surveys, but has also been observed frequently in past surveys, suggesting it may also be a response, in part or in whole, to other stressors (*e.g.*, sedimentation). In 2015, however, bleaching was independent of exposure and terrestrial-derived sediment, suggesting a regional stressor. High water temperatures in the latter half of 2014 resulted in a significant bleaching event, which only lightly affected Maui reefs. In 2015, a second bleaching event occurred as a result of high water temperatures, and early data compiled by KIRC natural

Table 14. Threats to nearshore coral reefs identified in the Kahoʻolawe Island Reserve: ʻIli O Kealaikahiki CAP (KIRC 2014) and the Kahoʻolawe Ocean Management Plan (Dames & Moore 1997).

Threat	
Potential alien species introduction via vessel	High
Erosion and sedimentation	
Fuel spill and vessel grounding	
Human trampling	Medium
Lack of knowledge of or presence of resources	
Increased human access	
Overharvesting	
Inappropriate vegetation	Low
Aquatic diseases and pathogens	
Introduced fish species	

resource staff suggest the Reserve's reefs were affected. Given recent events, climate change represents a significant, long-term threat to Kaho'olawe's reefs.

The KIRC staff faces significant challenges to address climate change because the source of this threat lies outside their management authority. Climate change cannot be solved at the local Kaho'olawe or Maui Nui level. Instead, management actions that reduce local stressors on Kaho'olawe's coral reefs need to be implemented in order to increase reef resilience. High reef resilience will reduce the susceptibility of the Reserve's reefs to the effects of climate change, and increase the ability of the reef to recover following damage. To this end, reducing sediment erosion and potential damage from human use, and ensuring fishery harvests are sustainably managed within the Reserve would increase reef resilience. Unfortunately, these "Reserve-derived benefits" are likely to be modest because these stressors appear to be having relatively small effects on the Reserve's marine resources.

Prevailing currents from west Maui have been shown to move primarily southwest (Storlazzi *et al.* 2006), suggesting, many of the marine species on Kaho'olawe may be at least partially dependent on the influx of larvae from Maui. Marine resources from Maui, especially those from the south shores, nearest to Kaho'olawe, show signs of significant impact from people, including decreased fish stocks and degraded benthic assemblages. Enhancing reef resilience includes actions such as increasing reproductive output and larval supply, protecting important trophic relationships, and improving the health of benthic assemblages, and will likely require management actions at a county or state scale, including:

- Rational and effective fishery management at a regional/state-wide scale, which would increase fish abundance across Maui Nui and re-establish degraded trophic structures (*i.e.*, apex predators, sharks, and jacks). Currently, fish assemblages in the main Hawaiian Islands are lacking apex predators and abundant populations of important grazers such as parrotfish and surgeonfish. These herbivores control algae which often directly compete with corals. Additionally, appropriate fishery management would increase the number of prime spawners, improving the reproductive capacity of the assemblage.

- Improvements in coastal water quality, which would reduce metabolic stresses (*e.g.*, through sediment reduction), reduce direct competition from fast growing algae (*e.g.*, through nutrient enrichment reduction), and improve coral reproduction through decreased larval mortality (*e.g.*, through chemical pollutants reduction) and improved settlement (*e.g.*, through sediment reduction).

Specific actions to promote these should be developed and implemented by the KIRC.

6.0 Acknowledgements

We thank Mike Naho'opi'i (KIRC Executive Director), Jen Vander Veur, Grant Thompson, Paul Higashino, Hoʻoleia Kaʻeo, and Kupaʻa Luat-Hueu all with the KIRC, without whom this project could not have been completed. Hawaiian Islands Humpback Whale National Marine Sanctuary provided boat support and captain Carmen DeFazio. Finally, we thank Roxie Sylva and Emily Fielding (TNC's Maui Marine Program) for their hospitality, logistical support, and most importantly, their tireless coordination with local partners.

This report was prepared by The Nature Conservancy under cooperative agreement award #NA13NOS4820145 from the NOAA Coral Reef Conservation Program, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of NOAA, the NOAA Coral Reef Conservation Program, or the U.S. Department of Commerce.

7.0 References

Cole, K. S. 2009. Size-dependent and age-based female fecundity and reproductive output for three Hawaiian goatfish (Family Mullidae) species, *Mulloidchthys flavolineatus* (yellowstrip goatfish), *M. valicolensis* (yellowfin goatfish), and *Parupeneus porphyreus* (whitesaddle goatfish). Report prepared for the Hawaiʻi Division of Aquatic Resources. 9 pp.

Cox, E. F., P. L. Jokiel, F. T. Te, and F. G. Stanton. 1995. Chapter 2: Community structure of corals and reef finsh. In "An Evaluation of the Nearshore Coral Reef Resources of Kahoolawe, Hawaiʻi" (Jokiel, P.L., E.F. Cox, and M.P. Crosby). Hawaii Institute of Marine Biology Technical Report, 185 pp.

Dames & Moore. 1997. Kahoʻolawe Ocean Management Plan. Kahoʻolawe Island Reserve Commission. State of Hawaiʻi. 70 pp.

DAR 2015. Hawaiʻi Fishing Regulations, August 2015. Division of Aquatic Resources, Department of Land and Natural Resources. 63 pp.

DeMartini, E. E., and K. G. Howard. 2016. Comparisons of body size at sexual maturity and at sex change in the parrotfishes of Hawaiʻi: input needed for management regulations and stock assessments. J. Fish. Biol. doi:10.1111/jfb.12831

Dierking, J., I. D. Williams, and W. J. Walsh. 2009. Diet composition and prey selection of the introduced grouper species peacock hind (*C. argus*). Hawaiʻi. Fisheries Bulletin 107: 464-76.

Dollar, S. J. 1982. Wave stress and coral community structure in Hawaiʻi. Coral Reefs 1: 71-81.

Fabricious, K. E. 2005. Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. Mar. Poll. Bull. 50:125-46.

Friedlander, A. M. and J. D. Parrish. 1998. Habitat characteristics affecting fish assemblages on a Hawaiian coral reef. *J. Exp. Mar. Biol. Ecol.* 224: 1-30.

Friedlander, A. M., J. D. Parrish, and R. C. DeFelice. 2002 Ecology of the introduced snapper Lutjanus kasmira (Forsskal) in the reef fish assemblage of a Hawai‘i Bay. J. Fish. Biol. 60: 28-48.

Friedlander, A. M., E. K. Brown, P. L. Jokiel, W. R. Smith, and K. S. Rodgers. 2003. Effects of habitat, wave exposure, and marine protected area status on coral reef fish assemblages in the Hawaiian archipelago. Coral Reefs 22: 291-305.

Friedlander, A.M., E. Brown, M. Monaco, and A. Clark. 2006. Fish Habitat Utilization Patterns and Evaluation of the Efficacy of Marine Protected Areas in Hawai’i: Integration of NOAA Digital Benthic Habitats Mapping and Coral Reef Ecological Studies. NOAA Technical Memorandum NOS NCCOS 23. 213 pp.

Friedlander, A.M., E. Brown, and M.E. Monaco. 2007a. Defining reef fish habitat utilization patterns in Hawai’i: comparisons between marine protected areas and areas open to fishing. *Marine Ecology Progress Series* 221-233 pp.

Friedlander, A.M., E.K. Brown, and M.E. Monaco. 2007b. Coupling ecology and GIS to evaluate efficacy of marine protected areas in Hawai’i. *Ecological Applications* 17: 715-30.

Friedlander A, Aeby G, Brainard R, Brown E, Chaston K, Clark A, McGowan P, Montgomery T, Walsh W, Williams I, Wiltse W. 2008. The State of Coral Reef Ecosystems of the Main Hawaiian Islands. pp. 158-199. In: Waddell, J.E. and A.M. Clarke (eds), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment’s Biogeography Team. Silver Spring, MD. 569 pp.

Friedlander, A., Z. Caldwell, E. Conklin, C. King, K. Laepaa, C. Lindsey, K. Pollock, D. Tokishi, J. VanderVeur, C. Wiggins, and S. Wood. 2010. Assessment of the Nearshore Marine Resources of the Kaho‘olawe Island Reserve. Report prepared for the Kaho‘olawe Island Reserve Commission. 28 pp.

Friedlander, A., M. Donovan, K. Stamoulis, and I. Williams. 2013. Meta-analysis of reef fish data in Hawai‘i: Biogeography and gradients of human impacts. Final Report to Hawaii Division of Aquatic Resources, Fall 2013. 60 pp.

Froese, R. and D. Pauly. 2011. *FishBase.* World Wide Web electronic publication. www.fishbase.org, version (06/2011).

Holland, K. N., C. G. Lowe, and B. M. Wetherbee. 1996. Movements and dispersal patterns of blue trevally (*Caranx melampygus*) in a fisheries conservation zone. Fisheries Resear. 25: 279-92.

Honebrink, R. R. 2001. A review of the biology of the family Carangidae, with emphasis on species found in Hawaiian waters. DAR Technical Report 20-01. 37 pp.

Hoover, J. P. 1998. *Hawai`i's Sea Creatures: A Guide to Hawai`i's Marine Invertebrates*. Mutual Publishing, Honolulu, HI. 366 pp.

Jokiel, P. L., E. K. Brown, A. Friedlander, S. K. Rodgers, and W. Smith. 2004. Hawai‘i Coral Reef Assessment and Monitoring Program: Spatial patterns and temporal dynamics in reef coral communities. Pac. Sci. 58: 159-74.

Jokiel, P.L. 2006. Impact of storm waves and storm floods on Hawaiian Reefs. Proc. 10th International Coral Reef Symp. Pp. 390-98.

Kawamoto, K. E., D. A. Bulseco, and T. Y. Kobayashi. 1981. The effects of siltation upon the nearshore marine environment of Kahoolawe. Student-Originated Studies PrograM, National Science Foundation report (Grant No. SPI-8004745). 95 pp.

King, P. N. 1993. A Local History of Kaho‘olawe Island: Tradition, Development, and World War. Kaho‘olawe Island Conveyance Commission. 174 pp.

KIRC. 2014. Kaho‘olawe Island Reserve: ‘Ili O Kealaikahiki. Conservation Action Plan. Kahoolawe Island Reserve Commission. State of Hawaii. 20 pp.

Kohler, K. E. and S. M. Gill. 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences* 32: 1259-69.

Langston, R., K. Longenecker, and J. Claisse. 2009. Growth, mortality and reproduction of kole, *Ctenochaetus strigosus*. Report prepared for the Hawaii Division of Aquatic Resources. 25 pp.

Longenecker, K., R. Langston, and J. Eble. 2008. Growth, mortality and reproduction of manini, *Acanthurus triostegus sandvicensis*. Report prepared for the Hawaii Division of Aquatic Resources and contribution No. 2008-006 to the Hawaii Biological Survey. 20 pp.

Longenecker, K. and R. Langston. 2008 A rapid, low-cost technique for describing the population structure of reef fishes. Final Report, Honolulu, Hawaii: Bishop Museum. 34 pp.

Marshall, P. and H. Schuttenberg. 2006. *A Reef Manager's Guide to Coral Bleaching.* Townsville, Australia, Great Barrier Reef Marine Park Authority.

McCormick, M. 1994. Comparison of field methods for measuring surface topography and their associations with a tropical reef fish assemblage. Marine Ecology Progress Series 112: 87-96.

Minton,D. E. Conklin, C. S. Couch, M. Garren, M. J. Hardt, R. Amimoto, K. Pollock and C. Wiggins. 2011. Survey of the Coral Reefs of Pelekane Bay. TNC Technical report prepared for the Kohala Center. 54 pp.

Minton, D., E. Conklin, P. Weiant and C. Wiggins. 2012. 40 Years of Decline on Puakō's Coral Reefs: A review of Historical and Current Data (1970-2010). TNC Technical report prepared for the National Fish and Wildlife Foundation. 140 pp.

Minton, D. E. Conklin, K. Pollock and R. Amimoto. 2014. 2013 Baseline Surveys of Marine Resources of Polanui, Maui. TNC Technical Report. 29 pp.

Minton, D., E. Conklin, A. Friedlander, R. Most , K. Pollock, K. Stamoulis, and C. Wiggins. 2015. Establishing the baseline condition of the Marine Resources: Results of the 2012 and 2013 Kaʻūpūlehu, Hawaiʻi marine surveys. TNC Technical Report. 37 pp.

Newman, S. J.and D. McB. Williams. 1996. Variation in reef associated assemblages of the Lutjanidae and Lethrinidae at different distances offshore in the central Great Barrier Reef. Environ. Biol. Fishes 46: 123-38.

Randall, J. E. 2007. *Reef and Shore Fishes of the Hawaiian Islands*. Sea Grant College Program, University of Hawaiʻi. 546 pp.

Randall, J.E., and V.E. Brock. 1960. Observations on the ecology of epinepheline and lutjanid fishes of the Society Islands, with emphasis on food habits. Transactions of the American Fisheries Society 89:9-16.

Rogers, C. S. 1990. Responses of coral reefs and reef organisms to sedimentation. Mar. Ecol. Prog. Ser. 62: 185-202.

Rodgers, K. S., P. L. Jokiel, E. K. Brown, S. Hau, and R. Sparks. 2014. Over a decade of change in spatial and temporal dynamics of Hawaiian coral reef communities. Pac. Sci. 69(1).

Schumacher, B. D. and J. D. Parrish. 2005. Spatial relationships between an introduced snapper and native goatfishes on Hawaiian reefs. Biological Invasions 7: 925-933.

Shpigel, M. and L. Fishelson. 1985. Habitat partitioning between species of the genus *Cephalopholis* (Pisces, Serranidae) across the fringing reef of the Gulf of Aqaba (Red Sea). Mar. Ecol. Prog. Ser. 58: 17-22.

Stanton, F.G. 2005. Kahoʻolawe underwater baseline surveys. Annual Report, June 2005. Prepared for the . Kahoʻolawe Island Reserve Commission (Contract No. 52792). 65 pp.

Stanton, F.G. 2006. Kahoʻolawe underwater baseline surveys. Annual Report, September 2006. Prepared for the . Kahoʻolawe Island Reserve Commission (Contract No. 54195). 75 pp.

Stanton, F.G. 2007. Kahoʻolawe underwater baseline surveys. Annual Report, July 2007. Prepared for the . Kahoʻolawe Island Reserve Commission (Contract No. 55573-01). 75 pp.

Stanton, F.G. 2008. Kahoʻolawe underwater baseline surveys. Annual Report, October 26, 2008. Prepared for the . Kahoʻolawe Island Reserve Commission. 62 pp.

Storlazzi, C. D., M. E. Field, J. D. Dykes, P. L. Jokiel, and E. Brown. 2002. Wave control on reef morphology and coral distribution: Molokai, Hawaii. WAVES 2001 Conference Proceedings, American Society of Civil Engineers, San Francisco, California, vol. 1: 784-93.

Storlazzi, C. D., E. K. Brown, M. E. Fields, K. Rodgers, and P. L. Jokiel. 2005. A model for wave control on coral breakage and species distribution in the Hawaiian Islands. Coral Reefs. 24: 43-55.

Storlazzi, C. D., E. K. Brown, and M. E. Fields. 2006. The application of acoustic Doppler current profilers to measure the timing and patterns of coral larval dispersal. Coral Reefs 25: 369-81.

Vitousek, S. and C. H. Fletcher. 2008. Maximum annually recurring wave heights in Hawaiʻi. Pac. Sci. 62: 541-53.

Walsh, W., S. Cotton, C. Barnett, C. Couch, L. Preskitt, B. Tissot, and K. Osada-D'Avella. 2013. Long-term monitoring of coral reefs of the Main Hawaiian Islands. 2009 NOAA Coral Reef Conservation Program Final Report (NA09NOS4260100). 97 pp.

Williams, I. D., W. J. Walsh, R. E. Schroeder, A. M. Friedlander, B. L. Richards and K. A. Stamoulis. 2008. Assessing the importance of fishing impacts on Hawaiian coral reef fish assemblages along regional-scale human population gradients. Environmental Conservation 35: 261-72.

Appendix A. Kahoʻolawe Survey Site Data (2009 & 2015)

Site Code	Wave Exposure	Date	Lat.	Long.	Rugosity	Depth (m)
2009-KIRC010	Exposed	08-Oct-09	20.51596	-156.69258	*No data*	32
2009-KIRC011	Exposed	07-Oct-09	20.52249	-156.70346	*No data*	36
2009-KIRC022	Exposed	08-Oct-09	20.53197	-156.70152	*No data*	31
2009-KIRC025	Exposed	08-Oct-09	20.53986	-156.69878	*No data*	58
2009-KIRC028	Exposed	07-Oct-09	20.52573	-156.71257	*No data*	40
2009-KIRC048	Sheltered	08-Oct-09	20.55879	-156.66833	*No data*	48
2009-KIRC054	Sheltered	08-Oct-09	20.54923	-156.68372	*No data*	38
2009-KIRC064	Exposed	06-Oct-09	20.50494	-156.63925	*No data*	35
2009-KIRC065	Exposed	06-Oct-09	20.5293	-156.53157	*No data*	34
2009-KIRC066	Exposed	06-Oct-09	20.52249	-156.53633	*No data*	53
2009-KIRC068	Exposed	06-Oct-09	20.50526	-156.65602	*No data*	43
2009-KIRC069	Exposed	06-Oct-09	20.51018	-156.63013	*No data*	50
2009-KIRC070	Exposed	06-Oct-09	20.51825	-156.54045	*No data*	36
2009-KIRC072	Exposed	06-Oct-09	20.50776	-156.58661	*No data*	30
2009-KIRC073	Exposed	06-Oct-09	20.51484	-156.61598	*No data*	41
2009-KIRC074	Exposed	06-Oct-09	20.51422	-156.55057	*No data*	33
2009-KIRC076	Exposed	06-Oct-09	20.51383	-156.56986	*No data*	39
2009-KIRC079	Exposed	06-Oct-09	20.50113	-156.66356	*No data*	35
2009-KIRC080	Sheltered	06-Oct-09	20.55131	-156.5483	*No data*	38
2009-KIRC083	Exposed	06-Oct-09	20.53962	-156.54207	*No data*	45
2009-KIRC090	Sheltered	06-Oct-09	20.56625	-156.54396	*No data*	47
2009-KIRC101A	Sheltered	09-Oct-09	20.5925	-156.61012	*No data*	51
2009-KIRC116A	Sheltered	08-Oct-09	20.58141	-156.62192	*No data*	25
2009-KIRC119	Sheltered	08-Oct-09	20.56731	-156.64253	*No data*	25
2009-KIRC121	Sheltered	05-Oct-09	20.5985	-156.5927	*No data*	18

Site Code	Wave Exposure	Date	Lat.	Long.	Rugosity	Depth (m)
2009-KIRC125	Sheltered	05-Oct-09	20.60349	-156.58122	*No data*	24
2009-KIRC128a	Sheltered	05-Oct-09	20.6054	-156.57132	*No data*	28
2009-KIRC134A	Sheltered	09-Oct-09	20.59762	-156.59579	*No data*	25
2009-KIRC135	Sheltered	05-Oct-09	20.59623	-156.59732	*No data*	29
2009-KIRC137	Sheltered	09-Oct-09	20.60607	-156.57117	*No data*	40
2009-KIRC140a	Sheltered	05-Oct-09	20.60537	-156.57114	*No data*	27
2009-KIRC143a	Sheltered	05-Oct-09	20.60394	-156.56212	*No data*	43
2009-KIRC145A	Sheltered	05-Oct-09	20.59325	-156.55138	*No data*	29
2009-KIRC152a	Sheltered	05-Oct-09	20.60535	-156.56657	*No data*	37
2009-KIRC158	Sheltered	09-Oct-09	20.57617	-156.53877	*No data*	36
2009-KIRC159	Sheltered	09-Oct-09	20.58571	-156.54594	*No data*	30
2009-KIRCHokioawa	Sheltered	05-Oct-09	20.59308	-156.55075	*No data*	
2009-KIRCHonokanaia	Exposed	07-Oct-09	20.50918	-156.68504	*No data*	36
2009-KIRCHonukanaenae	Exposed	07-Oct-09	20.51764	-156.70346	*No data*	31
2009-KIRCK3	Sheltered	09-Oct-09	20.5925	-156.606	*No data*	36
2009-KIRCK4	Sheltered	09-Oct-09	20.60059	-156.58932	*No data*	32
2009-KIRCK5	Sheltered	08-Oct-09	20.56128	-156.66084	*No data*	39
2009-KIRCK6	Sheltered	08-Oct-09	20.56394	-156.6503	*No data*	37
2009-KIRCK7	Sheltered	08-Oct-09	20.5543	-156.67894	*No data*	40
2009-KIRCK8	Exposed	08-Oct-09	20.54278	-156.68956	*No data*	33
2009-KIRCKuikui	Sheltered	05-Oct-09	20.6026	-156.56245	*No data*	31
2015-KIRC010	Exposed	6/15/2015	20.51596	-156.69258	*No data*	27.00
2015-KIRC022	Exposed	6/16/2015	20.53197	-156.70152	16.25	25.50
2015-KIRC025	Exposed	6/17/2015	20.53986	-156.69878	14.70	35.50
2015-KIRC048	Sheltered	6/17/2015	20.55879	-156.66833	14.20	16.00
2015-KIRC054	Sheltered	6/17/2015	20.54923	-156.68372	12.50	17.00
2015-KIRC068	Exposed	6/16/2015	20.50526	-156.65602	17.25	40.50

Site Code	Wave Exposure	Date	Lat.	Long.	Rugosity	Depth (m)
2015-KIRC079	Exposed	6/16/2015	20.50113	-156.66356	11.20	56.00
2015-KIRC101a	Sheltered	6/19/2015	20.59249995	-156.61012	14.50	49.50
2015-KIRC116a	Sheltered	6/18/2015	20.58140994	-156.62192	13.90	29.50
2015-KIRC119	Sheltered	6/19/2015	20.56731	-156.64253	32.50	25.50
2015-KIRC121	Sheltered	6/19/2015	20.5985	-156.5927	14.50	15.50
2015-KIRC125	Sheltered	6/18/2015	20.60349	-156.58122	13.75	25.00
2015-KIRC135	Sheltered	6/18/2015	20.59642403	-156.5974246	16.50	19.00
2015-KIRC152a	Sheltered	6/15/2015	20.60535	-156.56657	*No data*	45.00
2015-KIRC158	Sheltered	6/15/2015	20.57617	-156.53877	4.40	25.00
2015-KIRC159	Sheltered	6/15/2015	20.58571	-156.54594	19.50	37.00
2015-KIRC207	Exposed	6/16/2015	20.51085415	-156.6453653	11.50	32.50
2015-KIRC208a	Exposed	6/16/2015	20.50255367	-156.6751222	*No data*	36.00
2015-KIRC209	Exposed	6/16/2015	20.51540258	-156.6861351	*No data*	20.50
2015-KIRC210	Exposed	6/18/2015	20.52310358	-156.7207337	13.50	49.50
2015-KIRC211	Sheltered	6/18/2015	20.55814113	-156.6719609	31.00	35.00
2015-KIRC212	Sheltered	6/18/2015	20.56304611	-156.6541414	15.20	25.00
2015-KIRC215	Sheltered	6/19/2015	20.58685558	-156.6128775	12.30	19.50
2015-KIRC227	Exposed	6/16/2015	20.50538422	-156.6429328	7.80	30.00
2015-KIRC228	Exposed	6/16/2015	20.5134678	-156.688955	13.50	
2015-KIRC229	Exposed	6/16/2015	20.5242243	-156.7079933	14.50	39.00
2015-KIRC229a	Exposed	6/16/2015	20.52462749	-156.7070729	3.50	45.50
2015-KIRC233a	Exposed	6/18/2015	20.52173733	-156.7040387	12.00	47.50
2015-KIRC234a	Exposed	6/16/2015	20.53417993	-156.7053299	5.00	23.50
2015-KIRC241	Exposed	6/16/2015	20.51003352	-156.652209	*No data*	26.50
2015-KIRC242a	Exposed	6/18/2015	20.52670335	-156.7131799	*No data*	49.00
2015-KIRC246	Sheltered	6/18/2015	20.55255625	-156.679416	1.53	21.50
2015-KIRC247	Sheltered	6/18/2015	20.54793178	-156.685053	*No data*	25.00

Site Code	Wave Exposure	Date	Lat.	Long.	Rugosity	Depth (m)
2015-KIRCHakioawa	Sheltered	6/29/2015	20.59308	-156.55075	15.10	36.50
2015-KIRCHonokanaia	Exposed	6/15/2015	20.50918	-156.68504	11.80	26.00
2015-KIRCHonukanaenae	Exposed	6/17/2015	20.52053151	-156.6982995	*No data*	34.00
2015-KIRCK3	Sheltered	6/19/2015	20.5925	-156.606	*No data*	26.00
2015-KIRCK5	Sheltered	6/17/2015	20.56128	-156.66084	29.50	30.00
2015-KIRCK6	Sheltered	6/17/2015	20.56394	-156.6503	7.80	34.00
2015-KIRCK7	Sheltered	6/17/2015	20.5543	-156.67894	*No data*	26.00
2015-KIRCK8	Exposed	6/17/2015	20.54278	-156.68956	*No data*	26.00
2015-KIRCKA1	Exposed	6/17/2015	20.52088497	-156.7000636	12.80	36.00
2015-KIRCKA2	Exposed	6/17/2015	20.52211225	-156.7033849	14.00	37.00
2015-KIRCKAU1	Exposed	6/17/2015	20.53890263	-156.6953624	11.50	30.00
2015-KIRCKAU2	Exposed	6/17/2015	20.53616392	-156.6975182	14.50	20.00
2015-KIRCKuikui	Sheltered	6/15/2015	20.60393999	-156.5621199	15.70	13.00
2015-KIRCMUA	Exposed	6/17/2015	20.51039267	-156.6841291	12.50	27.00
2015-KIRCPUU1	Exposed	6/17/2015	20.52001988	-156.6958506	12.20	20.00
2015-KIRCPUU2	Exposed	6/17/2015	20.52105689	-156.6974351	13.75	27.50
2015-KIRCWeightRoom	Exposed	6/17/2015	20.51251145	-156.6838962	13.50	21.5

Appendix B. TNC Survey Methods and Data Analysis

The overarching goal of TNC's marine monitoring program is to detect change in the biological community over time on specific reef areas around the main Hawaiian Islands. In addition to detecting temporal change, the marine monitoring program seeks to provide data that can be used to compare coral reef areas with other reef ecosystems across the state and beyond. Such comparisons can provide a context within which to understand any observed changes. Thus, survey design and sampling protocols were specifically chosen to provide the greatest likelihood of compatibility with other monitoring efforts currently underway in Hawai'i.

TNC's marine monitoring team, along with partners at the University of Hawai'i's Fisheries Ecology Research Lab, conducted all benthic and fish surveys. Members of the monitoring teams have hundreds of hours of experience conducting underwater surveys of coral reefs, and provide regular monitoring for numerous sites around the main Hawaiian Islands. All surveyors are trained and calibrated to reduce differences among observers that can sometimes confound data in large, long-term monitoring programs.

Survey Sites

The survey area on Kaho'olawe and adjacent reef covered approximately 47 km of coastline and included coral reef habitat between 3 and 20 m deep. Fifty sites were randomly generated in ArcGIS within this area.

Sites were surveyed by divers deployed from a small boat or, for some sites close to shore, divers swam out from the beach. The survey teams navigated to each predetermined site using a Garmin GPS unit. Once on site, the survey team descended directly to the bottom, where divers established two transect start points approximately 10 m apart. From each start-point, divers deployed a 25 m transect line along a predetermined compass heading, with the transects running parallel to each other. If the bearing resulted in a large change in depth, the transect was "bent" to follow the depth contour.

Benthic Community Surveys

Benthic surveys were not designed to collect comprehensive biodiversity data. Instead, surveys were designed to collect quantitative data on specific taxa, primarily individual coral species, algae at higher taxonomic resolution (*e.g.*, red, green, brown, turf, crustose coralline, etc.), and abiotic substratum type when the bottom was something other than hard substratum.

At sites where benthic data were collect, benthic photographs were collected at 1 m intervals along one of the two 25 m transect lines. Photographs were taken with a Canon G11 camera (or equivalent) mounted on a 0.8 m long monopod, resulting in images that covered approximately 0.8 x 0.6 m of the bottom. Prior to photographing each transect,

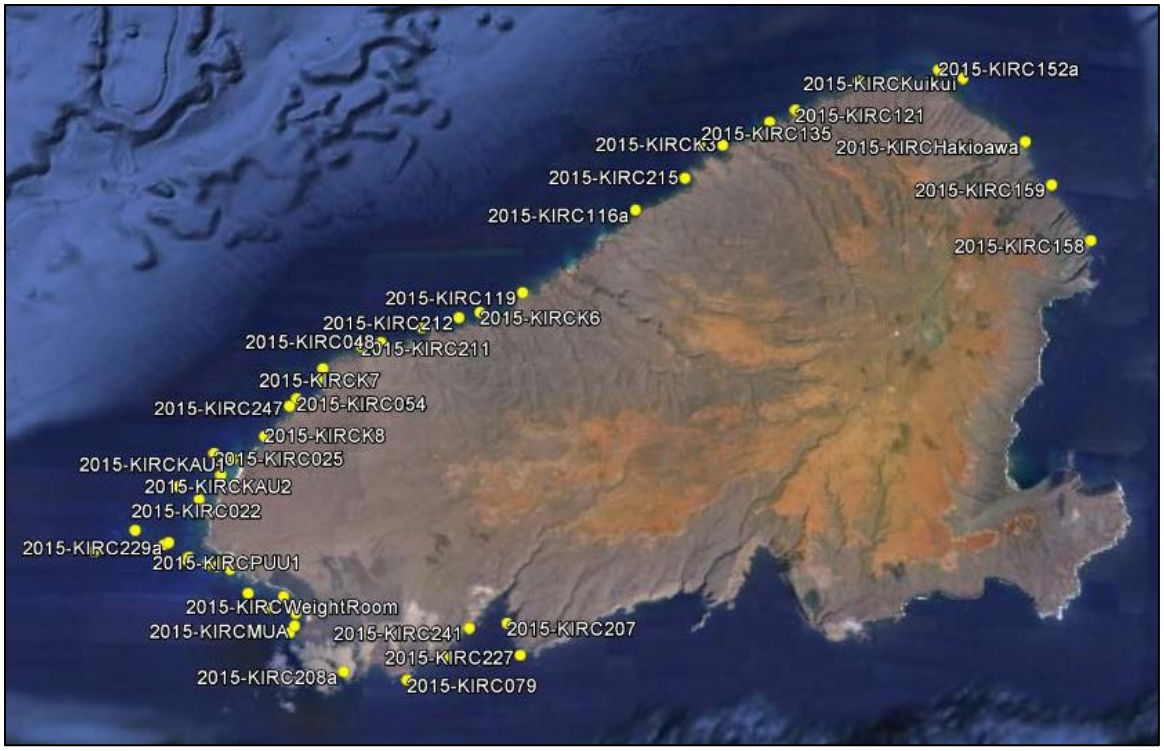


Figure B.1. Kahoolawe with the 50 randomly-generated marine monitoring sites surveyed during June 2015.

the camera was white balanced to improve photograph quality. A 5-cm scale bar marked in 1-cm increments was included in all photographs.

Each photograph was imported into Adobe Photoshop CS5 where its color, contrast, and tone were autobalanced to improve photo quality prior to analysis using the Coral Point Count program with Excel extension (CPCe) developed by the National Coral Reef Institute (Kohler and Gill 2006). Using CPCe, 30 random points were overlaid on 20 randomly selected digital photographs, and the benthic component under each point was identified to the lowest possible taxonomic level. To reduce observer variability, all photographs were processed by a single individual. The raw point data from all photographs on a transect line were combined to calculate the percent cover of each benthic component for the entire belt transect. The number of photos analyzed and points per photo were derived from a power analysis conducted to determine the optimal sampling effort to maximize the statistical power of annual comparisons.

Fish Community Surveys

All fish within or passing through a 5 m wide belt along each of the two 25 m transects deployed at each survey site were identified to species and sized into 5 cm bins (*i.e.*, 0-5 cm, >5-10 cm, >10-15 cm, etc.) Divers moved slowly along the transects, taking between 10 and 15 minutes to complete each belt survey. This method closely corresponds with that used by Dr. Alan Friedlander and colleagues for the "Fish Habitat

Utilization Study" (FHUS), and provides comparable data. Details of their method and results of those surveys are given in a number of recent publications (Friedlander *et al.* 2006, Friedlander *et al.* 2007a, 2007b).

At some sites, a 5-minute timed swim was conducted after divers completed surveying the 25 m transect lines. For the timed swims, the two fish surveyors swam approximately 5 m apart and visually censused all fish larger than 15 cm within or passing through a 5 m wide column (centered on the surveyor) extending from the ocean bottom to the surface. Divers communicated with each other to ensure that each fish was censused by only one surveyor (*i.e.*, fish were not double counted). All fish were identified to the lowest possible taxonomic level and sized into 5 cm bins.

Data Analysis

Individual fish biomass (wet weight of fish per m^2 of reef area) was calculated from estimated lengths using size to weight conversion parameters from FishBase (Froese and Pauly, 2010) or the USGS Hawai'i Cooperative Fisheries Research Unit (HCFRU). For analyses among survey sites, fish survey data were pooled into several broad categories, including: (1) all fishes, excluding manta rays; (2) target fishes[10], which are reef species targeted or regularly harvested by fishers (Table B.1); (3) prime spawners[11], which are target fishes larger than 70% of the maximum size reported for the species; and (4) non-target fishes, which are species not targeted by fishers to any significant degree. Non-target taxa included: non-target wrasses (all wrasse species other than those listed in Table B.1); non-target surgeonfishes (*Acanthurus nigrofuscus* and *A. nigricans*); hawkfishes (all species except the stocky hawkfish, *Cirrhitus pinnulatus*); triggerfishes excluding planktivores; corallivorous butterflyfishes (*Chaetodon multicinctus, C. ornatissimus, C. quadrimaculatus* and *C. unimaculatus*); and benthic damselfishes (all *Plectroglyphidodon* and *Stegastes* species).

Standard parametric and non-parametric statistical approaches, as appropriate, were used to test for differences between years. As necessary, fish biomass and abundance were log-transformed to correct skewness and heteroscedasticity prior to analysis. All means are presented as the average ± the standard error of the mean (SEM).

Benthic and fish communities were examined using the suite of non-parametric multivariate procedures included in the PRIMER statistical software package (Plymouth

[10] Nearly all fish species are taken by some fishers at some time in Hawai'i, therefore designating a fish species as either 'targeted' or 'non-targeted' is oftentimes difficult. These two groupings are intended to represent the high and low ends of the fishing pressure continuum. The majority of fish biomass at most sites is comprised of species that fall somewhere in the middle of this continuum, and these species were not included in either group for this analysis.

[11] Large target fishes are generally heavily targeted by fishers. In addition, fishes at the high end of their size range tend to be a disproportionately important component of total stock breeding potential due to greater fecundity of large individuals, and higher survivorship of larvae produced by large fishes (Williams *et al.* 2008). Therefore 'prime spawner' biomass is likely to be a good indicator of fishing impacts, and represents an important component of ecological function (*i.e.*, population breeding potential).

Table B.1. The fish species targeted by fishers in Hawai‘i included as “Target Fish” for this report.

Surgeonfishes (Acanthuridae)
- *Acanthurus achilles*
- *Acanthurus blochii*
- *Acanthurus dussumieri*
- *Acanthurus leucopareius*
- *Acanthurus nigroris*
- *Acanthurus olivaceus*
- *Acanthurus triostegus*
- *Acanthurus xanthopterus*
- *Ctenochaetus* spp.
- *Naso* spp.

Wrasses (Labridae)
- *Bodianus albotaeniatus*
- *Cheilio inermis*
- *Coris flavovittata*
- *Coris gaimard*
- *Iniistius* spp.
- *Oxycheilinus unifasciatus*
- *Thalassoma ballieui*
- *Thalassoma purpureum*

Parrotfishes (Scaridae)
- All

Non Target
- *Acanthurus nigricans*
- *Acanthurus nigrofuscus*
- *Anampses chrysocephalus*
- *Anampses cuvier*
- *Chaetodon lunulatus*
- *Chaetodon multicinctus*
- *Chaetodon ornatissimus*
- *Chaetodon quadrimaculatus*
- *Chaetodon reticulatus*
- *Chaetodon unimaculatus*
- *Chromis agilis*
- *Chromis hanui*
- *Chromis leucura*
- *Cirrhitops fasciatus*
- *Coris venusta*
- *Gomphosus varius*
- *Halichoeres ornatissimus*
- *Labroides phthirophagus*
- *Labridae sp.*
- *Macropharyngodon geoffroy*

Apex
- *Aphareus furca*
- *Aprion virescens*
- All Priacanthidae (big-eyes)
- All Sphyraenidae (barracuda)

Goatfishes (Mullidae)
- All

Jacks (Carangidae)
- All

Soldier/Squirrelfishes(Holocentridae)
- *Myripristis* spp.
- *Sargocentron spiniferum*
- *Sargocentron tiere*

Others
- *Chanos chanos*
- *Cirrhitus pinnulatus*
- *Monotaxis grandoculis*

Non Target (continued)
- *Novaculichthys taeniourus*
- *Oxycheilinus bimaculatus*
- *Paracirrhites arcatus*
- *Paracirrhites forsteri*
- *Plectroglyphidodon imparipennis*
- *Plectroglyphidodon johnstonianus*
- *Pseudocheilinus evanidus*
- *Pseudocheilinus octotaenia*
- *Pseudocheilinus tetrataenia*
- *Pseudocheilinus cerasinua*
- *Rhinecanthus aceleatus*
- *Rhinecanthus rectangulus*
- *Stegastes marginatus*
- *Stethojulis balteata*
- *Sufflamen bursa*
- *Sufflamen fraenatus*
- *Thalassoma duperrey*
- *Thalassoma lutescens*
- *Thalassoma quinquevittatum*
- *Thalassoma trilobatum*

Routines in Multivariate Ecological Research) (Clarke and Warwick 2001). These procedures have gained widespread use for analyzing marine ecological community data, and have significant advantages over standard parametric procedures (see Clarke 1993 for additional information).

Prior to analysis, percent cover data for each benthic category were square-root transformed and a Bray-Curtis similarity matrix generated (Clarke and Warrick 2001, Clarke and Gorley 2006). Non-metric multidimensional scaling (nMDS) plots were generated to explore patterns (Clarke and Gorley 2006) in benthic composition.

As with the benthic community data, fish biomass data at all sites were square-root transformed and a Bray-Curtis similarity matrix generated (Clarke and Warrick 2001, Clarke and Gorley 2006) prior to analysis in PRIMER. Non-metric multidimensional scaling (nMDS) plots were generated to explore patterns (Clarke and Gorley 2006) in fish community structure.

Key taxa representative of zones were selected using PRIMER's SIMPER analysis. Any taxa with a DISS/SD>1.4 were considered to be representative of the zone. The ratio of the average dissimilarity and standard deviation (DISS/SD) is given as a measure of how consistently the species contributes to the characterization of differences between groups, with larger values (>1.4) indicating greater consistency as a discriminating species (Clarke and Warrick 2001).

References for Appendix B

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117-43.

Clarke, K. R. and R. N. Gorley. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth.

Clarke, K. R. and R. M. Warwick. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. PRIMER-E, Plymouth.

Couch, C. S., J. Garriques, C. Barnett, L. Preskitt, S. Cotton, J. Giddens, W. Walsh (in review). Spatial and Temporal Patterns of Coral Health and Disease along Leeward Hawai`i Island. Coral Reefs.

Friedlander, A.M., E. Brown, M. Monaco, and A. Clark. 2006. Fish Habitat Utilization Patterns and Evaluation of the Efficacy of Marine Protected Areas in Hawai'i: Integration of NOAA Digital Benthic Habitats Mapping and Coral Reef Ecological Studies. NOAA Technical Memorandum NOS NCCOS 23. 213 pp.

Friedlander, A.M., E. Brown, and M.E. Monaco. 2007a. Defining reef fish habitat utilization patterns in Hawai'i: comparisons between marine protected areas and areas open to fishing. *Marine Ecology Progress Series* 221-233 pp.

Friedlander, A.M., E.K. Brown, and M.E. Monaco. 2007b. Coupling ecology and GIS to evaluate efficacy of marine protected areas in Hawai'i. *Ecological Applications* 17: 715-30.

Froese, R. and D. Pauly. 2011. *FishBase*. World Wide Web electronic publication. www.fishbase.org, version (06/2011).

Kohler, K. E. and S. M. Gill. 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences* 32: 1259-69.

Williams, I. D., W. J. Walsh, R. E. Schroeder, A. M. Friedlander, B. L. Richards and K. A. Stamoulis. 2008. Assessing the importance of fishing impacts on Hawaiian coral reef fish assemblages along regional-scale human population gradients. Environmental Conservation 35: 261-72.

Appendix C. Glossary of Scientific Terms

Abundance: The relative representation of a species in a particular ecosystem. It is usually measured as the number of individuals found per sample.

Assemblage: All of the various species of a particular type or group that exist in a particular habitat (e.g., all fish, all coral). A species assemblage is a subset of all of the species within an ecological community, e.g., the fish assemblage is part of the coral reef community.

Belt Transect: A sampling unit used in biology to investigate the distribution of organisms in relation to a certain area. It records the number of individuals for all the species found between two lines.

Benthic Organism: An animal or plant that resides primarily on the bottom, whether attached (e.g., coral, algae), or unattached (e.g., snail, crabs).

Biomass: The mass of living biological organisms in a given area or ecosystem at a given time. Usually expressed as a mass or weight per unit area, e.g., tons/acres or g/m^2.

Prime spawners: Large target fishes (>70% their maximum size) that are generally prized by fishers and tend to contribute disproportionately more to the total reproductive potential of the population than smaller individuals due to their greater egg and sperm production (i.e., higher fecundity) and the higher survivorship of their larvae. Prime spawner biomass is a good indicator of fishing impacts.

Quadrat (Photo-quadrat): A square used in ecology to isolate a sample, usually about with a relatively small area (e.g., 0.25 m^2 or 1 m^2). A quadrat is suitable for sampling sessile or slow-moving animals. A photo-quadrat is a picture taken of a quadrat.

Rugosity: A measure of small-scale variations in the height of the reef. As a measure of complexity, rugosity is presumed to be an indicator of the amount of habitat available for colonization by benthic organisms (those attached to the seafloor), and shelter and foraging area for mobile organisms.

Target fishes: Fish desirable for food, commercial activity, and/or cultural practices that reside in the habitats and depth ranges surveyed by the TNC marine monitoring team. Nearly all fish species are taken by some fishers at some time in Hawai‘i, therefore designating a fish species as either ‘targeted’ or ‘non-targeted’ is oftentimes difficult. These two groupings are intended to represent the high and low ends of the fishing pressure continuum. The majority of fish biomass at most sites is comprised of species that fall somewhere in the middle of this continuum.