Ola nā Papa i Mālama ʻia

Maui Nui Marine Resource Council

A Practical Plan for the Technical and Cultural Restoration of Maui's Coral Reefs

Version 2.0

Prepared by the
Maui Coral Reef Recovery Team
of the Maui Nui Marine Resource Council

Ola nā Papa i Mālama ʻia

Reefs thrive when they are cared for

A Practical Plan for the Technical and
Cultural Restoration of Maui's Coral Reefs
Version 2.0

MAUI NUI
MARINE RESOURCE COUNCIL

Maui Coral Reef Recovery Team
March 2015

Cover Photos:
Top: Dino Tassara, Multicopter Maui. Brown water event at Honokahua (DT Fleming Beach Park).
Bottom: Pauline Fiene

[This page intentionally left blank]

Suggested Citation

Maui Coral Reef Recovery Team. 2015. *Ola nā Papa i Mālama ʻia: A Practical Plan for the Technical and Cultural Restoration of Maui's Coral Reefs, Version 2.0.* Maui Nui Marine Resource Council, Kīhei, Maui. 116pp.

Acknowledgements

The National Fish and Wildlife Foundation, the Harold K.L. Castle Foundation, and Maui County Government generously provided funding, in support of the development of a Maui Coral Reef Recovery Plan, to the Maui Nui Marine Resource Council via its fiscal agent, Tri-Isle Resource Conservation and Development Incorporated.

This document was collaboratively authored by the members of the Maui Coral Reef Recovery Team (MCRT): Thorne Abbott (Coastal Planners, LLC); Ka'au Abraham (Hawaiian Islands Humpback Whale National Marine Sanctuary); Eric Brown, PhD (United States Department of the Interior, National Park Service); Jay Carpio (Abundance of Fish Committee Chair, Maui Nui Marine Resource Council); Rhiannon Chandler (Community Work Day Program); Eric Conklin, PhD (The Nature Conservancy); Mark Deakos, PhD (Hawaiʻi Association for Marine Education and Research, Inc.); Alan Friedlander, PhD (University of Hawaiʻi); Elia Herman, MEM (Hawaiian Islands Humpback Whale National Marine Sanctuary); Robin Knox (Water Quality Consulting, Inc.); Ekolu Lindsey (Maui Cultural Lands, Polanui Hiu CMMA) Manuel Mejia, MSc (The Nature Conservancy); Robin Newbold, MSc (Chair, Maui Nui Marine Resource Council); Dan Polhemus, PhD (United States Department of the Interior, U.S. Fish and Wildlife Service); Tony Povilitis, PhD (Life Net Nature); Robert Richmond, PhD and MCRT Chair (University of Hawaiʻi); Celia Smith, PhD (University of Hawaiʻi); Russell Sparks, MSc (State of Hawaiʻi Department of Land and Natural Resources, Division of Aquatic Resources); John Summers (Maui County Planning Department, Administrator, Long Range Planning Division); Brian Tissot, PhD (Washington State University); Wendy Wiltse, PhD (United States Environmental Protection Agency); and Darla White, MSc (State of Hawaiʻi, Department of Land and Natural Resources, Division of Aquatic Resources).

Tony Povilitis, PhD, conceived the project, wrote the grant proposal, produced a 52-page review of all prior coral reef conservation efforts on Maui (Povilitis, 2011), and participated on the MCRT. Mia Charleston, then administrative assistant (Maui Nui Marine Resource Council), provided organizational support and coordination for MCRT meetings and contributed to plan development. Amy Hodges, Operations and Programs Coordinator for MNMRC, helped with photos, layout, MCRT meeting coordination and produced the reference section, while Sarah McLane, then Executive Director for MNMRC produced all maps, added photos, and combined all sections. David Newbold completed the design and layout of the final document pro bono and the generous donation of his time and skills is greatly appreciated. Kuʻulei Rodgers, PhD (University of Hawaiʻi), with support from Eric Brown, PhD (United States Department of the Interior, National Park Service), wrote the technical paper and non-technical review of the current status of Maui's coral reefs. Russell Sparks (Hawaii DAR) provided the "Status of Maui's Reefs" paper. Editing, coordination of plan preparation, and facilitation of the MCRT throughout the eighteen-month plan development, writing, and peer review process was led by John Parks (Marine Management Solutions). Robin Newbold, Chair of MNMRC, managed the initial phases of the project and was joined by Amy Hodges in 2012 and Tegan Hammond in 2014.

We are deeply grateful to all of the above-mentioned individuals for sharing their expertise and contributing their time to the development of coral reef recovery plan for Maui.

For more information:

Visit the Maui Nui Marine Resource Council website at www.mnmrc.org or on Facebook at www.facebook.com/MNMRC.

Maui Coral Reef Recovery Team in February 2014 (from left to right): Mark Deakos, Amy Hodges (staff), Robin Knox, John Parks, Darla White, Eric Conklin, Ekolu Lindsey. Back row: Jay Carpio, Manuel Mejia, Ka'au Abraham, Eric Brown, Russell Sparks, Bob Richmond, Thorne Abbott. Front row: Wendy Wiltse, Mary Jorgenson, Robin Newbold, Mia Charleston, and Tegan Hammond. Not pictured: Rhiannon Chandler, Alan Friedlander, Elia Herman, Dan Polhemus, Tony Povilitis, Celia Smith, John Summers, and Brian Tissot.

Photo credit: John Parks

TABLE OF CONTENTS

Foreword

The Maui Nui Marine Resource Council (MNMRC or Council) was formed in 2007 as the vehicle for concerned community members to provide guidance for improving marine resource management of the coastal waters of Maui County, Hawaiʻi. The Council's founding chairman, Edwin Lindsey, was a widely respected and much loved native Hawaiian community leader on Maui. "Uncle" Ed's constructive approach to working with others made him a role model in the community. His effectiveness came in part from his commitment to adhere to the traditional Hawaiian principles of *aloha* (caring for each other and the land and sea), *kōkua* (compassion and honesty), *mālama* (taking care of things, properly), *hoʻomanawanui* (being patient), and *ʻike* (acknowledging, recognizing, and respecting the knowledge and opinions of others). The Council continues to abide by these principles. It is in this spirit that this document is offered.

The Council consists of twenty-eight voting representatives from the community and numerous advisors. Voting members represent a broad spectrum of the community including: commercial, recreational and subsistence fishers; ocean tourism and other Maui-based businesses, non-profit organizations, scientists, educators and cultural practitioners from throughout Maui County. Advisory members include: fishers, cultural, technical, and scientific representatives from a broad cross-section of the public and a variety of government and non-governmental organizations, including federal, state, and county government, academia, the private sector and not-for-profit organizations including The Nature Conservancy of Hawaiʻi.

The Council works through its two committees of local volunteers to help restore and maintain Maui's marine resources. The Clean Water Committee collaborates with partner organizations to find and implement solutions that address water quality issues. The Abundance of Fish Committee addresses threats facing Maui's coral reefs and reef fish communities, primarily by establishing and supporting Community Managed Makai Areas (CMMAs). The Council as a whole is dedicated to the development and implementation of this Maui Coral Reef Recovery Plan to achieve its goals: an abundance of native fish, healthy coral reefs and clean water.

In mid-2010, the Maui Nui Marine Resource Council was awarded a two-year grant under the Coral Reef Conservation Fund of the National Fish and Wildlife Foundation to develop a Coral Reef Recovery Plan. During late 2010, the Council established the Maui Coral Reef Recovery Team (MCRT), a volunteer group comprised of sixteen of Hawaiʻi's most widely recognized coral reef management and scientific research experts, and community representatives. Through a series of meetings, from early 2011 through mid-2012, the MCRT focused its considerable experience and knowledge on developing a science-based, results-driven, community- and peer-reviewed coral reef recovery plan for Maui. This document is the result of this eighteen-month effort. Pursuant to County and State approvals, the Council aims to support the implementation of this recovery plan with community, government, non-governmental, and donor partners starting in 2013.

This document represents a truly remarkable group effort, conceived by and reflecting the perspectives of not only scientific experts and management professionals, but also community leaders, local fishers, and ocean recreation enthusiasts. The Council would like to again express our deepest gratitude for the sustained commitment, tireless effort, and consistent enthusiasm and support that was graciously and optimistically provided by all sixteen MCRT members acknowledged in the Preface above.

In addition, individual Council representatives and advisors were highly instrumental from project conceptualization and design through the recovery plan development process. These include: Dale Bonar, PhD and Scott Fisher, PhD (Hawaiian Islands Land Trust); Maile Carpio (Wailuku Community Managed Makai Area); Lucienne deNaie (Maui Tomorrow Foundation); Terry George and Eric Co (Harold K.L. Castle Foundation); Kim Hum, Emily Fielding, Manuel Mejia and Roxy Sylva (The Nature Conservancy of Hawaiʻi); John Gorman, PhD (Maui Ocean Center); Solomon Kahoʻohalahala (former Maui County Council Member, Maunalei Ahupuaʻa - Lānaʻi); John Kittinger, PhD (Stanford University Center for Ocean Solutions); John Parks (Marine Management Solutions); Jeff Schwartz (Kela Associates); Robert Parsons (Environmental Coordinator, Maui County), Robert J. Toonen, PhD (University of Hawaiʻi Institute of Marine Biology); and Ivor Williams, PhD (United States National Oceanic and Atmospheric Administration, National Marine Fisheries Service).

Several draft versions were generated during the iterative process of this document's development. One of the most important steps in this process was the review of a revised draft by external peers, including community representatives. These peer reviewers tremendously strengthened and shaped the final version of this recovery plan, for which the Council and MCRT are most grateful. To that end, the Council and MCRT would like to recognize and sincerely thank the following peer reviewers for their useful insights, constructive criticism and excellent suggestions which significantly improved the plan's content and structure: Thorne Abbott (CARDNO); Carl Berg, PhD (Surfrider Foundation, Kauai Chapter); Eric Brown, PhD (National Park Service), Meghan Dailer, PhD (University of Hawaiʻi); Gerry Davis, PhD (United States National Oceanic and Atmospheric Administration, National Marine Fisheries Service); Emily Fielding (The Nature Conservancy of Hawaiʻi); Liz Foote (Coral Reef Alliance); John Gorman, PhD (Maui Ocean Center); Ekolu Lindsey (Maui Cultural Lands); John Kittinger, PhD (Stanford University Center for Ocean Solutions); Kem Lowry, PhD (University of Hawaiʻi);

Dwayne Minton, PhD (The Nature Conservancy of Hawaiʻi); Takeo Miyaguchi (fishing community leader); Kuʻulei S. Rodgers, PhD (University of Hawaiʻi Institute of Marine Biology); Rodney V. Salm, PhD (The Nature Conservancy, Asia-Pacific Region); Hudson Slay, PhD (United States Environmental Protection Agency); Darrell Tanaka (Roi Roundup organizer and fishing community leader); Bradley Tarr, PhD (United States Army Corps of Engineers); Robert J. Toonen, PhD (University of Hawaiʻi Institute of Marine Biology); Ivor Williams, PhD (United States National Oceanic and Atmospheric Administration, National Marine Fisheries Service); and Alan White, PhD (The Nature Conservancy, Asia-Pacific Region).

Photo credit: J. Petruzzi

Development of this recovery plan was made possible through the generous financial support of the National Fish and Wildlife Foundation, the Harold K.L. Castle Foundation and the Maui County Office of Economic Development. The Council's fiscal agent, Tri-Isle Resource Conservation and Development Incorporated, effectively conducted financial management of funding awarded in support of this project. We also thank John A. Hauʻoli Tomoso (Executive Director) and his team at Tri-Isle for their invaluable administrative support of the Council's efforts. The Council would also like to thank the NOAA Office of National Marine Sanctuaries for graciously hosting all of the MCRT meetings at its Hawaiian Islands Humpback Whale National Marine Sanctuary Education Center, in Kīhei, Maui. The NOAA Sanctuary team ensured that the Council and MCRT members were able to effectively complete the design and drafting of this plan from within a comfortable and productive workspace.

It is the hope and intention of the Council that this document can be used in collaboration with community, government, and non-government partners to encourage a more sustainable future for Maui. We invite you to be a part of this process by incorporating your aspirations and interests and taking an active role in the conservation and restoration of Maui's coral reefs.

We are grateful to all those mentioned above for their enthusiastic support of and participation in the development of the Maui Coral Reef Recovery Plan.

Robin Newbold
Chair
Maui Nui Marine Resource Council

Tegan Hammond
Maui Coral Reef Recovery Plan Coordinator
Maui Nui Marine Resource Council

[This page intentionally left blank]

Preface

The value of Maui's coral reefs for its economy, fisheries, culture, habitats, and aesthetics is widely recognized and appreciated, although not always appropriately considered in land-use and marine resource decision-making. Twenty-five percent of the marine species living on Hawaiʻi's coral reefs are found nowhere else in the world (Friedlander *et al.*, 2008). Hawaiʻi's coral reefs are renowned for their natural beauty and have long been an integral part of Hawaiian culture and sense of place. Hawaiʻi's coral reefs are the foundation of a thriving marine ecosystem, and offer essential shoreline protection from wave action, storm surge, and erosion.

Coral reefs also provide subsistence, recreational and commercial fishing, offer world-class surfing and diving locations, and are vital to Hawaiʻi's $12 billion annual tourism industry (Hawai'i Tourism Authority, 2010). The economic value of the State's coral reefs was estimated at $10 billion with direct economic benefits to the ocean tourism industry of $800 million per year in 2002 (Cesar and van Beukering, 2004 in: Friedlander *et al.*, 2008). A peer-reviewed study released in October 2011 surveyed the economic value that the American people hold for Hawaiʻi's coral reefs at $33.57 billion dollars (Bishop *et al.*, 2011). Outdoor activities of Hawaiian residents and visitors are closely linked to coral reefs. From 2005 to 2010, nearly 50% of all visitors participated in diving or snorkeling activities during their stay in Hawaiʻi (Hawaii DBEDT, 2005 in: Friedlander *et al.*, 2008; Hamnett, Liu, and Johnson, 2004; Hawaii Tourism Authority, 2010).

Photo credit: Save Honolua Coalition

Safeguarding coral reef health and the economic and environmental benefits that they provide to residents and visitors requires maintaining a healthy balance between land-sea connections and reducing harmful land-based sources of nutrients into near-shore waters (Goreau, 2003).

Significant declines in the health and abundance of corals and reef fish populations have been documented at eight important coral reefs on Maui over the last twenty years (DAR and HCRI, 2008). Major threats facing Maui coral reefs include: overfishing, declining water quality, invasive algae, coastal development and climate change.

Maui Coral Reef Recovery Team – third meeting

Photo credit: John Park

The Maui Coral Reef Recovery Team (MCRT) is a group of committed community, government and scientific representatives who are concerned with these declines. We came together to: (1) create a practical plan to reverse coral reef declines around Maui and demonstrate that recovery is possible; and (2) offer technical and experiential expertise to decision-makers, through recommendations. We do this to ensure a future where Maui coral reef ecosystems are biologically intact, ecologically functional and sustainably–managed, for the benefit of current and future generations.

Maui Coral Reef Recovery Team – Objectives Exercise

Photo credit: John Parks

To meet the challenge, in 2009 Maui County committed to develop and implement a protection and restoration plan (County of Maui, 2009). In support of this initiative, in late 2010 the Maui Nui Marine Resource Council assembled the Maui Coral Reef Recovery Team (MCRT) to provide a science-based, results-driven and publicly supported plan to achieve coral reef restoration.

Maui Coral Reef Recovery Team – Final Meeting

Photo credit: John Parks

Past efforts to conserve Maui coral reef ecosystems have fallen short (Povilitis, 2011), because recovery has, almost exclusively, involved a "species approach," as, for example, with the humpback whale (NMFS, 1991) and endangered forest birds (USFWS, 2006). We aim to apply holistic "recovery planning" concepts and procedures, because coral reefs are complex natural environments. We intend that the methods outlined in this document provide a learning opportunity for coral scientists and reef managers. Such learning can be shared among a wide variety of stakeholder interests and increase our collective understanding of how to manage coral reefs around Maui. When successful on Maui, this process will provide a model for efforts elsewhere in Hawaiʻi and beyond.

The development of this recovery plan during 2011-2012 involved an exciting, energetic and collaborative process during our 5 all-day workshops and through email. The plan begins by acknowledging the value and importance of coral reefs to residents and visitors, and stating our vision for what implementation will provide. We then list recovery goals, with associated objectives to guide action. We provide background information on the status of Maui coral reefs, threat assessment and situation analysis. We define geographic scope and priority areas. The strategy section summarizes specific practices that will be employed at priority sites. Appendices provide additional details, including specific components underlying our vision, in-depth analysis on some of the threats and preliminary thinking on how to measure progress, including biological and social outcomes and metrics that constitute "recovery".

Our next step is to seek government adoption of the plan and begin implementation. In collaboration with partners, we will develop a work plan and timeline to guide efforts over five and ten years. The work plan will delineate the various activities to be accomplished under each objective, supported through technical and funding partnerships. The plan will involve a broad cross-section of our community in one of Maui's greatest environmental challenges: sustainability of coral reef ecosystems.

According to the Hawaiian Creation Chant, the *Kumulipo*, the coral polyp was the first living thing to emerge from the sea during creation and is regarded as a foundational ancestor. The early Hawaiians recognized that coral reefs were an important part of the near-shore environment and used coral in religious ceremonies to honor and care for the ocean (Friedlander *et al*., 2005). Life as we know it in Hawaiʻi has been and remains tightly connected to healthy coral reefs. This Coral Reef Recovery Plan for Maui will help sustain and enrich that connection.

Coral polyps

Photo credit: Pauline Fiene

[This page intentionally left blank]

Executive Summary

In 2010, the Maui Nui Marine Resource Council was awarded a two-year grant (under the Coral Reef Conservation Fund program of the National Fish and Wildlife Foundation) to develop a Coral Reef Recovery Plan and coordinate its implementation. Later that year, the Council established the Maui Coral Reef Recovery Team (MCRT) composed of researchers, managers and stakeholders, to develop a science-based and results-driven plan for the recovery of Maui's coral reefs. The effort was spearheaded by concerned community members and was based on documented declines at important coral reef sites on Maui over the last twenty years that showed that collapse would continue if management efforts did not improve. These declines included decreases in both coral cover and reef fish populations, which negatively affects important sectors of the island community including the $800 million ocean tourism industry. The plan addresses the major causes of this decline (i.e., land-based sources of pollution, overfishing, deteriorating water quality, invasive algae, and climate change), and increases the adaptability of Maui's reefs to changing climates.

The principles supporting the recovery plan include:

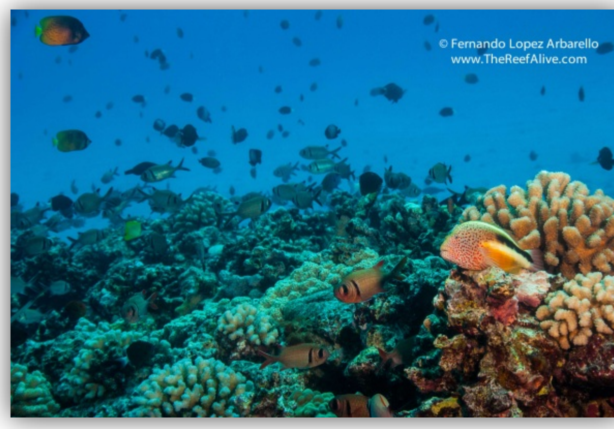
Community mapping project at Polanui CMMA
Photo Credit: Manuel Mejia

- Halting and then measurably reversing the declines in live coral reef cover at specified sites can be accomplished within seven to nine years;
- Improved prioritization and allocation of the necessary human and financial resources to protect Maui's coral reefs will occur;
- Increased public awareness and community involvement in reef management will manifest itself within local decision-making;
- Improved integration of science-based knowledge for coral reef management will reduce costs and improve outcomes;
- Improved intergovernmental coordination will support the plan; and
- Legislative and regulatory actions to address coral reef issues will result from the plan's improvements to knowledge sharing among researchers, managers and stakeholders.

The core values embraced by the MCRT are: optimism, pragmatism, credibility, accountability, respect and impact, with the understanding that to be successful, this Plan requires:

- Accountability and transparency;
- Scientific integrity and rigor;
- Respect for the host culture;
- Trust by the public; and
- Valuable community service.

Vision



Over the next fifteen to twenty years Maui's coral reef ecosystems are biologically intact, ecologically functional, and sustainably managed. They support an abundant diversity of native reef fishes and invertebrates. Maui's coral reefs are healthy, resilient and provide a wide range of ecological, economic, and cultural benefits and services to current and future generations of Maui residents and visitors. They are a beautiful and thriving example of successful coral reef restoration and management that is recognized around the world.

The plan proposes four goals and sixteen associated objectives to be achieved between 2015 and 2025:

Goal 1:Provide evidence of coral recovery at selected sites around Maui;

Goal 2:Use science to advance knowledge, improve understanding of the state of Maui's coral reef ecosystems, and document coral recovery;

Goal 3:Strengthen public awareness regarding the status of threats to and trends facing Maui's coral reefs; and

Goal 4:Strengthen the capacity for effective coral reef management on Maui.

Achievement of the goals will produce six major outcomes:

(1) Maui's coral reefs and reef fish populations are abundant, diverse and resilient;
(2) Coral reef ecosystems surrounding Maui are ecologically functional, dominated by native species and serve as a refuge for Hawaiʻi's unique biological diversity;
(3) The economic and other values of healthy and abundant coral reefs around Maui are widely recognized and used, fully and fairly, to guide public policy and decision- making;
(4) Cultural practices, traditional knowledge and traditional family activities in Maui's inshore waters thrive and are sustained through time;
(5) Maui's coral reefs support local jobs, a sustainable tourist industry, and other compatible uses; and
(6) There is a widely exercised and recognized ethic of coral reef conservation on Maui.

Healthy reef at Olowalu
Photo credit: Drew Sulock

Priority sites to implement restoration effort will be selected by an Advisory Council, based on scientific feasibility, social value, logistical feasibility, ecological representation, measurability, leverage, partnership suitability, financial feasibility, spatial discreteness, and vulnerability level. Examples of the potential priority sites include Kahekili, Olowalu and Māʻalaea to Kalama, among others. These sites have elements of baseline data, protection status, public interest, and economic value in tourism. Adjacent to each priority site, comparison sites will be selected where restoration techniques will not be applied. This will allow for comparisons in recovery levels between the two types of sites. At least three to five study sites must be assigned for each comparison area.

Specific actions of the Recovery Plan include direct restoration activities such as:

(1) Removal of high nutrient and sediment sources,
(2) Removal of invasive marine species,
(3) Restocking of native marine species, and
(4) Propagation and transplantation of corals;

Indirect restoration efforts such as:

(5) Use of "Best Management Practices" to control land-based pollution,
(6) Site-based coral reef management,
(7) Enforcement of current regulations,
(8) Community involvement, and
(9) Developing and recommending resource management policies;

Incorporation of cultural practices and traditional ecological knowledge by

(10) Promoting local marine resource management leaders,
(11) Encouraging the use of traditional resting periods, and
(12) Encouraging stewardship efforts that serve both culture and ecology; and

Engaging the public and partners by

(13) Identifying and engaging key stakeholders,
(14) Promoting public participation,
(15) Supporting community managed marine areas, and
(16) Developing partnerships and collaboration in restoration efforts.

Collaboration between government and non-government partners will be crucial to develop an activity work plan, and timeline to implement the recovery plan, as well as to guide, monitor and periodically evaluate the implementation through time. The plan will also serve as a model for other coral reef management and restoration interests in the Hawaiian Islands and beyond.




Photos credit: (left to right) Cynthia Matzke, Cynthia Matzke, Rick Long and Cynthia Matzke

[This page intentionally left blank]

I. Background

A. Value of Maui's Coral Reefs

Photo credit: Darla White

Coral reefs provide great biological, economic, and cultural value to the people of Maui. Hawai‘i's coral reefs include a large number of marine species found only in Hawai‘i (Friedlander *et al*., 2008), are renowned for their great natural beauty and inspiration, and have long been an integral part of Hawaiian culture and sense of place. Maui's reefs have provided subsistence, recreational, and commercial fishing opportunities, offer world-class surfing, snorkeling and SCUBA diving, protect our shores from storm waves and are vital to Hawai‘i's marine tourism industry.

The economic value of the State's coral reefs was estimated at US $10 billion with direct economic benefits of $364 million per year in 2002 (Cesar and van Beukering, 2004 in Friedlander *et al*., 2008). Outdoor activities of Hawaiian residents, as well as visitors, are closely linked to coral reefs (see Table 1). From 2005 to 2010, nearly 40-50% of all visitors participated in diving or snorkeling activities during their stay in Hawai‘i (Hawaii DBEDT, 2005 in: Friedlander *et al*., 2008; Hamnett, Liu, and Johnson, 2004; Hawaii Tourism Authority, 2010).

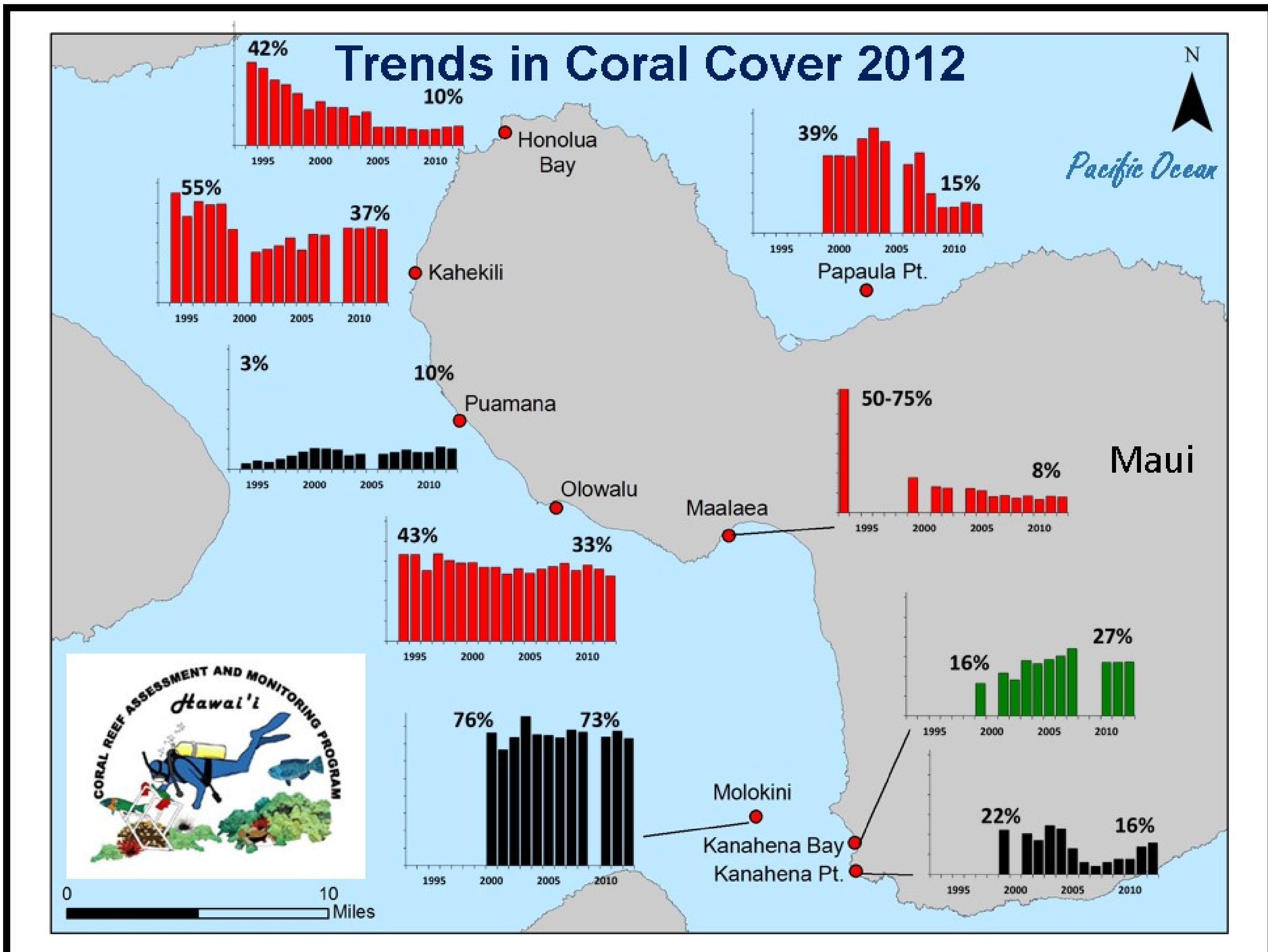
Table 1. Uses of the near shore environment by Hawai‘i residents (Hamnett *et al*., 2006 in: Friedlander *et al*., 2008).

Activity	*% of total households participating*	*Average number of times participating annually*
Ocean swimming	66%	28
Recreational fishing	31%	10
Surfing	29%	18
Snorkeling	32%	6
Subsistence fishing	10%	5

Photos credit: Darla White (left) and Linda Nakagawa (right)

B. Status of Maui's Coral Reef Ecosystems

Despite their value, significant declines in coral cover and reef fish abundance and biomass been documented on Maui over the last 20 years by the scientific community, particularly at eight well-documented study sites (DAR and HCRI, 2008). Some coral reef sites around Maui have experienced slower declines than others, while only a few show any evidence of possible increases in coral cover (DAR and HCRI, 2008). Coral and reef fish populations are declining less within Maui's Marine Life Conservation Districts (MLCDs) and other marine protected areas (MPAs) than in open areas (DAR and HCRI, 2008). However, the overall trend documented by the scientific community is a general decline in the health of Maui's coral and reef fish populations.



Status of Maui Reefs Graph – 2012
Each chart shows percent of healthy coral cover in each location over time
Credit: DAR and CRAMP, 2012

C. Threat Assessment and Trends

Like many of the main Hawaiian Islands, Maui's coral reefs face growing pressure from a wide range of threats (State of Hawaii, 2010). During late 2010, the MCRT worked with the Maui Nui Marine Resource Council to assess and rank known threats that negatively impact the health of Maui's coral reefs. The primary threats are: land-based pollution, overfishing, recreational overuse, invasive species, and climate change (see Appendix Two for further details regarding this analysis).

Land-based, anthropogenic sources of pollution include (1) sediment runoff from coastal development, road construction, agricultural lands, and watershed erosion; (2) excess nutrients from human waste (injection wells, cesspools, and leaking wastewater pipes); and (3) toxins and nutrients from chemical runoff (e.g., fertilizers and pesticides used in agricultural and landscaping practices).

Flood water from upcountry runs through North Kīhei to the reefs
Photos by: (From left to right) Ed Lyman, Hugh Starr, Mark Deakos.

Overfishing includes commercial fishing (for food and the aquarium trade), by recreational fishers (residents and visitors), and by local fishers (for subsistence or supplemental dietary protein needs).

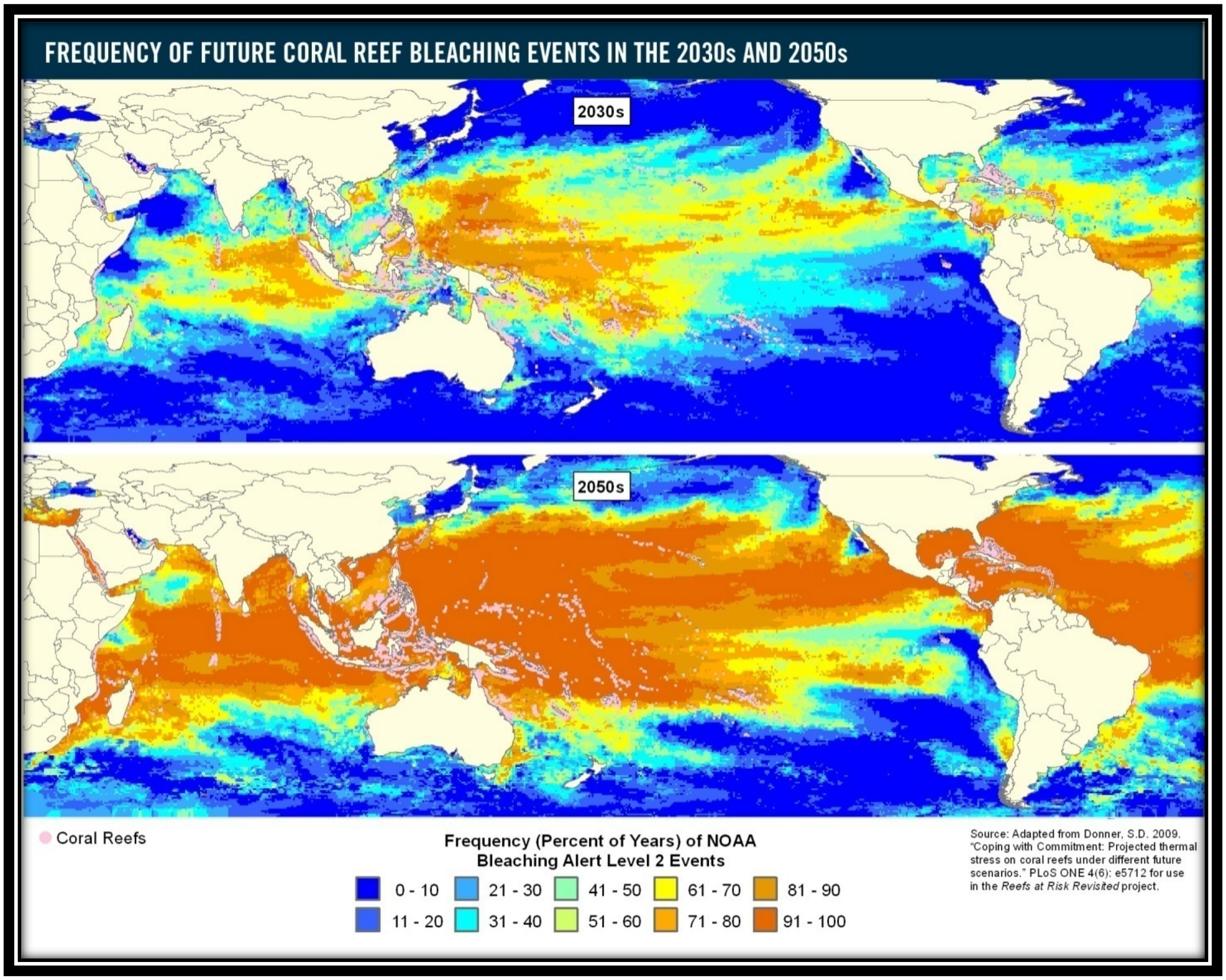
Recreation overuse not only includes recreational fishing, but also non-extractive impacts such as coral trampling by swimmers and snorkelers, anchor damage from recreational watercraft, and habitat disturbance by unknowledgeable or unconcerned visitor sites. Recreational overuse often can be clearly evident and reefs appear more disturbed than at non-recreation sites.

Trampling of reef (Left) and invasive algae smothering a reef

Photos Credit: Liz Foote (left) and Darla White (right)

Invasive marine species are an increasing problem on Maui's reefs, particularly alien algae that proliferates with increased nutrient availability. These species compete with corals for space and often overgrow coral reefs, especially when an abundance of nutrients are present. Overgrowth leads to an undesirable phase shift in the reef community structure to one dominated by microalgae, as pictured at right, bottom (Hughes, 1994).

While the impacts of climate change on Hawaiʻi's coral reefs have only recently being scientifically documented and are still being investigated, they will increasingly become an issue. Impacts include: a) warming of sea surface temperature which causes more frequent coral bleaching events, b) coral de-calcification and dissolution due to increasing ocean acidification, and c) increased storm and wave damage due to changing weather patterns and increased storminess.



Map Credit: World Resources Institute – Reefs at Risk Revisited Project

D. Situation Analysis

At the outset of the MCRT's efforts a study was conducted to assess prior coral reef management efforts for Maui Island. A literature review was conducted and consultations made with key informants. Summary profiles were prepared including a synopsis of supporting legislative mandates. A draft version of the report was peer reviewed for accuracy and completeness, including by MCRT members

This assessment (see Appendix Three) concluded that past coral reef management efforts to address threats facing Maui's reefs have fallen short (Povilitis, 2011). This is partly due to insufficient effort in light of the pervasive and widespread impacts of current threats. Another reason is lack of sufficient human, technical, and financial resources to adequately support the necessary management actions. This includes inadequate capacity and resources to fully implement and enforce existing regulations by local and State management authorities. A cumbersome legislative process and lack of political will to adopt recommended management policies or choose lower environmental impact development alternatives has also slowed progress. Finally, the majority of visitors, residents and public officials has been unaware of the declining health of Maui's coral reefs, and therefore has not changed their behavior or engaged in protection efforts to benefit Maui's reefs.

Fishing at the border of a marine protected area, Maui, Hawaiʻi

Photo Credit: Povilitis, 2011

Clearing waterfront land for Maluaka development, Makena, Maui

Photo Credit: Povilitis, 2011

Degradation of Maui's coral reef ecosystems, and decreased health of their component parts, will continue unless focused, collaborative action at an appropriate scale by scientists, managers, governing officials, and citizens is taken. The rationale for immediate action is clear.

Fortunately, two case examples in Hawaiʻi demonstrate how focused recovery efforts have improved coral reef health: Kahoʻolawe Island and Kāneʻohe Bay (see Appendix Four). The Kahoʻolawe example illustrates how measures which successfully control sedimentation and reduce land-based pollution to inshore waters allow recruitment of new coral colonies to occur. The Kāneʻohe Bay case history illustrates how coral reefs can recover quickly from major natural disturbances, but not necessarily under polluted conditions.

Some of the State's Marine Life Conservation Districts (MLCDs) illustrate benefits of protection from certain threats (e.g., overfishing) or reduction from other threats (e.g., recreation overuse and land-based pollution). Oʻahu's Hanauma Bay Nature Preserve is one example (Friedlander and Brown, 2004). Honolua Bay on Maui was another until runoff from development above the bay significantly impacted corals.

Hanauma Bay Nature Preserve, Oʻahu (left) and sediment in Honolua Bay, a Marine Life Conservation District, West Maui (right)

Photo Credits: University of Hawaiʻi (left) and John Carty (right).

II. Aims

This section outlines the aims of the Maui Coral Reef Recovery Plan, including underlying tenets and core values, a vision of success and the goals and objectives that are to be achieved.

A. Tenets and Core Values

1. Tenants

The Maui Coral Reef Recovery Team (MCRT) asserts that by acting boldly and strategically we can first halt and then measurably reverse the declines in coral reef health at specified sites within seven to nine years. This plan will promote coral reef recovery around Maui through effective partnerships and establish a process to advise county, state, and federal decision makers and the public on the status and trends in Maui's coral reef health.

This plan will allow Maui's coral reef ecosystems to

(a) Recover from current stressors, thereby restoring and strengthening the human-ecological connection that was once commonplace for Maui's residents;

(b) Leave behind a legacy of balance, improvement and resilience instead of decline, destruction and regret;

(c) Serve as a thriving natural "savings account" of abundant and healthy marine resources that can be sustainably used into perpetuity and successfully adapt to global climatic, environmental, and social changes.

2. Core Values

Five core values underlie this Maui Coral Reef Recovery Plan. These five values are the cornerstones upon which successful implementation of this plan will be achieved.

(a) Optimism –The necessary tools exist to assess, diagnose and restore our coral reefs. We recognize the challenges of global climate change and together we will prepare Maui's reefs to cope with and adapt to these stressors.

(b) Pragmatism – Our vision is realistic and obtainable and our foundation is strong. We can build from existing efforts and plans (Povilitis, 2011). The technical skill, practical knowledge and expertise already exist to do the work outlined. Sufficient scientific data and methods to characterize threats and measure changes in reef health over time are available.

(c) Credibility – We represent a broad range of scientists and other recognized experts. Our work and this plan are based on scientific integrity and rigor that the public can trust. Credibility, objectivity and the highest professional standards will be maintained. The plan will be open to public involvement and peer review in a fully transparent manner.

(d) Accountability – Regular reporting to the public and policy makers by resource managers will ensure that progress is made and appropriate management activities undertaken.

(e) Respect – We respect the beauty, complexity, and diversity of the natural world. We recognize the intrinsic value of coral reefs and fish populations to exist and thrive in balance with human interests and uses. We respect the people and local communities of Maui Island. We respect the ancient and honorable fishing traditions of Maui's people. We recognize that our families benefit from the food and income that Maui fishers provide. Our work is an attempt to honor the knowledge and traditions of the Native Hawaiian people and follow in their stewardship footsteps.

B. Vision

Our vision affirms in the present tense what Maui's coral reefs will look like fifteen to twenty years following the effective implementation of this restoration plan.

> *Maui's coral reef ecosystems are biologically intact, ecologically functional, and sustainably managed through a partnership arrangement of government, non-government, and community stakeholders. Thriving, dense coral habitat supports an abundant diversity of native marine life, in turn providing a wide range of ecological, economic, and cultural benefits and services to current and future generations of Maui residents and visitors. They are a beautiful and thriving example of successful coral reef management and restoration that is recognized around the world.*

The underlying biological, economic and socio-cultural elements associated with this vision statement are listed in Appendix One.

C. Goals and Objectives

This section presents the four goals and eighteen associated objectives of the Maui Coral Reef Recovery Plan.

Goal 1: Evidence of coral reef ecosystem recovery at selected sites around Maui

Recovery will be demonstrated and measured at selected "priority" sites. Technical and scientific resources will be focused at these sites. Observed changes will be carefully documented.

Progress toward this goal will expedite coral reef recovery elsewhere around Maui and throughout Maui Nui, with a concurrent expansion of technical capacity; human and financial resources (see Goal 4).

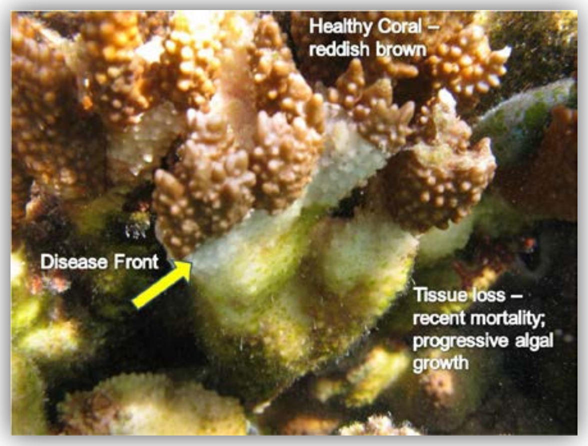
Goal 1 has five objectives:

Objective 1a: Increase the live coral reef and crustose coralline algal cover with essential fish habitat at two priority sites by 2020, and at five sites by 2025.

Objective 1b: Increase the relative abundance of two functional groups of culturally and ecologically important coral reef fish and/or invertebrates[1] and their average individual biomass at two sites by 2020 and at five sites by 2025.

Objective 1c: Decrease the observed algal (macro and turf algae) cover (including both invasive and native species) at two sites by 2020 and at five sites by 2025.

Objective 1d: By 2020, measure and document increased or sustained coral reef recruitment and survivorship rates, as well as decreased disease prevalence, at sites that were observed as experiencing declining health between 2000 and 2012.



Coral disease
Photo Credit: Darla White

Objective 1e: Incorporate Native Hawaiian traditional management practices into the restoration activities at two priority sites by 2015 and at five sites by 2020.

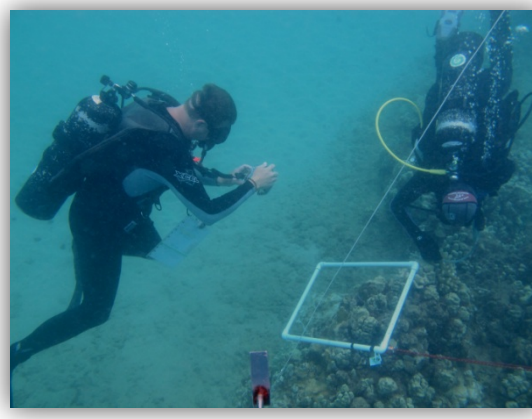
---

[1] Functional groups of "culturally and ecologically important" coral reef fish and/or invertebrates will be identified through a participatory process conducted by an appropriate group of stakeholders for each priority site. Some overlap may occur between sites in terms of which species are selected.

Goal 2: *Advance knowledge to improve our understanding of the state of Maui's coral reef ecosystems and document coral recovery*

The purpose of this goal is to provide the best available ecological science that is accurate, adequate and accessible to:

(a) Identify the key stressors influencing the health of Maui's coral reefs and related marine resources;
(b) Evaluate the effectiveness of implemented restoration strategies;
(c) Serve as an "early warning system" to guide threat prevention and mitigation decision-making and planning.



Reef Monitoring

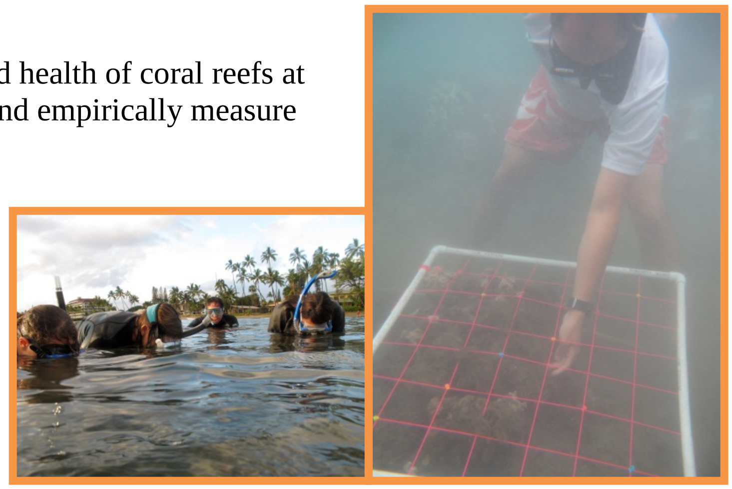
Photo credit: Darla White

Achieving this goal will improve our understanding of the causes of coral reef decline around Maui and provide the necessary scientific evidence to document reef recovery (DAR and HCRI, 2008).

Goal 2 has three objectives:

Objective 2a: Periodically monitor the status and health of coral reefs at paired priority and control sites, and empirically measure the rate of coral reef recovery.

Objective 2b: Summarize and communicate the findings via a technically comprehensive and rigorous "State of Maui's Reefs" assessment conducted every three years, and share findings with stakeholders and relevant government agencies.



Demonstrating underwater monitoring techniques to community members

Photo credit: The Nature Conservancy

Objective 2c: By 2016, refine our understanding of the causes of coral decline, including the relative contributions of known threats and synergistic interactions and share findings with stakeholders, the scientific community and relevant agencies.

Goal 3: *Strengthen public awareness regarding the status, threats, and trends facing Maui's coral reefs*

The purpose of this goal is to build awareness and understanding of Maui residents and visitors about threats to Maui's coral reefs and what they can do to help. Increased awareness can be an important, although admittedly not always successful, first step toward desired behavior change, such as personal action or consumer preference. Increased awareness can be a critical precursor to affecting social change, including increased acceptance and support of management actions and restrictions, inter-generational "peer pressure", and conflict reduction or resolution. This goal focuses on education and outreach efforts.

Achievement of this goal will increase sustainable resource use and encourage compliance with management rules and resource regulations. It will also help strengthen cultural identity and connection to Maui's reefs and enhance understanding of the responsibility for maintaining them. Key elements include documenting historical changes and declines while demonstrating cause and effect for positive changes (for example, increased fish abundance and biomass).

Goal 3 has four objectives:

Objective 3a: By 2016 ensure that the recovery plan has been reviewed, endorsed and adopted by Maui decision makers and residents[2].

Objective 3b: By 2016, increase the awareness of Maui's residents regarding the status, threats, and trends facing Maui's coral reefs, as well as the relationship between the health of Maui's coral reefs and their own economic and cultural well-being.

Community Outreach
Photo credit: Lisa K. Agdeppa

Objective 3c: By 2016, active community involvement and consistent local participation in coral reef management efforts is underway at three sites, including proper stewardship practices by residents and visitors.

Objective 3d: By 2016, share recommended methods and processes for active remediation and scientific research with priority target audiences through the focused delivery of communication products, using appropriate messages and media.

Goal 4: Strengthen the capacity for effective coral reef management on Maui

The purpose of this goal is to support and expand the technical capacity, human and financial resources necessary for effective coral reef and water quality management around the entire island of Maui. This will involve improving capacity at community, county, state and federal levels to better address the full range of threats to coral reefs, both from the watershed and in the water.

Improved capacity must include on-site management, signage, enforcement and surveillance of resource rules and regulations and governance and policy making, as well as integration of native Hawaiian traditional marine resource management practices (Jokiel *et al.*, 2011).

[2] This may include members of the ʻAha Kiole Advisory Committee.

Goal 4 has six objectives:

Objective 4a: By the end of 2014 and periodically thereafter, convene a Maui Coral Reef Recovery Team that works to:

- Ensure that recovery goals, objectives and activities are achieved in a timely manner;
- Enhance consistent and transparent collaboration between community groups, non-governmental organizations and government agencies;
- Provide input to government decision-makers on how to incorporate coral reef protection into their actions and decisions; and
- Guide spending for recovery plan implementation.

Objective 4b: By June 2017, work with Maui County and local partners and elected official to have a clear set of coral reef policies to improve and build upon existing federal, state, and local ordinances, regulations, and policies.

Polanui Hiu CMMA in Lāhainā
Photo Credit: Manuel Mejia

Objective 4c: By mid-2017, support and expand community involvement and participation through a Community-Managed Makai Area (CMMA) process at five successful sites including corresponding watershed planning processes.

Objective 4d: By 2016, thorough incorporation of the recovery plan into local government policy and practice, improve the awareness and technical ability of County decision makers to address the primary threats facing Maui's reefs and include adequate protection in County plans, decisions and actions by using recommended coral reef and watershed management tools.

Objective 4e: By 2020 secure grant funding and initiate a private sector partnership led by the tourism sector (as the primary economic driver on Maui) to support the recovery plan and generate funding (via a small fee) and in-kind support for coral reef and watershed restoration and management activities around Maui to a level equivalent to 5% of total gross revenues of all ocean-related activities managed by Maui-based private businesses.

Objective 4f: By 2018, through a partnership-driven process, add two full-time enforcement, management and scientific staff within relevant County and State agencies to focus on water quality protection and watershed and coral reef management around Maui, growing to five staff by 2020.

D. Intended Outcomes

An adaptive management approach will be taken to systematically learn and objectively assess progress toward our objectives and to adapt as necessary. Modification of the stated goals and objectives may be result.

Achieving our goals and objectives is expected to result in 6 major outcomes:

a) Maui's coral reefs and reef fish populations are abundant, diverse and resilient;
b) Coral reef ecosystems surrounding Maui are ecologically functional, dominated by native species and preserve Hawaiʻi's unique biological diversity;
c) The economic and other values of healthy and abundant coral reefs around Maui are widely recognized and used to guide public policy and decision-making;
d) Cultural practices, traditional knowledge and traditional family activities in Maui's inshore waters thrive and are sustained through time;
e) Maui's coral reefs support local jobs, a stable economy and sustainable uses;
f) A widely exercised and recognized ethic of coral reef conservation becomes widespread on Maui.

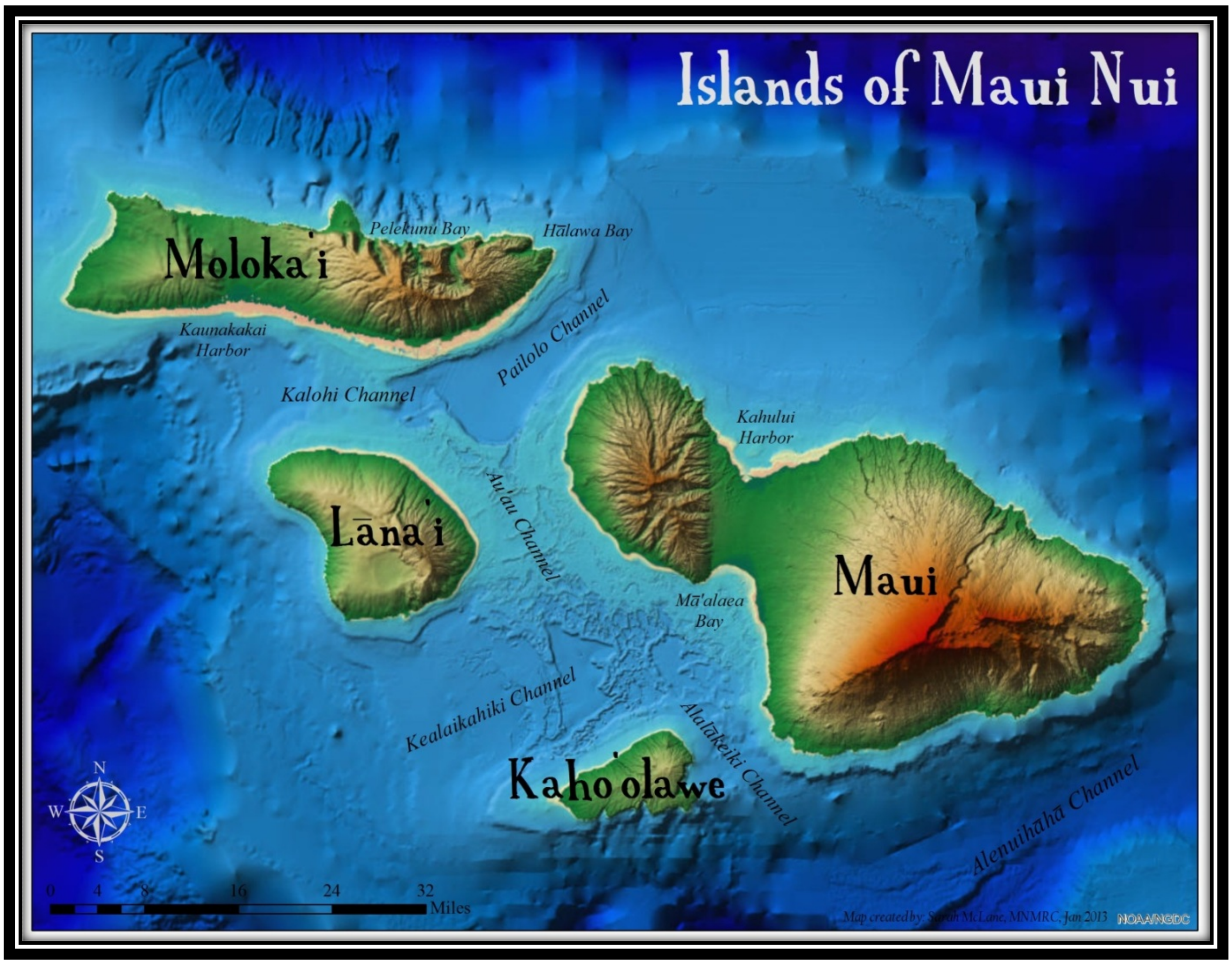
Māʻalaea to Kīhei Coast
Photo Credit: Ron Dahlquist

[This page intentionally left blank]

III. Geographic Scope

Accurately defining the geographic scope of site-based reef recovery efforts requires clearly understood, accepted and peer-reviewed terms and definitions. For the purposes of this plan, definitions for biodiversity, coral, coral reef, coral reef component, coral reef ecosystem, research and restoration will be adopted from the United States Coral Reef Conservation Act (as proposed under Reauthorization language introduced by the United States Congress (2011)). Definitions are found in this plan's glossary.

The geographic scope of this Coral Reef Recovery Plan is the island of Maui located within the Maui Nui complex of the Hawaiian Archipelago. Maui Nui includes the islands of Maui, Lānaʻi, Molokaʻi, and Kahoʻolawe. Initial recovery efforts will focus on sites selected as priority recovery sites in order to showcase recovery efforts.



Islands of Maui Nui
Map created by: Sarah McLane, MNMRC

A. The Island of Maui

This coral reef recovery plan is focused on restoration efforts to be carried out around the island of Maui, home to some of Hawaiʻi's most heavily impacted coral reefs. Such impact is partly due in to a high rate of land development, shoreline change and engineering, coastal residential housing construction and commercial development. Maui's rapidly growing resident population and increasing number of visitors have had significant negative impacts on Maui's coral reefs over the past three decades. Scientific monitoring results clearly illustrate that Maui has the majority of the most degraded and unhealthy coral reefs in Maui Nui.

Coastal Stabilization in Kāʻanapali to protect hotel fronts after repeated coastal erosion

Photo credit: Zoe Norcross-Nuʻu

Successful coral reef recovery around Maui should encourage similar efforts not only in Maui Nui, but also throughout the main Hawaiian Islands and perhaps, beyond. The coral reef restoration techniques and marine stewardship efforts outlined under this recovery plan will provide many process lessons and management recommendations that can be applied elsewhere.

B. Priority Recovery Sites

The Maui Coral Reef Recovery Plan requires the active implementation, demonstration, and evaluation of restoration strategies focused around specific "priority recovery sites." These sites will provide evidence of successful coral recovery techniques and will serve as a foundation for expanded efforts throughout the Maui Nui island complex, and beyond.

The recovery sites are a critical step to the overall viability of the recovery plan, as successful recovery at these sites will demonstrate the cause-and-effect relationship of applied restoration strategies compared to similar sites with no restoration efforts. Pairing managed sites with unmanaged sites will provide evidence that intervention leads to recovery. MCRP resources will be allocated where appropriate to these initial priority sites.

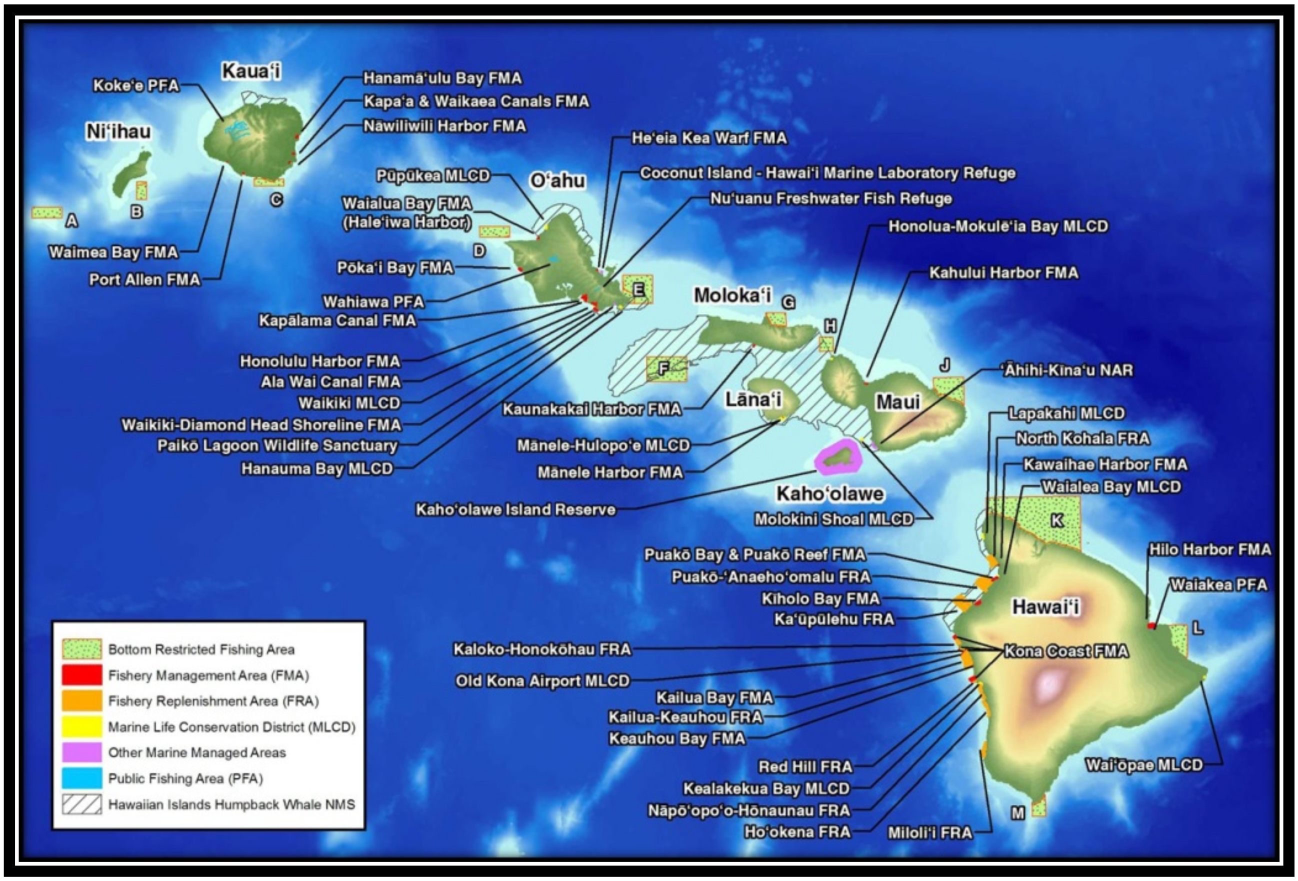
The MCRT recommends that restoration efforts also move forward elsewhere on Maui through the application of island-wide policies and regulations.

Selection criteria for priority recovery sites include:

- *Scientific Feasibility* – the site is scientifically viewed as having the potential for biological recovery (including water quality considerations);
- *Socially Acceptable* –the local community supports recovery efforts and shows interest and readiness to participate in reef restoration efforts;

- *Logistical Feasibility* – the site is logistically easily accessible;
- *Technical Feasibility* – it is technically possible for reef restoration strategies to be implemented at the site (for example State law allows coral propagation or transplantation);
- *Ecologically Representative* – the site is inclusive of a wide range of representative habitats, known threats (including sources of common land-based pollution), and management opportunities;
- *Measurability* – the site has an existing, base-line data set associated with previous and current conditions and trends;
- *Leverage* – recovery efforts will build upon existing site-based coral reef conservation or other marine resource management efforts;
- *Partnership Suitability* – the site lends itself to strategic and useful partner organizations which would cooperate with and support reef restoration efforts;
- *Financial Feasibility* – the site ideally already has, or is likely to secure, financial resources to support reef restoration efforts;
- *Spatially Discrete* – the site offers clear boundaries; and
- *Vulnerability* – the site is at risk of degradation in the near future - including from global climate change.

In addition to these selection criteria, the MCRT recognizes that for comparative purposes, it will be important to select sites both within areas that are currently benefiting from active marine management efforts (such as Marine Life Conservation Districts, Fishery Management Areas, Community Managed Marine Areas, or other State-led marine managed areas), and sites that have no current management efforts.

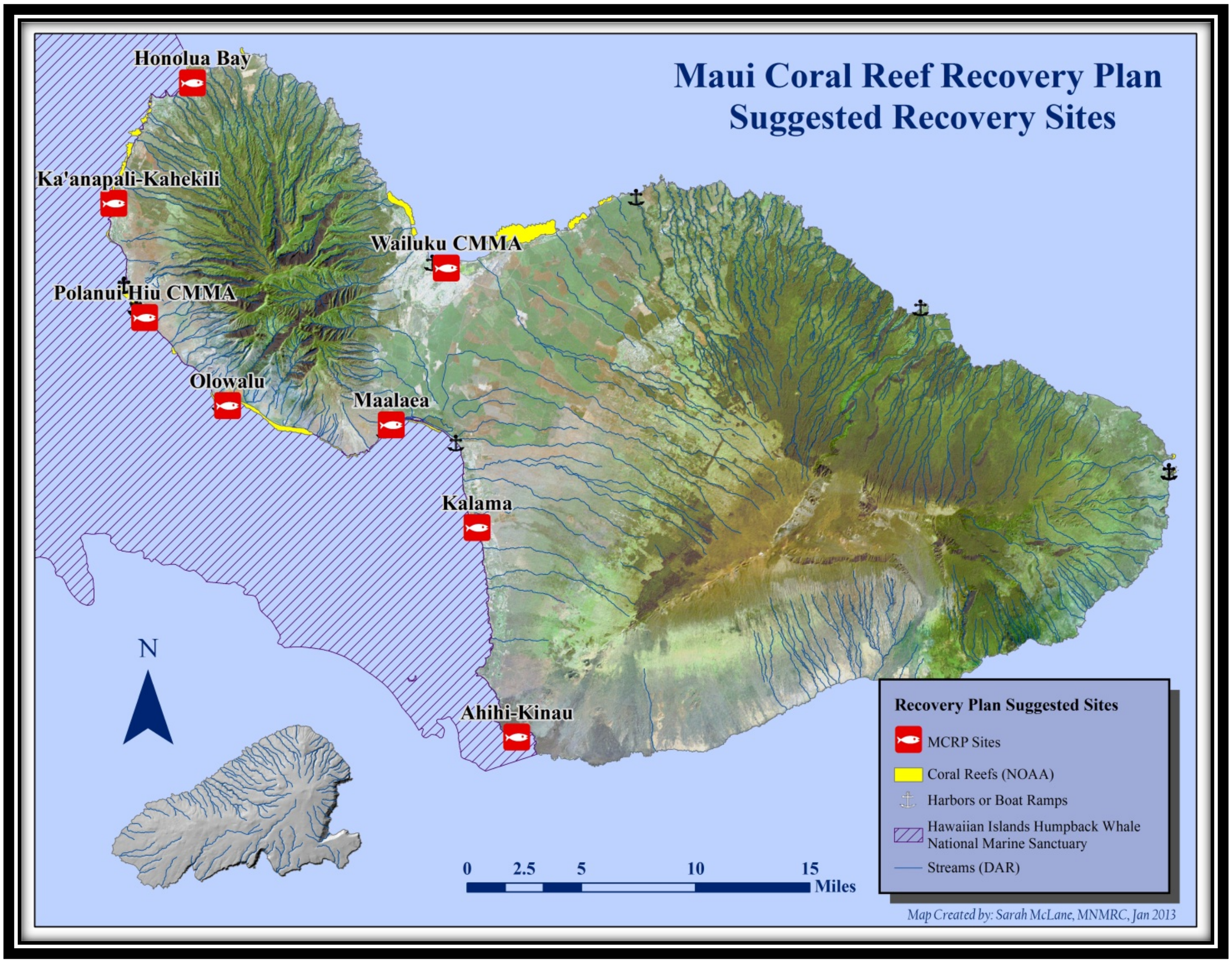


Marine Protected Areas in Hawaiʻi.
Even though more than 60% of the coral reefs found in U.S. waters are in Hawaiʻi,
less than 4 percent of the State's near shore waters (less than 60 feet deep) have some level of protection.
Photo credit: DLNR

The MCRT (with input from the State of Hawaiʻi Department of Land and Natural Resources) recommends that the sites listed within the below table be prioritized for site-based reef recovery support under this plan:

Priority Level	Reef Recovery Site Name	Comments
Immediate Priority	Polanui Hiu	• Community Managed Makai Area (CMMA) with strong local management support system in place; • CMMAs have partnership and CMMA Network interest and support; • Opportunity to build on existing community outreach and engagement efforts, while strengthening traditional use and subsistence harvest sustainability; • CMMAs have high public interest and use with local oversight and enforcement from engaged community members; • CMMAs afford an opportunity to build public support for priority reef restoration efforts.
Immediate Priority	Olowalu	• Rare, unique and old corals; reef in relatively good condition; source of larvae that help to replenish and populate West Maui, Molokaʻi, and Lānaʻi reefs; • Important site for mantas, black-tip sharks; could be starting point for wider restoration efforts; • Threatened by proposed urbanization; • Opportunity to strengthen reef conservation, work with proposed adjacent development efforts and encourage remediation measures; • Designated a priority reef site under the State of Hawaiʻi Coral Reef Strategy; • Marine area of high public and visitor use; affords outreach opportunity with residents, visitors, fishers and water sport business support; • Important cultural site with traditional and historic significance; opportunity to strengthen traditional use.
Immediate Priority	Kahekili	• Fishery Management Area designated by the State of Hawaiʻi, viewed as strong potential for success; • Designated priority coral reef and watershed area by federal and state authorities as potential implementation partners; • Existing management efforts and community outreach led by partners; • Opportunity to strengthen traditional use and subsistence harvest sustainability.

	ʻĀhihi-Kīnaʻu	• Natural Area Reserve designated by the State of Hawaiʻi, viewed as strong potential for success; • Could build on significant management efforts; community outreach underway, led by partners; • Upland management efforts currently underway (e.g. ungulate fencing and erosion control); • La Perouse Bay current reef monitoring study site by State and University, showing reef in decent condition; • Opportunity to strengthen reef conservation, work with proposed adjacent development efforts and encourage remediation measures.
	Māʻalaea-Kalama	• Limited areas of coral reef still in decent condition; could be starting point for wider restoration efforts within the area; • High public interest and use; outreach opportunity with public and business support; • High economic dependence of residents on healthy marine waters due to tourism industry and water sport operators; • Could serve as an important 'hope site'; high demonstration value; • There is concern about lumping these sites together because the reef communities are quite different and have different levels of stressors; • There is also concern due to the extreme degradation of Māʻalaea.
	Honolua Bay	• Within Honolua - Mokuleʻia Marine Life Conservation District, with potential for success; • Could build on marine and watershed management efforts led by a number of community, government, and non-government partners; • Upland watershed management efforts underway with partner agencies/organizations; • Opportunity to promote traditional management and sustainable use.



Map of Potential Recovery Plan sites on Maui Island
Map created by: Sarah McLane, MNMRC, January 2013.

MCRT recommends that 2 to 3 reef recovery sites be considered for implementation support during the start-up phase of this plan (2014-2016). Ideally, at least one recovery site would have active marine management efforts underway to build off of, while another would be without active efforts underway.

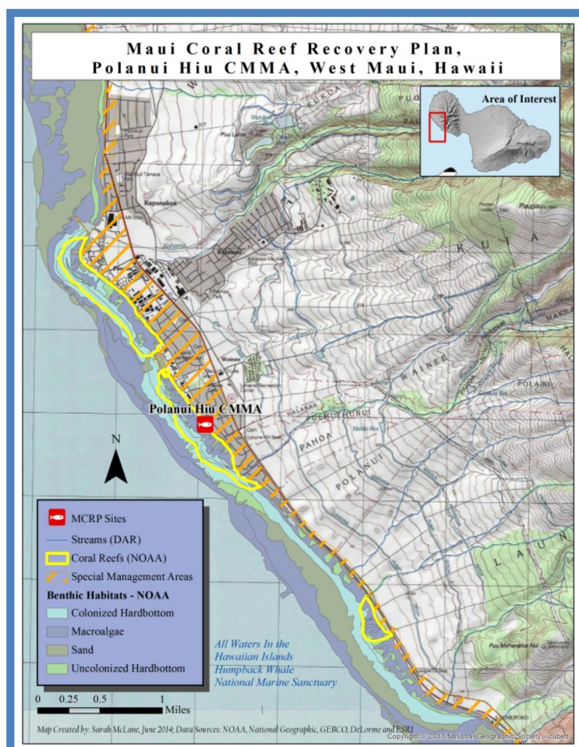
In addition to monitoring the effects of MCRP implementation within each reef recovery site selected, the MCRT recommends identifying areas adjacent to recovery sites to also periodically monitor for comparative purposes between sites where reef restoration techniques are being applied versus adjacent sites where they are not. At least 3 to 5 comparative study areas should be assigned to each designated recovery site.

The following sections are summary site descriptions for those proposed reef recovery sites that have been recommended as "immediate priority" sites by the MCRT (as of 2013-2014).

1. Polanui Hiu Reef Recovery Priority Site

Polanui is the Native Hawaiian name of an ahupuaʻa (traditional land/sea division) located in Lāhainā, West Maui. The half-mile of Polanui coastline stretches from Lāhainā town in the north to Makila point in the south, encompassing over 220 acres of intertidal sandy beach and rocky zone habitat. The Polanui reef area encompasses the waters off these beaches westward to a depth of approximately 100 feet (30 meters), including fringing and patch reefs. At present, a number of threats are negatively impacting Polanui reef and its surrounding nearshore waters, including: (a) multiple recreational uses by both tourists and residents; (b) increasing sedimentation and non-point source pollution from development and urbanization; (c) reduction of natural fresh water inputs and flow; (d) disruption of natural accretion and erosion cycles; and (e) periodic discharge of chlorinated water onto Polanui reef by neighborhood swimming pools. Despite this, Polanui reef remains a dynamic ecosystem, with resident reef sharks, Hawaiian monk seals, and green sea turtles. Historically, the Polanui area was well known for its rich abundance of marine resources, with the reef system traditionally named *Na Papalimu O Piʻilani*. For both Native Hawaiian families with deep, ancestral ties to the Polanui area and neighboring families who settled the area during the past 100 years, Polanui continues to be considered one of the most culturally sacred and traditionally important reef systems in West Maui.

The Polanui Hiu is a community action group that is comprised of resident families, concerned citizens, and partner organizations who are actively working to reverse observed declines in marine resource populations. In 2005, community leader and Kupuna (revered elder) Ed Lindsey conceived of the Polanui Hiu as an approach for locally establishing and overseeing a Community Managed Makai Area (CMMA). Launched in 2010, the Polanui Hiu CMMA integrates modern marine resource management strategies within an existing framework of customary Native Hawaiian management practices and traditional knowledge. Under the guidance of the Lindsey ʻOhana (the customary managers of Polanui), a number of external partners engage with and support the Polanui Hiu, including non-government organizations (including the Nature Conservancy of Hawaiʻi and the Maui Nui Marine Resource Council), local marine tourism operators (including Atlantis Submarine), and a number of marine scientists and resource management professionals from Hawaiʻi and other Pacific Islands.



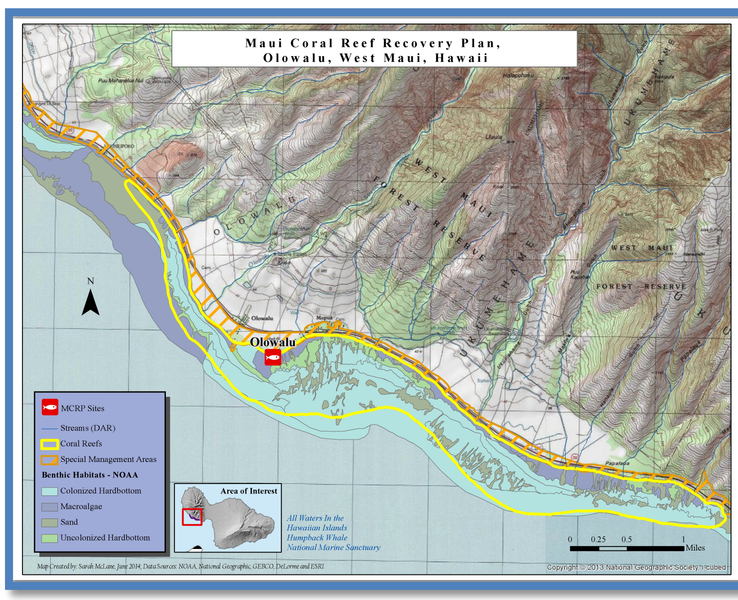
Map of Polanui Hiu Recovery Site in West Maui

Map created by: Sarah McLane, June 2014

The vision for the Polanui Hiu CMMA is to restore the health of Polanui to where it once again is thriving with an abundance of native fishes and limu (native seaweed species). To achieve this vision, the Polanui Hiu works with government and non-government partners to implement their community-based conservation action plan, aimed at educating and creating awareness with local residents and users, promoting and re-establishing *pono* (culturally appropriate and biologically sustainable) fishing and recreation use practices, improving enforcement effectiveness of both existing marine resource regulations and traditional rules, and empowering local families and residents to honor the traditions and strengthen stewardship of Polanui reef for the benefit of future generations.

2. Olowalu Reef Recovery Priority Site

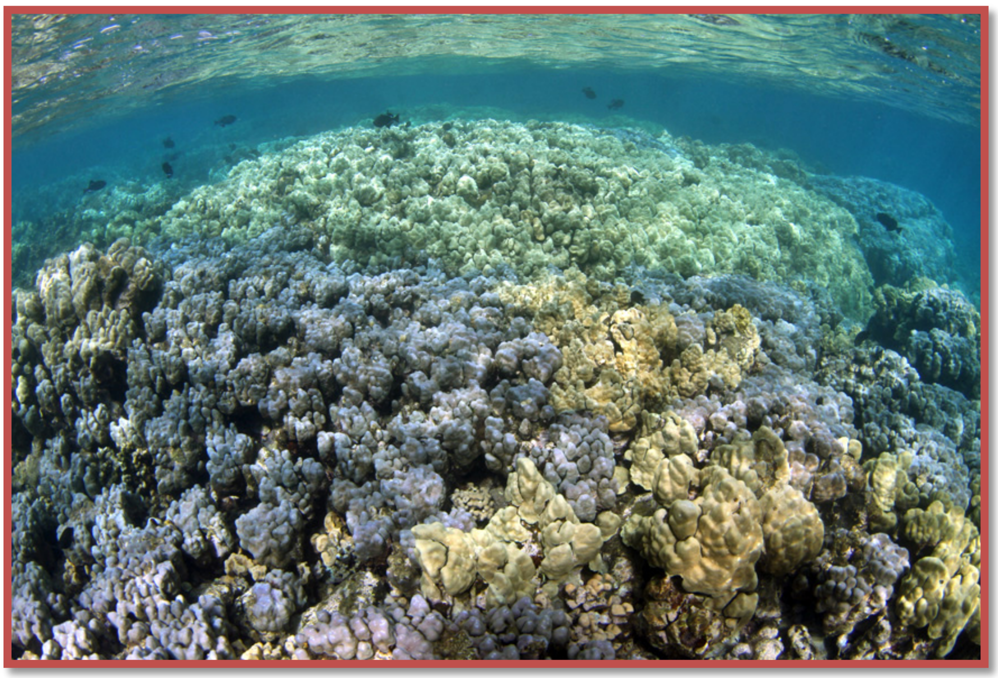
Olowalu is located in the calm, protected waters southeast of Lāhainā and Polanui, along the West Maui coastline. The Olowalu reef area is encompasses nearly 1000 acres of coral reef habitat, half of which is home to some of the healthiest and oldest coral colonies on the island of Maui. Recent studies by Storlazzi and Field (2008) demonstrate that coral larvae released from Olowalu reef during broadcast spawning events likely drift with prevailing currents toward the coral reefs of West Maui, South Molokaʻi, and North Lānaʻi in the prevailing currents. In essence, this suggests that Olowalu reef may serve as an important source of coral recruits for these neighboring reef systems. Federal scientists have documented coral colonies at Olowalu reef as being among the oldest living corals measured within the main Hawaiian Islands (Curt Storlazzi, pers. comm.). A number of other unique features characterize Olowalu reef, including high coral species diversity (including some of the rarest ones), critical nursery habitat for black tip reef sharks, an elaborate spur-and-groove reef system with micro-atoll features, and a globally-rare aggregation of over an estimated 350 manta rays which may frequent the area for critical courtship and reproductive purposes.



Map of Olowalu Reef Recovery Site in West Maui
Map created by Sarah McLane, June 2014

Today, Olowalu increasingly is being threatened with many of the trends that are believed to be responsible for observed declines on other reef systems around Maui. The two primary threats facing Olowalu are the hardening of the shoreline to protect the coastal highway from sea level rise, and sedimentation and pollution from the proposed residential development of 1,500 homes immediately upland of the reef. Sedimentation has occurred in the area for decades due to upland agricultural practices. In addition, the natural beauty and sheltered waters of Olowalu reef make it a highly desirable tourist destination with both commercial dive tours and snorkeling operations. Recreation and commercial fishers also frequent the area. It is hoped that relatively healthy reefs such as Olowalu will be ecologically resilient through time, and therefore have a greater chance of adapting to and overcoming the increased stressors associated with climate change; for example: sea level rise, sea surface temperature rise, increased acidity of ocean water, and increased frequency and severity of storms. Olowalu reef has a deeper, secondary reef further offshore located at about 60 feet depth, which may be more protected against such increasing threats. Such offshore reefs may experience reduced impacts from fishing than shallow ones, since they are deeper and less easily accessed.

Olowalu reef is also home to a rich cultural history, being an important contributor of traditional Native Hawaiian knowledge and practice from West Maui regarding the island's marine resources. Building upon these existing traditions and practices, designation as a reef recovery site under this plan would present a proactive opportunity to guide and support future coral reef management efforts in and around Olowalu reef.



Olowalu Reef, Maui
Photo credit: Pauline Fiene

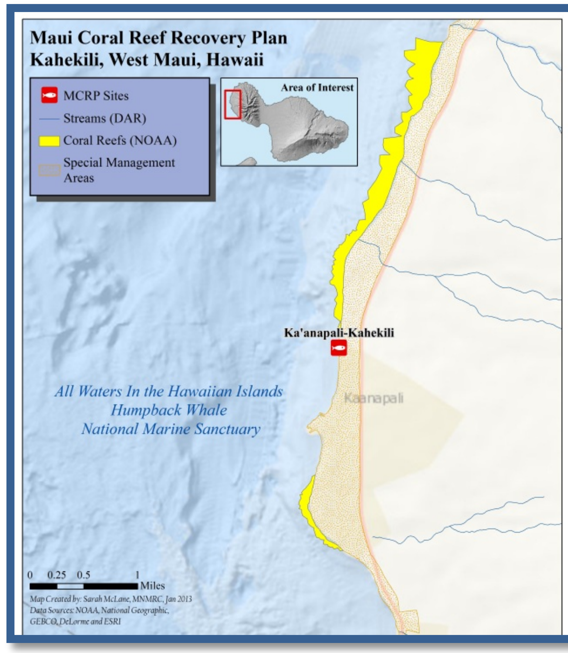
3. Kahekili Reef Recovery Priority Site

The Kahekili Fishery Management Area (FMA) is located along the West Maui coastline (see map), and has been proposed as a reef recovery priority site by the MCRT based on input from the State of Hawaiʻi and local community members.

Expert coral reef scientists and knowledgeable members from Hawaiʻi and other U.S. coral reef jurisdictions of the U.S. Coral Reef Task Force (USCRTF), identified Kahekili as a high priority sit as it meets many of the site selection criteria. West Maui and Kahekili are officially designated management priorities under the State of Hawaiʻi (2010) Coral Reef Strategy (the "Kāʻanapali-Kahekili priority near-shore coral reef site"), and also priority watershed areas (the

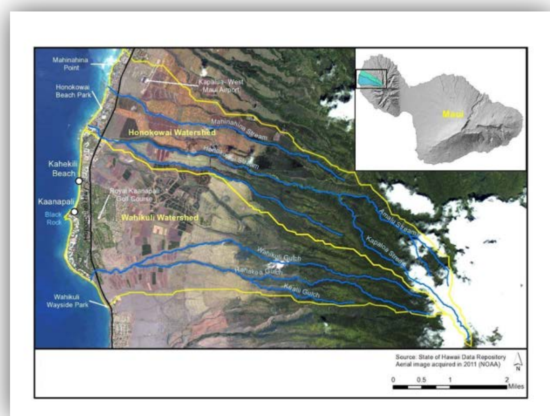
West Maui Watershed) within the U.S. Pacific Islands region, by the U.S. Coral Reef Task Force.

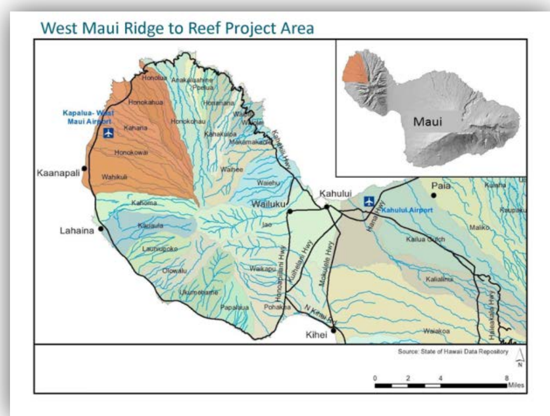
Nuisance algae blooms at Kahekili in 1989, 1991 and 1992 initially raised concerns among community members and prompted a search for influencing factors (Soicher and Peterson, 1997). Since then, community support has grown for research activities (Smith, J., J. Runcie and C. Smith, 2005) and management actions (West Maui Watershed Management Advisory Committee, 1997) to understand and reduce the potential threats to the fringing reef tract fronting Kahekili Park.



Map of Kahekili Recovery Site in West Maui
Map created by: Sarah McLane, January 2013

Monitoring programs at this site documented declines in coral cover in the late 1990s with improvements in coral cover since 2006 (DAR and HCRI, 2008). Consequently this site has potential for coral recovery. Fish assemblages, especially herbivore stocks, appear to be depleted (DAR and HCRI, 2008). This prompted the Hawaiʻi Division of Aquatic Resources to establish the Kahekili herbivore protected area. With growing community support, existing baseline information, management actions currently underway, and a full range of anthropogenic impacts, this site is well suited as a coral reef recovery priority site.





Maps of West Maui Ridge to Reef Initiative Project Area and of the two priority watersheds – Honokōwai and Wahikuli
Maps provided by West Maui Ridge to Reef Initiative

[This page intentionally left blank]

IV. Strategies and Practices

Strategies are the basic approaches to accomplishing the objectives. For a strategy to be appropriate, it must:

1. Directly address objectives;
2. Identify and focus on specific practices;
3. Match available human and financial resources;
4. Respond to site-specific biophysical conditions; and
5. Be acceptable to residents and decision-makers, given local cultural and social norms.

Practices are the specific policies and actions that enact the strategies. For a practice to be desirable, it must:

1. Reflect accepted standards;
2. Offer the highest probability of accomplishing a given task, based on past experience;
3. Be practical, with reasonable training and orientation; and
4. Be foundational, in that it is an activity upon which other activities follow.

The plan adopts four strategies. The first two are direct and indirect restoration. A third strategy, to support cultural and traditional management, will ensure the appropriateness of the first two. A fourth strategy, to engage the public and build partnerships, will broaden support and expand implementation resources. Each strategy is outlined below, along with its associated practices. The recommended level of priority for each practice is listed in Table 2. Priorities were based on cost, technical requirements, logistics and legal provision.

Table 2. Strategies, Practices and Priorities

Strategy: Associated Practice		*Priority*
Direct Restoration		
	Reduce nutrient, pathogen and sediment inputs	High
	Remove invasive marine algae	High
	Restock native marine species	Medium
	Propagate and transplant corals	Low
Indirect Restoration		
	Increase site-based management efforts and presence	High
	Encourage compliance with rules and regulations	Medium
	Increase community involvement	High
	Recommend resource management policies	Medium
Cultural and Traditional Management		
	Promote local marine resource management leaders	High
	Encourage the use of traditional resting periods	Medium
	Encourage stewardship efforts that serve both culture and ecology	High
Public and Partner Engagement		
	Identify and engage key stakeholders	High
	Promote public participation	High
	Support community-managed marine areas	High
	Develop partnerships and collaboration	High

Specific activities and methods will be developed and reviewed by an Advisory Council, with direction and oversight from the MCRT and the MNMRC.

The following descriptions are summaries. The specifics of the methods and processes to be used, under each practice, are to be developed, peer-reviewed and approved following adoption of this recovery plan.

A. Direct Restoration

1. Reduce Nutrient, Pathogen and Sediment Inputs

Nutrients are essential to the health of near-shore waters. Eutrophic coral reef ecosystems feature an unnatural overabundance of nutrients and are detrimental to reef health. Eutrophication can occur as a result of land-based pollution, including: (a) fertilizers from agricultural runoff and livestock waste; (b) urban runoff, including from impervious surface and storm drains; (c) suburban runoff, including from landscaping, golf courses and pet and animal waste; (d) wastewater from injection wells, leach fields and cesspools; and (e) eroded soil, carried by rainwater runoff into coastal waters.

Aerial Images of Honolua Bay (Left) and Kāʻanapali Beach, Maui

Photos Credit: Coastal Geology Group – University of Hawaiʻi - SOEST

Eroded soil can remain suspended within the water column, reducing sunlight needed by the corals' zooxanthellae for photosynthesis. When the sediment settles out of the water column onto the coral in sufficiently high volumes, it can cover and smother the coral polyps. Low sunlight and sedimentation allows both native and invasive algae to grow, out-compete and replace live coral and coralline algae as the dominant habitat type (Littler and Littler, 1984; Steneck, 1997). Global climate change may accelerate and magnify the negative impacts of land-based pollution (for example, through increased storminess leading to more frequent sediment 'pulse' events).

Herbivorous animals such as fish and urchins help limit algal growth and keep it from overtaking live coral cover. Reducing herbivore populations through overfishing or encourages algae growth on an unhealthy reef (for example, urchin die-off due to disease, overfishing for food, or the poaching of sea turtles).

> "The long-term consequences of the resultant phase shifts from coral to algal dominance include loss of productivity and biodiversity, a decrease in the intrinsic value of the reef, changes in the community structure of reef fishes dependent upon corals and algae and ultimate erosion of the physical structure of the reef." (Hughes, 1994).

Sediment exposed in watershed areas, such as from illegal dirt biking (top), after fires (middle), or from agriculture or development leaves large, open areas of soil to be washed into near shore reefs during storms

Photos Credit: West Maui Mountains Watershed Partnership, Wahikuli-Honokōwai Watershed Management Plan and Save Honolua Coalition

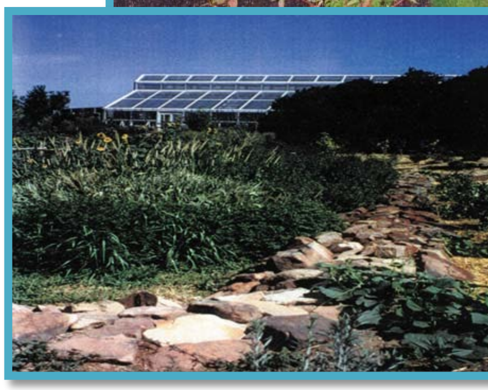
Reducing nutrient and sediment inputs to coastal waters near coral reefs is an important practice. Clean water is essential to support coral recruitment and growth of corals.

Nutrient and sediment sources are generally well understood for Maui's watersheds. More work is needed to identify loads from specific land uses and disturbances within individual watersheds. We also need to improve our ability to determine the cause(s) of coral decline and to identify pollutants of concern. Because land-based pollutant controls can be costly, these two pieces of information help to focus management efforts to benefit corals. Watershed plans developed for West and South Maui identify and prioritize pollutant sources and offer effective practices for restoring coastal water quality.

Active methods to remove or reduce nutrient and sediment loads will be employed under this strategy. Careful consideration must be given to where and how to take action, given the different impacts of persistent versus pulse (infrequent but high impact) rain events and surface versus groundwater loading and retention.

The following list identifies specific management actions that the MCRT suggests could be used, through this recovery plan, to reduce nutrient and sediment inputs and help restore water quality, as an essential condition for coral reef recovery:

- Develop ahupua`a (watershed-based) plans and priorities initially for MCRT priority sites and eventually all Maui watersheds. Institute planning committees within each targeted watershed to inform decision-makers of actions to protect watersheds and coral reefs.
- Reduce nutrient and pollutant loads from wastewater injection wells. This can be achieved via increased reuse, wastewater nutrient removal, constructed wetlands, deep well injection, deep ocean outfall, decentralized treatment, etc.
- Reduce nutrient loads from onsite cesspools and septic systems by upgrading or connecting to sewer lines. Focus on systems close to the shoreline, near streams and in low-lying areas, where the groundwater table is high.
- Improve storm water management with expanded use and design of construction and post-construction best management practices (BMPs), retrofit problematic storm water systems, improve drainage and storm water requirements and grading ordinance, improve compliance and enforcement, limit impervious surfaces, etc.



BMPs such as Rain gardens (top) or Constructed Wetlands (bottom) can help to accumulate and settle sediment before it reaches storm drains

Photos Credit: CWRM, 2008 – Handbook for Stormwater Reclamation and Reuse – Best Management Practices in Hawaii

- Reduce erosion and sedimentation by removing feral ungulates from watersheds and implement improved agricultural erosion BMPs. Stabilize abandoned plantation and farmland by planting drought-tolerant groundcover, native trees and shrubs and installing BMPs to reduce erosion and allow runoff infiltration.
- Reduce sediment transport and loading by installing BMPs that facilitate onsite infiltration of storm water and restoring riparian corridors, floodplains and wetlands.
- Maintain existing sediment retention basins, via regular inspections and removal of accumulated sediment. Expand the capacity of existing basins where feasible and consider appropriate retrofits.
- Maintain agricultural diversion, dam and ditch structures to prevent catastrophic failure and mass loading of sediment and pollutants.
- Replace impervious surfaces with permeable surfaces and native plant species that allow for rainwater absorption and reduced runoff.
- Restore flood storage capacity in urbanized areas and along shorelines by installing infiltration basins and creating or enhancing wetlands.

Photo Credit: Fernando Lopez Arbarello

- Improve technical, financial and human capacity of communities, NGOs, county, state and federal governments for reducing land-based pollution.
- Improve harbor practices to reduce pollutant loads from waste disposal, fueling, wastewater disposal and boat cleaning and maintenance activities. Ensure that fuel- or oil-spill prevention and cleanup measures are in place and that personnel are trained. Provide adequate pump-out facilities at all marinas and develop enforceable measures to ensure proper wastewater disposal.
- Ensure that watersheds adjacent to marine managed areas have adequate storm water management, erosion control, pollution control measures and land protection, to maintain good water quality.
- Improve linkages between land-use planning and marine spatial planning.

Implementation of such measures may reduce the level and frequency of harmful pathogens, associated with sewage, that are introduced into inshore waters and may lead to the spread of coral disease (as well as human health issues).

2. *Physically Remove Invasive Marine Algae*

Employ control methods that have been tested and used successfully in the marine environment. These methods fall into three categories:

1. Mechanical removal, using a barge with a pump-driven vacuum to remove algae;
2. Manual removal, through contract labor and/or volunteers, who remove invasive alien algae by hand; and
3. Limiting the introduction and spread of invasive alien algae species.

Hawaiʻi has a reasonable level of expertise and experience with employing these practices to learn from and build upon, particularly on Oʻahu.

Photo Credit: Jonathan Blodgett

The 'Supersucker' is an underwater mechanical suction device that a dive team uses to vacuum invasive algae off of reef habitat and onto a barge. The Supersucker uses a bladeless Venturi pump system to avoid fragmentation and spread of siphoned algae and to allow native marine life, unintentionally taken up in the process, to be returned to the water unharmed, following manual sorting on the barge. Recovered algae can be used for compost. Five to eight divers and operators are capable of removing up to 750 lbs. of algae per hour. Mechanical removal works as a temporary solution; it does not prevent the same species from reclaiming the area. The Hawaiʻi Marine Algae Group (a partnership between Hawaiʻi DLNR-DAR, The Nature Conservancy (TNC) and the University of Hawaii) successfully deployed the Supersucker in Kaneohe Bay, Oʻahu. Mālama Maunalua and TNC partnered at Maunalua Bay, Oʻahu, using a 'Minisucker', essentially a smaller version of the Supersucker.

The second practice for algae removal is manual removal, typically by volunteers. Community participants concentrate on specific areas of local interest sometimes transplanting native algae from areas of cleaned reef. Volunteers see first-hand the algae's destruction, becoming both more aware of its presence and better stewards of their area. Such projects have proven successful on other islands. Oʻahu's Maunalua Bay Reef Restoration Project successfully used both paid labor and community volunteers during 2010 and 2011 to remove over 2.5 million pounds of invasive, alien, leather mudweed (*Avrainvellia amadalpha*) from Maunalua Bay, clearing more than twenty-two acres of reef in the process.

Photo Credit: Jonathan Blodgett

Due to incomplete understanding of the effectiveness and impacts of such practices, an experimental approach with scientific partners is recommended for both: (1) the removal of invasive fish species, such as 'roi' (peacock grouper), from coral reefs, in order to protect native herbivore populations; and (2) the control of invasive alien algae, through the capture and redistribution of sea turtles or herbivorous fish, into coral reef areas with high algae growth. Increased experience and objective measurement of the effects of such practices may elevate them to standard recommended best practices for removing invasive marine species, under this strategy and future reef recovery plans.

3. Restock Certain Native Marine Species (non-coral)

Previous research on problem algae and herbivores in Hawaiʻi (and elsewhere) has indicated "strong negative associations between local biomass of herbivorous fishes and percent cover of problem algal species" (Williams and Polunin, 2001). This suggests that efforts to increase populations of herbivorous fishes could help to reduce vulnerability to invasive algae blooms and even reverse previous coral-to-algal shifts.

Herbivore populations help to prevent the proliferation of nuisance macroalgae. Therefore, in areas where the water quality is good and herbivores are under some form of active management or full protection, both passive and active restocking of native marine species may be helpful for reef recovery.

Passive restocking is achieved through the fisheries management (for example, allowing natural replenishment of native herbivores). Hawaiʻi's Division of Aquatic Resources is studying the benefits of protecting herbivores from fishing pressure within a Beach Herbivore Fisheries Management Area in Kahekili, Maui. Natural recruitment, coupled with harvest restrictions, may be a cost-effective method of increasing stocks, compared to active restocking. Full prohibition of harvest of herbivores would likewise allow for replenishment of stocks through natural recruitment.

Fish disease

Photo Credit: M. Ramsey

In some locations outside Hawaii, native herbivores are repopulated through ranching: the capturing or collecting of juveniles and holding them until adulthood for relocation into depopulated areas, or moving adults from areas of high concentration into lower ones.

Aquaculture can generate juveniles through captive-breeding programs, where they are held and grown in culturing facilities until they reach appropriate size to release into the wild. Specialized feeding mechanisms and variable diet preferences among herbivorous species, imply that some groups or size-classes of reef fishes are more important in controlling invasive algae (Choat, Robbins, and Clements, 2004; Hobson, 1974).

Active restocking efforts require precautions to prevent disease transmission. Restocking of native herbivorous fish within coral reef areas is under investigation in Hawaii. It could become a useful active restoration practice on coral reefs where fish populations have been decimated. Active replanting of native marine algae species may be useful at restoration sites, where appropriate, particularly following the removal of invasive marine algae species. There are several projects in the main Hawaiian Islands, including sites at Waiheʻe, Maui and ʻEwa, Oʻahu, where native algae transplanting and cultivation is underway.

Urchin propagation and restocking is under investigation on Oʻahu, via hatchery and could be a useful element, should research and trials verify their potential. Although some argue that ancient Hawaiian fishpond husbandry was essentially a restocking effort (due to accidental introduction or intentional release of managed reef fish from fishponds), active restocking is not a common practice in modern-day Hawaii. Replanting native species in wetlands and littoral habitat adjacent to reef areas may also be a useful element of this practice.

Sea urchin larvae and grazing sea urchins

Photo Credit: Jonathan Blodgett

Active restocking would likely require substantial financial and technical investment, over a significant period of time, to be deployed at scale. Further, current State and Federal laws restrict or even prohibit such activities. Therefore, active restocking is not considered a high priority. Instead, this plan recommends experimental trials at priority locations with scientific partners to assess their potential as reef restoration efforts.

4. Propagate and Transplant Corals

Coral restoration, through propagation and transplantation, is underway in many places around the world that have suffered high coral mortality. MCRT reviewed the methods, lessons and cost estimates from these programs. International experience in establishing and maintaining low-cost, community-led 'coral gardens' of transplants has grown within the past two decades, particularly within the Indo-Pacific and Caribbean regions.

International organizations such as Global Coral Reef Alliance and TNC now provide detailed, peer-reviewed guidance and technical capacity for establishing, maintaining and monitoring coral transplantation programs. Such efforts are often promoted locally with fishing communities to increase awareness of the need for coral management and recruit volunteer labor, via snorkel, scuba or hookah operations.

Growing Coral at the Maui Ocean Center

Photos Credit: John Gorman

In the Philippines and Indonesia, some coral gardens became popular dive sites and attract dive tourism operators who also assist with maintenance costs. In some cases, propagation and transplantation sites were designated as MPAs, to prevent fishing or destructive practices from occurring at restoration sites. Maintenance includes removal of invasive algae and clean-up of marine debris. Local reef health and threats education and outreach programs, particularly targeting youth, often occur as part of coral garden programs. The conservation benefits and effectiveness of such programs has yet to be validated scientifically and is viewed as a questionable management practice by most marine management professionals. Transplantation may not achieve comparable genetic diversity. This is due to the lack of sufficient polymorphic genetic markers for most coral species. Further, aquaculture facilities often do not maintain genetic diversity because they have limited brood stock.

Coral propagation and transplantation has neither a current legal basis within Hawaiʻi's inshore waters nor a strong base of existing political support. However, CMMA members have expressed interest in experimental redistribution of components of an artificial reef within their managed area, with assistance from scientific partners.

Global experience suggests that the cost runs to thousands of dollars per acre. Such costs exceed the budgets of the partners to this plan. Given the costs and the demanding technical requirements, the restoration value of coral propagation and transplantation may not be justifiable over that of improving environmental conditions (e.g., water quality) and allowing natural recovery to occur.

Coral propagation and transplantation was carefully considered and discussed by the MCRT, which resulted in its low priority rating. Peer-review feedback from outside the team, strongly agreed with this conclusion. Experimentation and research to explore the potential for future application was preferred. Even in ideal conditions, coral propagation and transplantation would only be part of the overall solution to reef restoration.

The Out to Sea museum exhibition in Switzerland contains shocking amounts of plastic flotsam and garbage, including 6.6 tons collected on Kahoʻolawe by Hawaiʻi Wildlife Fund. HWF's Cheryl King traveled overseas to educate on the cleanup

Photo Credit: Cheryl King/Hawaiʻi Wildlife Fund

MCRT members recognize that coral transplantation is useful only in locations where the root causes of reef decline are addressed; i.e., where land-based pollution has been minimized, overfishing curbed and resiliency built to adapt to climate change.

Experimentation is recommended only in areas of ideal conditions, including high water quality, healthy surrounding habitat and absence of significant human disturbance or stressors (for example, within well-managed marine protected areas). Such candidate sites are rare around Maui Island.

Experimental coral propagation would require producing corals and live rock prior to transplantation, at facilities on land (e.g., the Maui Ocean Center, Waikiki Aquarium or inland artificial seawater facility.) It could involve ocean-based propagation stations (tethered floating or stationary grow-out cages (e.g., within a MLCD or Hawaiian fishpond), prior to the redistribution and transplantation of propagated corals.

B. Indirect Restoration

Indirect restoration efforts focus on controlling and modifying people's behavior, rather than manipulation of the biological environment. Indirect restoration is seen by the MCRT as a critically important piece of Maui's reef restoration effort.

This recovery plan focuses on the four following indirect restoration practices:

1. Increase site-based management efforts and presence;
2. Encourage compliance and enforce rules and regulations;
3. Increase community involvement; and
4. Recommend appropriate resource management policies.

Such practices require significant volunteer and paid labor investments. MCRT recognizes that volunteer efforts alone would be insufficient to effectively employ all four practices.

Reef Resilience Training for the community

Photo Credit: Mia Charleston

1. Increase Site-based Management Efforts and Presence

Increased management efforts include the following activities:

(a) Cooperatively develop and implement site-based action plans with community members, stakeholders, user group representatives and government officials;

(b) Expand previously-designated marine managed areas (MMAs) around Maui, including MLCDs and NARs;

(c) Legally designate new MMAs around Maui as components of a biologically representative and redundant MPA network;

(d) Support TNC’s effort to establish and manage a Maui MMA learning network;

(e) Explore opportunities to implement collaborative fisheries management with local communities and local, state and federal government authorities;

(f) Periodically characterize, assess and map habitat, water and the biological community, including quantity and quality;

Community training at Polanui Hiu CMMA

Photo Credit: Mia Charleston

(g) Review, update and identify critical and sensitive coral reef sites, based on a geospatial analysis for decision-making purposes (e.g., TNC’s assessment of priority conservation areas of Maui’s coral reefs);

(h) Develop and implement conservation plans for landowners and neighboring priority recovery sites, to protect stream and riparian areas and for land use decision making;

(i) Assess neighboring watershed conditions (e.g., forest cover, water quality, vulnerability level) and create ahupuaʻa-based watershed-management plans at neighboring reef recovery demonstration sites and MMAs;

Train the Trainers Events to facilitate community management of marine resources

(j) Selectively and cautiously institute participatory coastal and marine spatial planning exercises, both for recovery sites and, at the seascape level, with users, stakeholders and community groups (e.g., see the NOAA-supported West Maui Coastal Mapping project);

(k) Document and integrate customary practices (e.g., harvest calendar) and traditional knowledge (e.g., spawning grounds) within management efforts;

(l) Develop and implement site-based climate change adaptation plans for recovery of demonstration sites; and

(m) Define NOAA's Marine Sanctuary role in assuming jurisdiction of near-shore marine ecosystems in State waters, recognizing their plan to expand from a single-species to a broad-based ecosystem approach, along with expansion to new areas within the main Hawaiian Islands.

Increased management presence includes periodic visits by professional management staff and researchers in support of the recovery plan (e.g., State DLNR/DAR representatives, DOCARE officers, University researchers and NGO staff), as well as the regular presence of participating community volunteers and supporting fishers and non-extractive users. An example of such an effort is the ʻOpihi Monitoring Partnership.

2. Encourage Compliance and Enforce Rules and Regulations

Another important indirect restoration practice is improving compliance with current marine resource rules and regulations through education and enforcement.

Encouraging compliance with existing rules and regulations involves education and outreach (such as public awareness campaigns), installing signage and operating informational kiosks at recovery demonstration sites, working with schools to build curricula related to coral reef conservation, designing and focusing compliance messages to specific target audiences, using appropriate media (e.g., radio/TV, handouts, newspapers, social media) and community meetings.

Marine resource management rules and regulations are poorly enforced on Maui. MCRT emphasizes the need for a sufficient DOCARE presence, including enhanced on-site patrolling. This requires increased budgets and legislative approval. Community volunteers can be trained, via community 'watch' programs, to provide surveillance (including documentation of observed user type and frequency) and real-time position and activity of suspected violators. Volunteers can then, in an appropriate way, approach and confront suspected violators to inform them of possible rule infractions. An example of such an effort is the DLNR-sanctioned Makai Watch program, which is supported by Conservation International and TNC. It provides capacity-building opportunities and private funding.

3. *Increase Community Involvement in Coral Reef Management*

Top-down management practices require substantial financial and human resources and are needed where human presence is low or uninformed and disengaged from management issues.

In areas where enforcement is lacking, local management strategies, designed to meet community goals, can achieve greater compliance and conservation than those designed solely for biodiversity conservation (Churnpagdee, Fraga, and Jorge, 2004; Chuenpagdee and Jentoft, 2007; Kittinger in review; McClanahan et al., 2006). Community participation in coral reef management efforts has been successful in areas such as the Philippines, Fiji, Indonesia, Palau, the Federated States of Micronesia and Papua New Guinea, leading to documented improvements in coral reef health, and improved socioeconomics and supportive governance and policy decision making (LMMA Network, 2010).

CMMA members examine root causes of coral reef degradation

Photos Credit: Mia Charleston

Community Managed Makai Area (CMMA) efforts on Maui combine traditional knowledge and customary management practices with modern management and scientific approaches. They exemplify and support the case for the relevance of traditional management practices within management program. Once a community group has been formed to support local management, the CMMA process involves three phases:

1) Site appraisal through direct observation; documentation of historical information; and development of seasonal harvest calendars;
2) Designate area boundaries and establish a community vision, core values and prioritized management goals and strategies; and
3) Develop and implement an action plan.

CMMAs encourage local participation and active support of restoration efforts. CMMAs at restoration sites would engage with efforts already underway for Polanui Hiu in Lāhainā, Wailuku, Kīpahulu, Mūʻolea and emerging CMMAs on Lāna`i and Molokaʻi, along with ʻĀhihi-Kīnaʻu NAR. The MNMRC is also now a supporting member of the Maui Nui Community Managed Makai Area Learning Network.

Upgrading a fishing check in station at the Wailuku CMMA

4. *Recommend Passage of Appropriate Marine Resource Management Policies*

The goals and objectives reflect the MCRT's understanding that effective reef restoration requires supporting rules and policies. Accordingly, indirect restoration practices must include communicating findings and recommendations to policy-makers. This includes the State legislature and Maui County officials and local decision-makers (for example, within processes to develop County Community Plans). Potential policy recommendations include:

Olowalu reef

Photo Credit: Cynthia Matzke

(1) Requesting the Maui County Council adopt this Recovery Plan;
(2) Linking recovery plan actions with site-based development plans, through the County Council, including exploring how specific language under this plan could be incorporated in Community Plans;
(3) Building policy support for improved regulatory compliance and increased site-based enforcement;
(4) Ceding State management authority to certified community groups, implementing collaborative marine management;
(5) Requesting State administrative support for restoration practices, such as on-site enforcement presence and abatement of land-based pollution sources;
(6) Building a network of MMAs, across Maui, with ecological and social connectivity (including securing the legislative mandate to create such a network);
(7) Defining climate change adaption policies; and
(8) Providing alternative scenarios that reflect the impacts of action versus inaction.

Maui Nui Community Managed Makai Area Learning Network meeting, Keʻanae, Maui

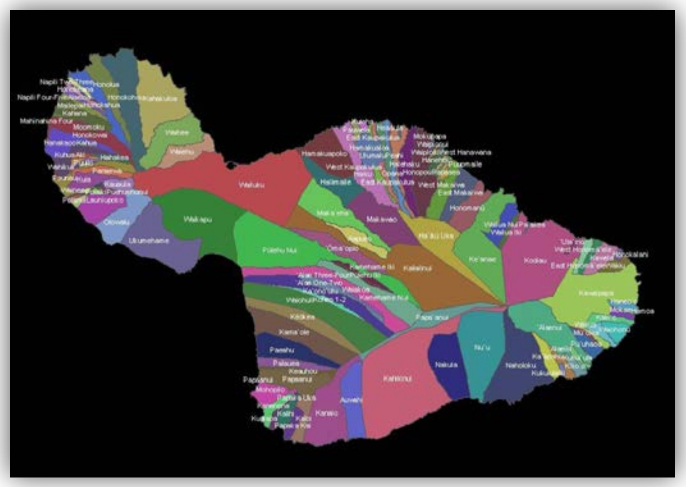
Photo Credit: The Nature Conservancy

C. Cultural and Traditional Management

Even fifty years ago, educational material was already in circulation to encourage resource managers to adopt traditional cultural practices that had maintained human societies in the Hawaiian Islands for over 1,500 years. Thomas Maunupau describes such practices in the 1965 book, ***Ancient Hawaiian Civilization***:

> "The ancient Hawaiian did everything he could to preserve the fishing ground. No fishing ground can be preserved unless precautions such as the Hawaiians observed are taken. This is true not only of Aku and Ahi fishing but of every other kind of fishing. The Hawaiians had a *kapu* on alongshore fishing in certain places when deep sea fishing was open. In the case of inshore fishing, one place was kapu for a month; then this area was open and the next was kapu. At certain times of the year, certain seaweeds were kapu, because when fish food was preserved by this means, the shore fishing was saved for the people. There used to be plenty of fish in Hawaiian waters, but these have to a great extent disappeared because constant fishing has wiped them out. The fish are gone for good unless we have closed and open seasons for different kinds of fishing. The government is trying to place certain restrictions on fishing. If the ancient form of kapu used by the old time Hawaiians could be revived in these new governmental restrictions, we should again have plenty of fish, provided the restrictions were observed as were the kapus in the old days." (Maunupau, 1965)

Traditionally, natural resources were managed by the law of the *Aliʻi* (Chiefs) to ensure the sustainability of life in each location – whether on an island, an *ahupuaʻa* (land division of the island), or an area within an *ahupuaʻa*. Each district of the island was distinct, comprised of different ecosystems, climates, seasonal reproduction periods and populations. The *ahupuaʻa's* population directly influenced the management of its natural resources. Hawaiians had no way to import food. Survival meant living sustainably. Unchecked, overharvested, or unmanaged natural resources could lead to starvation, warfare and even extinction.



Ahupuaʻa on Maui – Maui Island Plan

Photo Credit: County of Maui

Early residents placed high value on natural resources. Polynesian religion sees the natural environment as a physical manifestation of gods and ancestors. Natural resources were typically managed by *Konohiki* – stewards appointed by the *Aliʻi* to carry out the will of the chiefs. *Konohiki* were aware (or had *kahuna* who were aware) of the spawning periods and rate of repopulation of each species and enforced *Kapu* (or no-take restrictions) accordingly, to ensure sustainability. The pollution of natural resources and the harvesting of items that were *Kapu* – either forbidden or restricted – were among the most serious crimes. Penalties ranged from additional taxation to execution.

In the context of this restoration plan, early Polynesian resource managers practiced "rest" rather than "restoration." In ***Hawaiian Fishing Traditions***, Mary Kawena Pukui explains how the fishing *kapu* worked, in the district of Kaʻū, on the Big Island, both to allow people to use the resources and to ensure a continuous supply:

> "There was never a time when all fishing was tabu. When inshore fishing was tabu (kapu), deep sea fishing (lawaiʻa-o-kai-uli) was permitted and vice versa. Summer was the time when fish were most abundant and therefore the permitted time for inshore fishing. Salt was gathered at this time, also and large quantities of fish were dried…In winter, deep sea fishing was permitted….A tabu for the inshore fishing covered also all the growths in that area, the seaweeds and shellfish, as well as the fish. When the kahuna had examined the inshore area and noted the condition of the animal and plant growths and decided that they were ready for use, that is, that the new growth had had a chance to mature and become established, he so reported to the chief of the area and the chief ended the tabu." (Titcomb, 1952)

Traditional marine resource management practices, as stated in ***Ancient Hawaiian Civilization***, also included the following perspective on the role of fishers in management:

> "The old Hawaiian fisherman was a skilled and selected person. He had knowledge of and respect for, the traditions and customs of fishing. He was careful to observe these customs, because through them, fishing was preserved for the coming generations and his children were trained in the skill they would need as they became fishermen. Fishing in those days was not a matter of getting all the fish and moving on to another fishing ground. The Hawaiian fisherman was much too clever to do this and he respected the traditions of his people too much to do it. Laws today cannot help to preserve the fish in Hawaiian waters, unless in addition to the laws, we have a feeling of respect for them and observe them because we see that they are beneficial." (Maunupau, 1965)

Throw net demonstration and practice
Photo Credit: Manuel Mejia

Such traditional management practices, in Hawaii, have been of recent research interest as possible sources of contemporary management alternatives (McClenachan and Kittinger, 2012). From this rich cultural history, we can glean several important resource management practices that are clearly relevant today, from the perspective of coral reef restoration efforts outlined under this plan:

1. Promote and support local marine resource management leaders;
2. Encourage the use of traditional resting periods; and
3. Encourage community stewardship over neighboring inshore waters.

Each of these cultural and traditional management practices is briefly described below.

1. Promote and support local marine resource management leaders

Resource managers must have first-hand knowledge of the status of local marine resources. Resident families and local fishers, with the knowledge of cultural management practices in an area, must be actively incorporated into local coral reef restoration efforts, assuming that they have the interest and willingness to support them. Our contemporary government system often attempts to manage Maui's marine resources from Honolulu or Washington DC alone and this is ineffective. The traditional practice of promoting and supporting experienced and respected local leaders, with significant first-hand knowledge, as *Konohiki*, allowed them to assess and share perspectives on the health of the local shoreline ecosystem, prior to the creation or removal of restrictions or closures. Under this plan, such knowledgeable and respected local voices, within priority recovery areas, must be identified and supported.

Wailuku CMMA training
Photo Credit: Mia Charleston

2. *Encourage the use of traditional resting periods*

Like Native Hawaiians of the past, today's resource managers understand the interdependence of marine resources. Species-specific catch limitations and size restrictions, alone, are not as successful as closing the entire fishery in a given area to harvest activities, either permanently or temporarily (Friedlander *et al.*, 2007). Because permanent closures may not be socially acceptable or operationally possible to achieve in all locations of concern around Maui, temporary closures, consistent with traditional practice, may be a feasible alternative.

Ko'ie'ie Fishpond
Photo Credit: Darla White

Temporary (typically six months to a few years in duration) closure is an ancient practice throughout the Pacific Islands (e.g., "tabu" and "tambu" declarations in Melanesia, "bau" in Micronesia and "kapu" in Polynesia), including Hawaii. Traditionally, such closures, or "resting periods," occurred on a rotational basis.

Data from contemporary rotational closures indicate that recovery is not always evident, particularly for shorter closure periods and/or where high poaching and human activity occur. Waikiki beach is an example: rotational closures exhibited low effectiveness (Williams *et al.*, 2006).

However, in low population areas of Maui, where shoreline residents actively support closures and regularly monitor and encourage compliance, rotational closures may experience greater success. Coupled with the other three strategies, periodic closures within active CMMAs may meaningfully contribute to recovery.

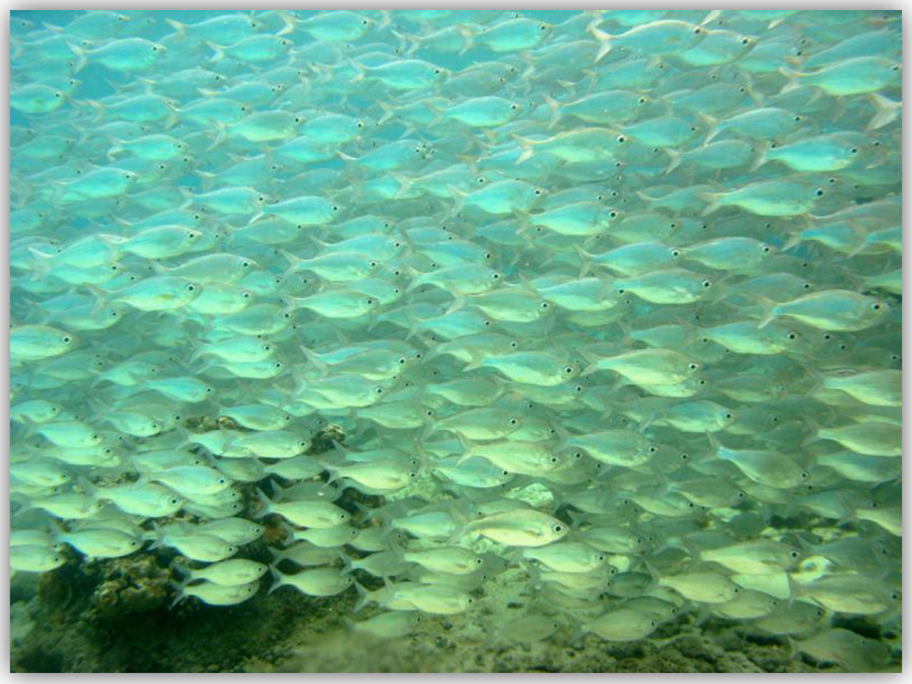


Photo Credit: Linda Nakagawa

Resting periods, even where effectively managed, may not be able to offset the negative effectives of global climate change. Conventional wisdom holds that a sufficiently large network of both MPAs and CMMAs, with resting periods, must be created, in order not only to encourage reef recovery, but also to increase the likelihood of successful adaptation, by Maui's coral reefs, to the negative impacts of climate change.

3. Encourage stewardship efforts that serve both culture and ecology

MPAs and CMMAs around Maui must include active surveillance and enforcement efforts, designed to encourage compliance and deter or penalize violators.

Traditionally, the reopening of a *Kapu* area was decided locally, based on the observed abundance of target resources rather than on a specific date. The area remained closed until the *Konohiki* decided that the resources were ready. *Kapu's* were sometimes reinstated after limited harvesting. *Kapu* was strictly enforced, with dire consequences for violators.

Increasing public awareness of and respect for such traditional stewardship practices mean that it may be appropriate, in certain areas, to empower CMMAs that employ these practices. Within communities of numerous Native Hawaiian ancestry households, active support of CMMA activities encourages both reef recovery and cultural practice.

Polanui CMMA Training
Photo Credit: Mia Charleston

Several marine organisms are both integral to Hawaiian culture and ecology. Such organisms can become important 'keystone' species, around which to rally the support of cultural practitioners.

Preliminary research suggests that *Kapu* areas may have yielded standing fish biomass roughly equivalent to no-take MLCDs of today (Friedlander, Shackeroff, and Kittinger in review).

D. Public and Partner Engagement

Public and partner engagement is a critical requirement for effective plan implementation. The public and partner engagement strategy will focus on the beneficiaries of the recovery plan, including local community residents, user groups and other stakeholders.

Four additional practices will be enacted, under a public and partner engagement strategy, as follows:

1) Identification and engagement of Key Stakeholders in each community or *ahupuaʻa*;
2) Promotion of public participation in restoration efforts;
3) Support by community-managed marine areas; and
4) Development of reef recovery partnerships and collaborations.

1. Identification and Engagement of Key Stakeholders

MCRT will work with potential partners to complete a stakeholder analysis that identifies priority stakeholder groups and characterizes their interests and influences. MCRT will strategically engage with key stakeholder groups and recruit their support and participation.

Stakeholder engagement will remain a core practice, underlying all recovery actions.

2. Promotion of Public Participation in Restoration Efforts

MCRT recognizes that Maui residents must play an active and vital role throughout the entire reef recovery process. Accordingly, members of the public will be encouraged to participate, including:

MNMRC Meeting
Photo Credit: Mia Charleston

(a) Site-based volunteer efforts such as surveillance and documentation of user activity at recovery sites, fish and water quality monitoring and manual algae removal;

(b) Attending MCRT and MNMRC meetings;

(c) Providing input into public opinion polls to assess public awareness and reactions to proposed actions, such as user fees; and

(d) Providing input on how best to frame the issue of reef degradation and recovery (for example, how coral reefs relate to Maui's visitor industry).

3. Support by Community-Managed Marine Areas

Graduates of the CMMA Train the Trainers Program
Photo Credit: The Nature Conservancy

On August 18, 2010, a group of community leaders and resource users, from Polanui Hiu (Lāhainā area) and Wailuku Ahupuaʻa requested assistance from the Maui Nui Marine Resource Council to design and implement CMMAs within their areas. Making use of traditional knowledge and based on established community trust, two CMMA working groups were formed.

Between September 2010 and November 2011, these two CMMA working groups were trained to design and develop local management plans, in conjunction with their local communities and user groups. These CMMAs incorporated traditional and modern practices in their plans. They plan to seek formal recognition by the State government and authority to manage their own resources, as has been done at Moʻomomi and Hāʻena.

During early 2011, these two CMMAs expressed their interest to actively support the implementation of the Maui Coral Reef Restoration Plan. MCRT intends to build CMMA participation into restoration plan implementation.

4. Development of Reef Recovery Partnerships and Collaboration

This plan aims to support the ability of Maui's people to sustainably harvest marine resources. MCRT views Maui's fishing families, community groups, private businesses, educators, non-governmental organizations and agency authorities as critical partners and allies in the implementation of this plan. The MCRT recognizes potential partners to invite support of the recovery plan, including those listed in the table below:

Government	*Non-government Organizations*	*User/stakeholders*
Maui County **Mayor's office** **Governor's office** **Policy Makers** **NRCS** **State DOH** **State DOA** **USDA/Farm Bureau** **NOAA Sanctuaries** **NOAA Fisheries** **CRC** **HTA/Maui Visitor's Bureau** **DBEDT - OP/CZM** **DOT/State Transportation** **DHHL, OHA** **Watershed Partnerships** **USFWS** **NPS/DOI** **USGS** **USEPA** **USACOE** **DLNR**	Hawaiʻi Water Environmental Association The Nature Conservancy Coral Reef Alliance (CORAL) South Maui Sustainability Maui Tomorrow Surfrider Foundation Hawaiʻi Wildlife Fund Sierra Club Bishop Estate Kamehameha Schools University of Hawaii Hawaiʻi Sea Grant Project S.E.A.-Link Castle Foundation Hawaiʻi Community Foundation Watershed management NGOs Soil/water conservation districts Hawaiʻi Association for Marine Education and Research, Inc.	Land owners Community associations Local fishing clubs Taro farmers Dive Tour associations Whale watching tour operators Maui visitor industry businesses Commercial fishers

MCRT acknowledges that responsibility for the plan's implementation and evaluation must be shared among several partners, including government authorities (e.g., Governor's office, DLNR, DOH, County Commission and managers at local, county, state and federal levels), non-governmental groups (e.g., fishing clubs, community groups, MNMRC, The Nature Conservancy, Conservation International) and academia (e.g., DOE, University of Hawaii, local schools).

To coordinate these groups, MCRT proposes creation of a Reef Restoration Council (RRT). This Council will assume the lead decision-making role and lead engagement with public decision-makers for all recovery activities. The Restoration Council will oversee the MCRT, which will remain a separate, scientifically-focused body, providing independent analysis and objective review of the condition of Maui's reefs, along with technical implementation support. The roles and functions of this partnership-driven governance over the plan will be defined by relevant authorities and partners, immediately following the adoption of the plan.

Maui businesses, NGOs and government agencies, committed to the success of this plan, sponsored the North Kīhei Flood Forum in 2011

Photo Credit: Mia Charleston

[This page intentionally left blank]

Appendix One – Elements of the Recovery Plan Vision

The vision of successful coral reef recovery around Maui in 15 to 20 years is as follows:

> *Maui's coral reef ecosystems are biologically intact, ecologically functional, and sustainably managed through a partnership arrangement of government, non-government, and community stakeholders. Thriving, dense coral habitat supports an abundant diversity of native marine life, in turn providing a wide range of ecological, economic, and cultural benefits and services to current and future generations of Maui residents and visitors. They are a beautiful and thriving example of successful coral reef management and restoration that is recognized around the world.*

Photo Credit: Don McLeish

There are several biological, economic, and socio-cultural elements associated with this recovery plan's vision statement:

Biologically, we envision that in 15 to 20 years:

- Maui's coral reefs will be intact and ecologically functional, with balanced populations of thriving native marine organisms inhabiting the reef.
- Maui's reefs will have increased live coral cover and health, and host abundant and thriving reef fish populations.

- Maui's reefs will be able to sufficiently replenish themselves through time due to high reproductive capacity, connectivity, and consistently successful recruitment of juvenile organisms.
- Maui's reefs will be home to the full range of biological diversity and endemism that makes Hawaiʻi's near shore marine environment globally unique and special (Roberts *et al.*, 2002).
- Maui's reefs will be resistant to natural and human disturbances with relatively low rates of disease and be successfully adapting to the effects of periodic land-based pollution. Effective management will successfully address threats and minimize negative impacts on coral reef habitats and fish populations.
- Maui's reefs will be more resilient and have a higher likelihood of recovery following periodic natural and human disturbances. Maui's reefs will be as best prepared as they can be to successfully cope (in the short term) and then adapt (over the long term) to the effects of global climate change, including sea level rise, sea surface temperature increases, and ocean acidification.

Economically, we envision that in 15 to 20 years:

- A thriving and sustainable inshore recreational, cultural and subsistence fishery will support local residents and communities engaging in *pono* fishing practices that are widely understood and followed. These practices will support local livelihoods and interests, including dive tourism, recreational fishing, and supplying sustainably- and locally-caught seafood for Maui restaurants.
- The sustainable extractive and non-extractive use of Maui's coral reefs will support a stable local economy and a wide range of local businesses and diverse job opportunities, including the beach hotel industry, scuba-diving related tourism, whale watching tours, and other ocean recreation activities, as well as supporting the availability of locally-caught seafood within Maui restaurants, through small-scale commercial fishing efforts.
- Some Maui families will be engaged in small-scale commercial reef fisheries in a sustainable manner that allows them to maintain their traditional livelihoods and provide for their families.

Photo Credit: Mia Charleston

- The inherent value of Maui's coral reefs will be widely recognized and accepted by the public, and incorporated appropriately into economic assessments of Maui's natural marine environment.
- Decision-making regarding coastal development will reflect the intrinsic value of Maui's coral reefs.
- Local career opportunities will exist relating to the health and wellbeing of Maui's coral

reefs, including natural resource managers, marine educators, marine scientists, community project participants, individuals involved in restoration, and environmental engineers.

Socio-culturally, we envision that in 15 to 20 years:

- Maui residents will have a strong awareness of the need for preserving and protecting coral reefs through effective resource management. Increased citizen peer pressure and self-policing to observe reef management rules and obey marine resource regulations will encourage compliance and minimize violations. This will lead to increased respect and value for Maui's reefs by its users and visitors, who will consistently strive for "zero impact."
- Due to a participatory management approach, the Maui public will be actively engaged in the management of Maui's inshore waters. Stakeholders will fully participate in and support consensus-driven decision making processes that effectively maintain the health of Maui's reefs under a "culture of care."
- Culturally appropriate resource management efforts will be utilized as an important component to reef sustainability. Management efforts will incorporate traditional place-based observations and scientific methodologies to provide the best information available for resource managers.

Photo Credit: Don McLeish

- Traditional knowledge will be perpetuated through the generations, and continue to evolve naturally through the course of history. Maui's coral reefs will support a wide variety of cultural practices to maintain this traditional knowledge.
- Restored Hawaiian fishponds will thrive, supported by restored streams, and Native Hawaiian seasonal harvest calendars will be observed.
- Traditional fishing and gathering techniques will be practiced effectively because healthy coral ecosystems support an abundance of marine resources. Maui families will be able to maintain fishing traditions and sustainably gather marine resources for cultural practice.
- The lost connection between Maui's people, its coral reefs, and the ocean will be revived. Maui residents will understand and share the belief that their health and well-being is closely tied to that of Maui's coral reefs. Maui's families and communities will maintain a strong cultural identity with healthy coral reefs and inshore waters.

[This page intentionally left blank]

Appendix Two – Threat Analysis

A. Threat Identification and Assessment

The MCRT conducted a qualitative assessment during late 2010 of known threats that are most frequently having a negative impact on Maui's coral reefs. The assessment involved the participation of 29 knowledgeable and recognized coral reef experts, including the MCRT members. Based on this assessment, the most frequently identified threats facing Maui's coral reef ecosystems are as follows (listed from most to least often cited by respondents):

1. Land-based sources of pollution in the form of: (1) sediment runoff from coastal development, road construction, agricultural lands, and watershed erosion; and (2) excess nutrients from human waste (e.g., injection wells, cesspools, and leaking wastewater pipes; agricultural and landscaping practices).
2. Overfishing by non-aquarium commercial fishing operations.
3. Land-based sources of pollution in the form of chemical runoff (e.g., fertilizers and pesticides).
4. Overfishing by recreation fishers (both residents and visitor charter boats).

Invasive algae smothering a reef
Photo Credit: Greta Smith Aeby

5. Invasive species, particularly alien algae that proliferate from increased nutrient availability.
6. Climate change impacts in the form of ocean acidification.
7. Overfishing by local fishers for subsistence or supplemental protein needs.
8. Climate change impacts in the form of sea surface temperature rise.

Some of these threats cumulatively degrade or destroy coral reef habitat. The 29 assessment participants reported that the severity of the majority of these threats is increasing through time. The threats that assessment participants cite that are increasing the most rapidly are human waste and chemical runoff, overfishing, and coral habitat alteration/destruction due to coastal development or ocean acidification.

Other threats and confounding factors identified by the MCRT include:

1. Coral reef habitat alteration or destruction due to vessel groundings.
2. Coral reef habitat alteration or destruction due to non-extractive recreational uses and trampling.

3. Invasive fish species.
4. Marine pollution spills or dumps (accidental or otherwise), including oil and toxic chemicals and boat exhaust.
5. The spread of coral disease.
6. Incompatible land use policies and practices and poor urban/suburban growth planning.

The root cause for all of these threats and confounding factors is thought to be increasing use of coral reef habitat as a result of human population growth and in-migration to Maui Island.

Invasive Roi fish harvested during the 2008 Roi Roundup public fishing event

Photo Credit: Coral Reef Alliance

B. General Points of Agreement

The MCRT came to consensus on the following general points of agreement regarding the overall status of Maui's coral reef ecosystems:

- Maui's coral reefs face growing pressure from a range of threats. Significant declines have been documented on Maui's coral reef communities over the last 20 years, particularly at eight well-documented study sites. Decreases are also being observed in the relative abundance, species diversity, and individual biomass of coral reef fish populations. Some coral reef sites have declined less than others; only a few sites show any evidence of possible increases in coral cover (recovery). Reef and reef fish populations declined less within Maui's Marine Life Conservation Districts (MLCDs) and other marine protected areas (MPAs). In general, the trend is an overall decline in the health of Maui's coral and reef fish populations.

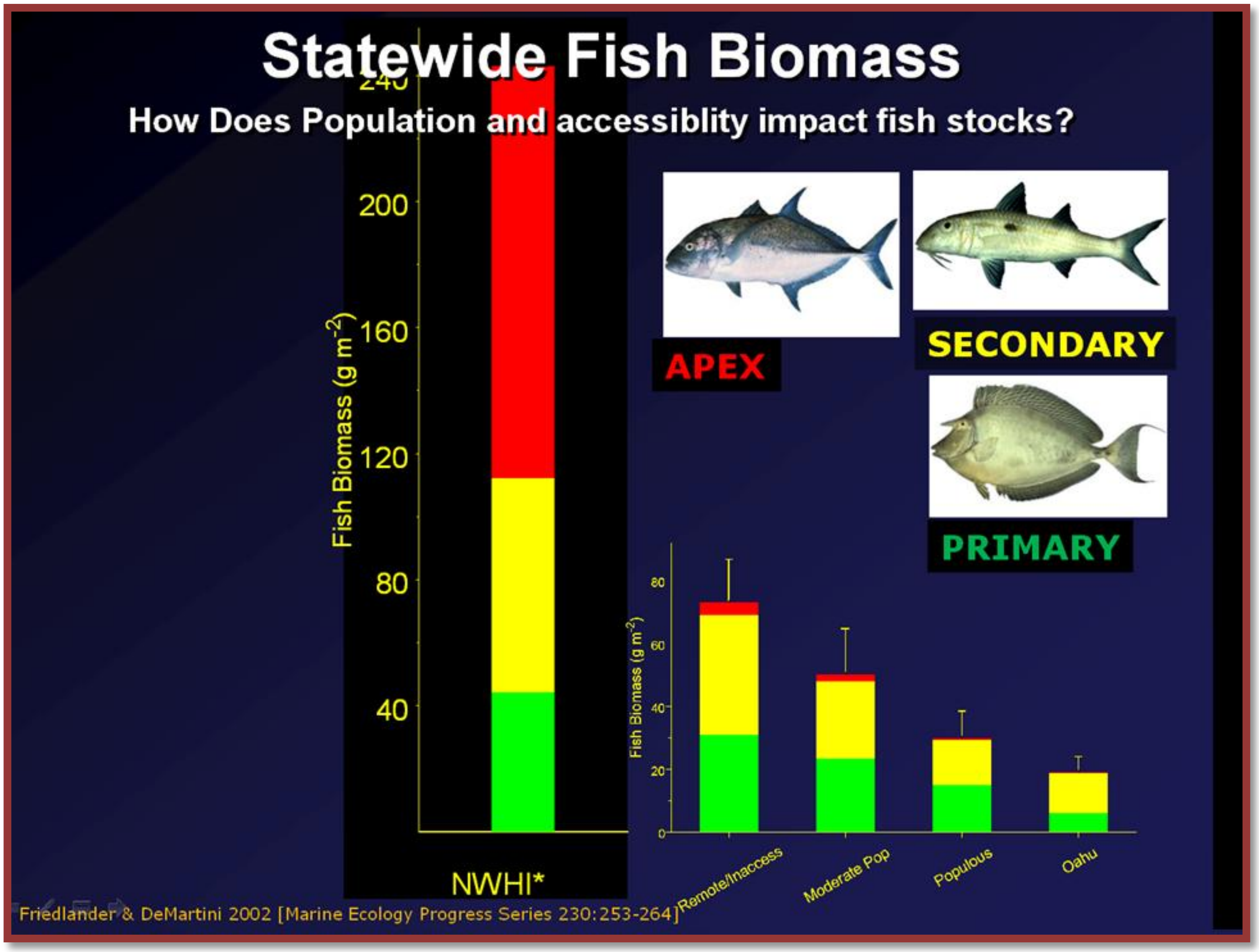
- Land-based pollution is one of the top threats to Maui's coral reefs. Land development and construction has resulted in increased degradation of near shore habitat through the destruction (conversion or removal) of coastal wetlands adjacent to coral reefs. Periodic storms and seasonally heavy rains create events of high rainwater volume runoff that carry and deposit sediment and non-point source pollutants onto Maui's reefs. Development practices (for commercial space, housing, road construction, agriculture, golf courses, etc.) contribute to land-based pollution and reef degradation when proper regulations and practices are not fully implemented. Feral ungulates such as goats, deer, and pigs contribute to soil erosion and thereby increase the amount of runoff discharge that negatively impacts reefs.

Silt choked runoff in North Kīhei following a heavy rain on Haleakalā
Photo Credit: Hugh Star

- Overfishing is also thought to be another primary threat to Maui's coral reefs. This includes over harvesting of reef fish for the commercial aquarium trade as well as heavy recreational fishing pressure and small-scale commercial fishing. Neither proposed bans on aquarium fishing or attempts to reform the fishery into a 'sustainable' practice through voluntary, non-governmental certification efforts have been successful at getting aquarium fishers to set and follow harvest restrictions. Bag and size limits for recreational fishers are difficult to enforce due to the low number of enforcement officers and lack of a recreational fishing license. Small-scale commercial fishing operations, including operators from neighbor islands, are known to regularly harvest fish from already overfished reefs.

- Other threats facing Maui's coral reefs include the spread of invasive marine species like alien algae and introduced fish, coral damage caused by scuba divers and snorkelers, tramping of live coral by recreational users, oil and sewage spills, and boating and ship impacts (e.g., groundings, anchor damage, and collisions with marine species).

- The increasing impacts of global climate change will negatively impact Maui's coral reefs through sea level rise (reduces sunlight), increased sea surface temperature (triggering coral bleaching), increased frequency and intensity of storm events (eroding the shoreline), and coral habitat loss due to ocean acidification (decalcification).



Relationship of fish biomass to remoteness

Photo Credit: Alan Friedlander

Given these direct threats, improved local decision-making support and political will by Maui County elected officials is essential. There is a lack of a legal basis upon which appropriate action can take root and be nurtured through time. Managers often have insufficient information to plan or make informed management decisions. In addition, they may not have access to the latest management techniques and technology needed for effective management, despite its availability.

In general, assessment participants acknowledged that the compound threat of land-based sources of pollution (viewed as having the most acute, pervasive, and destructive impacts) and the emerging and poorly understood threat of climate change warranted further analysis and consideration. The results of the assessment of these two threats are described below.

C. Detailed Threat Analysis: Land-based Sources of Pollution

Common land-based sources of pollution include sediment runoff from suburban centers and roadways, coastal construction and development projects, feral ungulates in the watersheds, households and landscaping, agricultural areas, disturbed watersheds and gulches. Land-based pollution from fertilizer and pesticide runoff and human waste via cesspools and injection wells are also of great concern. Animal waste (domestic and feral) contains disease that can kill marine animals. Storm water management needs to be improved for developed and agricultural land.

Hawaiian corals and coral reefs are sensitive to sediment loading (Jokiel, 2008; Wolanski, Martinez, and Richmond, 2009). Sediment is considered a primary, if not the leading, land-based pollutant causing alteration of reef community structure in the main Hawaiian Islands (Friedlander *et al.,* 2008). Impacts of sediment on corals include detrimental effects to living tissue and coral larvae (recruits), as well as other reef organisms. Impacts reviewed and documented by Rogers (1990) and Jokiel (2008) include: (a) reduced sunlight penetration and thus reduced coral photosynthesis and reef development and growth; (b) direct burying, smothering and physical abrasion of living coral polyps/tissue; (c) expenditure of energy to remove sediments, reducing reproductive potential; (d) inhibition of larval recruitment/settlement; and (e) addition of significant nutrients and sediment toxins into the ecosystem and food web.

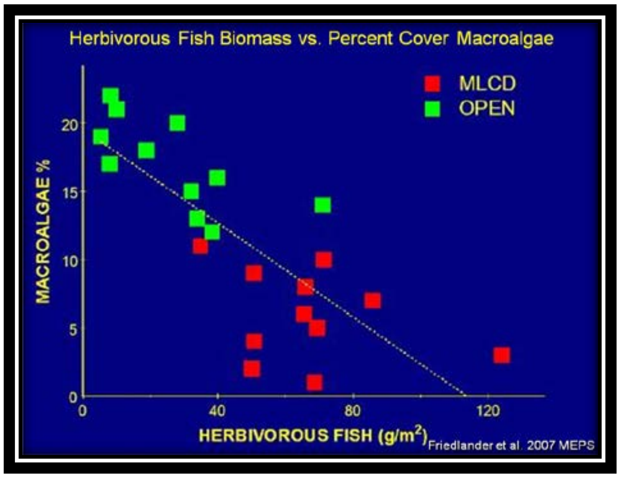
MNMRC hosted public Flood Forums in response to severe runoff in Kīhei during heavy rain events
Photo credit: The Nature Conservancy

Observed coral declines around Maui correlate with land use change and development. Areas of reef decline appear to be concentrated in areas with high human population or in areas suffering from extensive land disturbance and sedimentation (Jokiel *et al*., 2004; Jokiel, 2008). Historically a major cause of erosion, runoff and accelerated sedimentation on Hawaiian coral reefs has been plantation agriculture and overgrazing of agricultural lands in watersheds adjacent to reef areas. A review has been completed on the importance of this process on the reefs of south Molokaʻi (Jokiel, 2008; Field *et al*., 2008). Overgrazing by feral ungulates (e.g., pigs, goats, and deer) continues to damage watersheds on Molokaʻi, Lānaʻi, West Maui and the north coast of Kauaʻi.

Feral ungulates root up native plants, spread disease and exacerbate erosion (at left). Species like Axis deer (*Axis axis*) have no predators in Hawaiʻi and unchecked populations can lead to severe land-based degradation that flows downstream during storms

Photo Credits: Left – West Maui Mountains Watershed Partnership, Right – DLNR-DOFAW.

Increased land-based pollution can lead to an over-abundance of nutrients (eutrophication) resulting in algal blooms which negatively impact coral reef communities. Municipal wastewater injection plumes have been detected in the ocean at Kīhei and Lāhainā, Maui (Hunt and Rosa, 2009). Wastewater presence was confirmed by the detection of multiple wastewater tracers, the most conclusive being bacteria, pharmaceuticals, organic waste indicator compounds, and heavy δ15N in submarine seeps near the shore. The effluent plumes likely constitute large nutrient fluxes to the near shore environment. The effluent plumes are not the sole source of nutrients discharging to the ocean on Maui. Groundwater contaminated by fertilized agriculture and landscaping is similarly enriched in nitrogen, while phosphorus concentration is considerably higher in effluent than in contaminated groundwater by forest or agricultural land cover. It should be noted that groundwater is naturally much higher in nitrogen than ocean waters, even in areas where anthropogenic nutrient inputs are absent. Sections of the Kīhei and

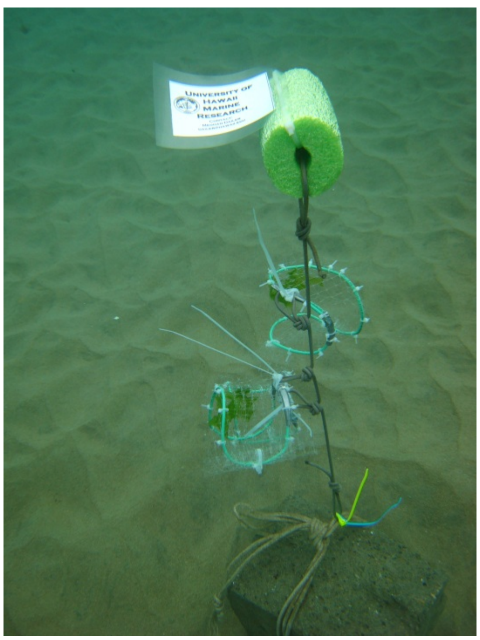


Herbivorous fish can help to prevent an overabundance of macroalgae in reefs, as long as their populations stay healthy and can be protected, either by conservation areas (such as a Marine Life Conservation District (MLCD)) or by sustainable harvesting

Photo Credit: Friedlander et al., 2007.

Lāhainā coasts have been designated as impaired water bodies or "Water Quality Limited Segments" because surface water exceeds one or more water-quality criteria, such as nitrogen, turbidity, or suspended sediment (State of Hawaiʻi, 2012).

Macroalgal blooms of *Hypnea musciformis* and *Ulva lactuca* in coastal waters of Maui occur only in areas of substantial anthropogenic nutrient input, sources of which include wastewater effluent from injection wells, leaking cesspools and agricultural fertilizers. Algal $\delta^{15}N$ signatures were used to map anthropogenic nitrogen through coastal surveys (island-wide and fine-scale) and algal deployments along near shore and offshore gradients. Algal $\delta^{15}N$ values of 9.8‰ and 2.0–3.5‰ in Waiehu and across the north-central coast, suggest that cesspool and agricultural nitrogen, respectively, reached the adjacent coastlines (Dailer *et al*., 2010). Nitrogen derived from wastewater was detected in areas proximal to the Wastewater Reclamation Facilities (WWRF) operating Class V injection wells in Lāhainā, Kīhei and Kahului through elevated algal $\delta^{15}N$ values (17.8–50.1‰). From 1997 to 2008, the three WWRFs injected an estimated total volume of 193 million cubic meters (51 billion gallons) of effluent with a nitrogen mass load of 1.74 million kilograms (3.84 million pounds) (Dailer *et al*., 2010). Nutrient inputs from sewage systems are of highest concern on the developed and urbanized coasts of Oʻahu and Maui (Friedlander *et al*., 2008).

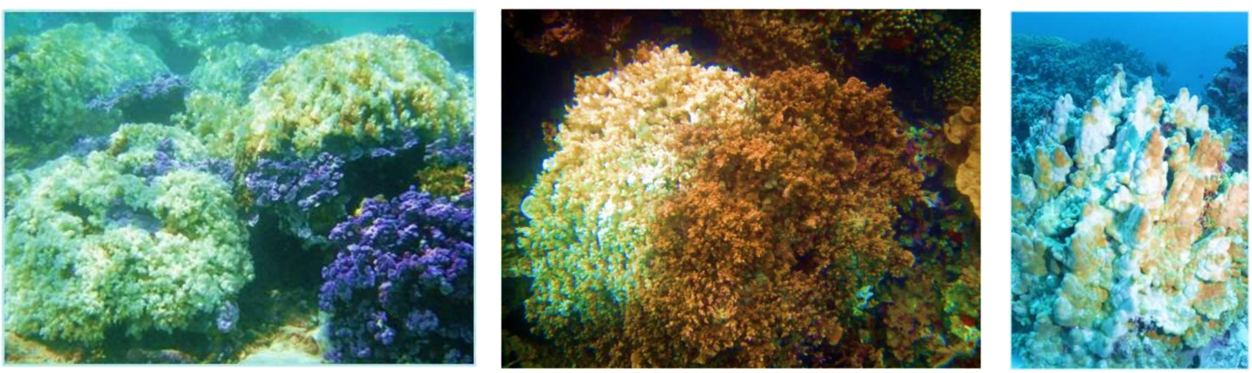


Measuring algae growth off Kahekili Beach Park in West Maui
Photos Credit: Megan Dailer

D. Detailed Threat Analysis: Climate Change

Another threat to Maui's reefs arises from the impacts of global climate change which leads to changes to: (a) sea surface temperature (SST), with associated potential for coral bleaching and subsequent increased susceptibility to disease (Hoeke *et al*., 2011; Veron *et al*., 2009); (b) sea surface height (SSH), with attendant threats from coastal inundation and erosion (Nicholls *et al*., 2011); and (c) ocean chemistry, particularly ocean acidification (Hoeke *et al*., 2011). Because these potential impacts are the result of global stressors, local management alone will not be sufficient to prevent them. Since land-based pollution also affects acidification, and can intensify its effects (Kelly *et al*., 2011), concentrating management efforts on stressors that are under local control will provide Maui reefs with the possible chance of withstanding climate change impacts (Selig, Casey, and Bruno, 2012).

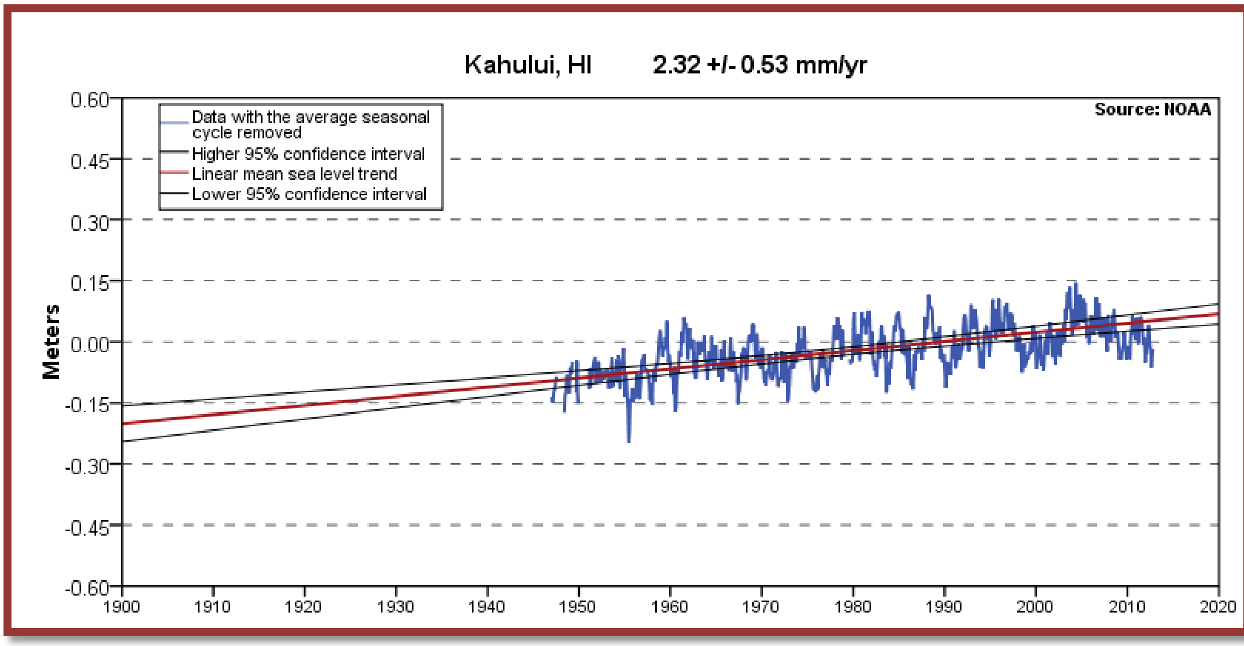
Considerable uncertainty still exists in regard to global projections of climate change (National Research Council, 2011). In addition, these effects may or may not scale linearly with global mean temperature, sea surface temperature, or ocean circulation patterns (Hansen and Sato, 2011). Even so, data from the last 50-100 years reveal certain broad trends. First, there has been a gradual warming throughout the twentieth century across most of the Indo-Pacific (Hoegh-Guldberg and Bruno, 2010). This warming has been relatively uniform, despite annual variations on local scales, and has been accompanied in Hawaiʻi by a slight reduction in precipitation and stream base flow (Oki, 2004). Current global circulation models predict warming of SSTs in an equatorial strip, stronger evaporative cooling outside the equator, a weakening of Hadley Cells and associated atmospheric circulation (Vecchi *et al*., 2006), and more persistent El Niño



Coral bleaching and disease events on Maui
Photos Credit: Greta Aeby, Hawai'i Institute of Marine Biology.

conditions in the Eastern Pacific (Xie *et al*., 2010). These model predictions, however, are based primarily on data collected prior to 1995, and are not supported by more recent observations. Instead, climate in the Eastern Pacific during the past 15 years has been characterized by increasing trade wind speeds, cooler SSTs, and more persistent La Niña conditions. This dichotomy between global model predictions and current reality may possibly be linked to the Pacific Decadal Oscillation (PDO), a climate cycle that operates on a much longer scale than the ENSO cycle that drives El Niño and La Niña events. The current 15 year prediction (2009-2024) for the PDO indicates that SSTs in the Hawaiʻi sector will remain cooler than long term averages during this period (Meehl, Hu, and Santer, 2009), which if true may buy Maui time to implement improved management practices before the PDO cycle shifts to a heightened warm phase and brings additional stress to Maui's reef ecosystems.

Global sea level has been rising steadily at 3 mm/year from 1993 onward, but this rate is not uniform around the globe (Nicholls and Cazenave, 2010). In Hawaii, the average rate of sea level rise has been 1.46 mm/year since 1900, half the global rate yet similar to trends seen on the West Coast of North America). Even within the archipelago this rate is variable, being fastest at Midway in the far northwest (+5 mm/year.), and lowest at Hilo (+1 mm/year.). By contrast, there has been a rapid rise in sea level in the Western Tropical Pacific from 1995 onward (Merrifield, M., S. Merrifield, and Mitchum, 2009), a rise that correlates well with the above noted onset of stronger winds and SST cooling in the Eastern Pacific (Firing *et al.*, 2004).



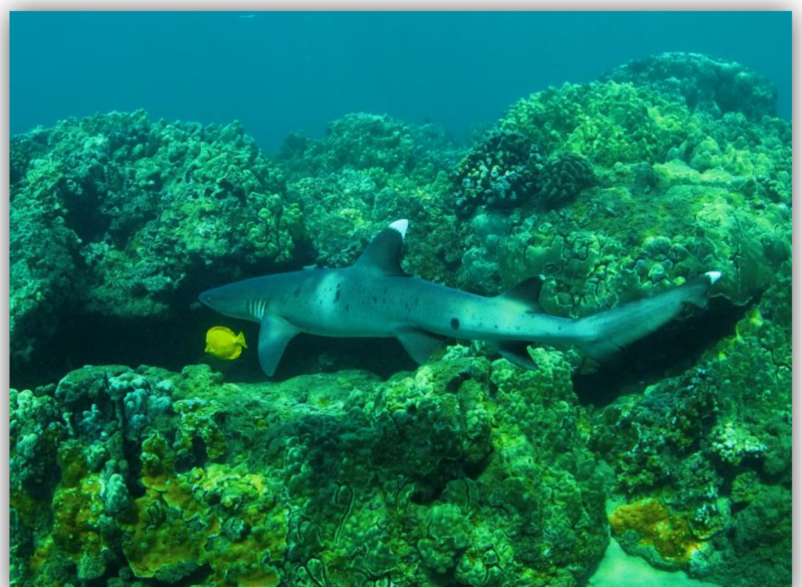
Sea level rise in Kahului, Hawaiʻi in meters, from 1900 – 2012, with projections through 2020
Photo Credit: NOAA

These trends have been largely collected from tide gauge records, and recently cross-validated with satellite altimetry; the data correlate well, indicating that the tide gauge records are accurate for the pre-satellite time series. For Maui, these trends mean that sea level around the island is rising at approximately one half the global rate (i.e., about +1.5 mm/year.), one inch every 7 years, and one foot every 82 years. As such, threats to Maui from rising sea level, if current rates are maintained, are potentially less than for other areas of the world.

Beach erosion in front of the Kahului Wastewater Treatment Plant
Photo Credit: Zoe Norcross-Nuʻu and Chip Fletcher

Global models indicate a total global rise in sea level of 3-5 feet in the next one hundred years, particularly if current rates of carbon emission continue on their sharp upward trend (Nicholls *et al.*, 2011; Rignot *et al.*, 2011). Therefore, the currently low level of sea level rise on Maui may well be an interim anomaly linked to the current phase of the PDO, and more rapid, non-linear rises in sea level may manifest themselves in future decades. Maui's reef managers should consider the impact of possible future sea levels in regard to various land-based facilities such as sewage plants, dump sites, and other contaminant sources that could adversely impact reefs if flooded, and actively seek relocation of such facilities. Rising sea level and increasing storm frequency will increase coastal erosion and sediment transport to the reefs.

As ocean temperature and atmospheric carbon dioxide concentrations change, the amount of carbon sequestered in the ocean in the form of carbonic acids also changes (Feely *et al*., 2001, 2009). The concentration of hydrogen ions increases, making it more difficult for many organisms, including corals, to incorporate calcium carbonate into their shells (Wootton, Pfister, and Forester, 2008). Although current models and observations indicate that ocean acidification proceeds more rapidly at depth and in colder waters, its effects eventually work their way into the upper ocean layers inhabited by reef-building corals, a trend that already appears to be playing out in the northern Pacific (Byrne *et al*., 2010). Statistical analysis of trends in pH as measured at more than 50 stations in Hawaiʻi by the Department of Health shows pH decreasing at significantly faster rates in inshore waters than at Station Aloha, an oceanographic monitoring site northeast of Oʻahu (Karl and Lukas, 1996). Land-based sources of groundwater pollution are suspected (Dulaiova and Berg, 2010). Previous data from Station Aloha indicate that water density is increasing near the surface, and decreasing at depth. This is an unstable equilibrium that results in greater mixing at depth; it is gradually bringing more acidic water toward the ocean surface. Overall, the upper ocean mixed layer appears to be thickening at a rate of about 4 m/decade and its temperature increasing at 0.5 °C/decade, both trends that correlate with increasing ocean acidification at the surface. For Maui, these trends put greater stress and have unpredictable effects on the island's coral reefs. This is a problem that is not fully amenable through local management alone and highlights the importance of addressing stressors that can be controlled. This will promote the best possible resilience in the face of the all but certain globally based climate stresses to come.



Ocean acidification can make the food web collapse, effecting even larger predators

Photo Credit: Don McLeish

Appendix Three – Coral Reef Management Assessment

A. Summary of Coral Reef Management Efforts to Date

A study was conducted at the outset of the formation of the MCRT to assess and evaluate past coral reef management efforts for Maui Island (Povilitis, 2011). A literature review of previous coral conservation and management efforts was conducted, paired with a series of consultations with key informants. Summary profiles were prepared for previous coral reef management efforts, including a synopsis of their supporting legislative mandates. A draft version of the report was peer reviewed for accuracy and completeness, including by MCRT members.

In sum, the study documents that the majority of management efforts to date have been non-regulatory. Most have been implemented since 2000. Overall, Maui has seen a proliferation of efforts, with more than 50 programs and plans dedicated to conserving marine resources completed to date, including: 7 efforts/projects by the County of Maui, 16 by the State of Hawaii, 8 with the US Federal Government and 20 with non-government organizations. Only a few efforts involved academia or private business.

Community driven, non-governmental groups have been successful with conservation efforts across Maui

Photo Credit: Amy Hodges

Strengths of previous coral reef management efforts around Maui include a robust policy commitment and framework (particularly at the federal level), large investments in awareness and education and a recent surge in coral conservation interest and initiatives, particularly by non-governmental groups. Weaknesses of prior efforts to date include uncertainty that management efforts can meet the requirements for coral reef recovery and health, a heavy emphasis on process instead of local action and results and a disconnect between policies and specific decisions needed to meet conservation goals.

The study recommends that for future efforts to be effective:

(a) Decision-making processes must be aligned with policy commitments.

(b) Elected officials and key decision makers must be directly involved throughout the process.

(c) Coverage beyond a single, small Maui reef site must be attempted.

(d) Best management practices (BMPs); water quality standards and fisheries management efforts must be applied to specific coral reef recovery requirements.

(e) The public should be educated and informed strategically, not broadly.

The study concludes with the following recommendations:

(a) An objective non-government scientific body of trusted scientific and management experts should be formed to periodically monitor and report on Maui's coral reef status, threats and trends, providing a complementary function that is currently missing in Maui's local government.

(b) This scientific body should offer policy implementation advice and solutions to local decision makers and work closely with them to meet their policy needs.

(c) This scientific body should systematically apply technical expertise, including by compiling and disseminating management and recovery standards for coral reefs, fish populations and water quality, assisting federal and state agencies in developing related bio-criteria, evaluating and improving BMPs to curtail polluted runoff and identifying data needs, rapid assessment procedures and priorities for research.

(d) A Maui Coral Reef Recovery Plan should be approved and implemented.

(e) Non-government groups and local government (particularly Maui County) should work together to provide factual information for public outreach, education and decision making.

(f) The effort for Maui should position county, state and federal agency decision makers at the cutting edge of conservation efforts.

B. Retrospective Analysis of Management Challenges and Failures

The MCRT came together a few times during 2011 to complete a retrospective analysis that examines past failures and challenges for Maui County. The summary results from this group analysis are:

*Past resource management decisions or efforts that have **failed** to conserve or fallen short of the desired level of conservation include:*

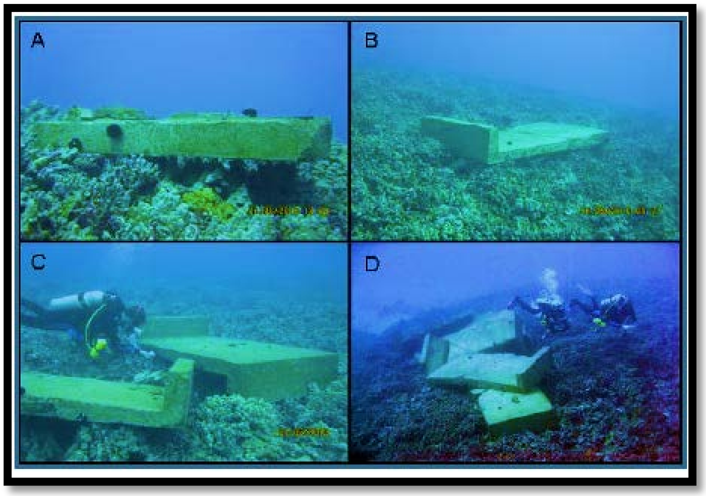
(a) Storm water management and flood control measures;

(b) County approval of development planning in floodplains and wetlands;

(c) Statutory initiatives led by the State Legislature;

(d) Placement of injection wells and wastewater treatment facilities;

(e) State implementation of federally-funded coastal zone management efforts;



Damaged healthy reef at Keawakapu due to an accident during the creation of an artificial reef nearby
Photo Credit: NOAA, NMF, DLNR-DAR

(f) Federally-funded past local efforts (outputs, but not outcomes);

(g) Scientific studies not anchored to follow-on actions;

(h) Lack of accounting of cumulative impacts on coral reefs;

(i) Unrealistically high community expectations;

(j) Poorly chosen indicators of stress and recovery and measures of success;

(k) Mismanaged artificial reef efforts damaged live reef; and

(l) Coastal zone management program not fully or effectively implemented.

Inhibiting conditions that created management ***challenges*** *and contributed toward the failure to conserve or protect Maui's coral reef ecosystems include:*

(a) Lack of political will;

(b) Lack of scientific evidence and knowledge on reef health;

(c) Lack of public awareness of the problem;

(d) Inconsistent, insufficient and ineffective State enforcement of rules and regulations;

(e) Lack of State resources to manage and enforce marine resource rules and regulations;

(f) Cumbersome State rule-making process and timeframe (2-3 years);

Concerned residents protest the practice of boats dumping their wastewater in near shore ocean waters, resulting in pump out stations being installed in the Lāhainā and Māʻalaea harbors

Photo Credit: Pump Don't Dump

(g) State legislative willingness to compromise coral reef health for special interests and limited but vocal public opinion groups;

(h) Decision-makers placing economic development ahead of natural resource protection;

(i) Poor or absent State agency leadership;

(j) Polarization of stakeholders and special interest groups from decision making; including between adversarial/non-collaborative stakeholder groups;

(k) Inadequate application of integrated land/coastal management principles;

(l) Lack of infrastructure and technical capacity to implement best management practices regarding water management;

(m) Poor integration of science, policy and management;

(n) Poor integration of social science knowledge into coral conservation projects;

(o) Federal loopholes allowing for development permits with negative impacts;

(p) Lack of understanding and appreciation of coastal resources economically, socially, culturally; and

(q) County-level missteps, including inadequate planning for climate change and sea level rise and acquiescence to land developers.

C. Retrospective Analysis of Management Successes

The MCRT also met and completed a group retrospective analysis to examine past coral reef management successes for Maui County. The summary results from this group analysis are:

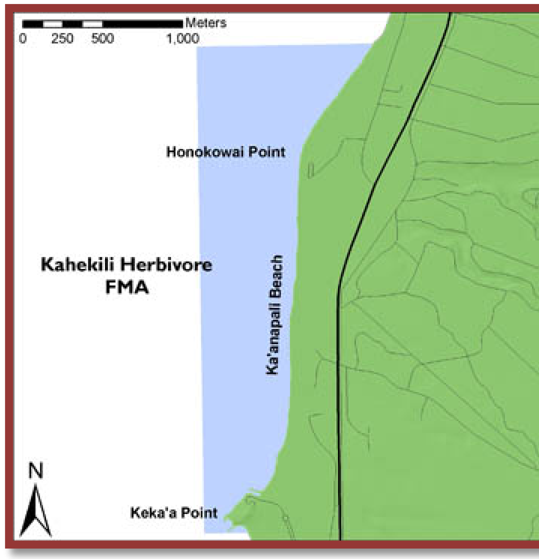


Photo Credit: DAR

(a) Maui Nui's Marine Life Conservation Districts (i.e., Honolua, Molokini, ʻĀhihi-Kīnaʻu, Mānele) have protected reefs, increased fish populations, enhanced tourism, increased landowner and local resident awareness of the value of protected marine resources;

(b) Kahekili Herbivore Fisheries Management area has broad stakeholder support and improving enforcement;

(c) The Maui County government is a progressively environmentally-friendly county in the Hawaiian Islands and is interested in supporting the implementation of a coral reef recovery plan;

(d) Efforts to address land-based sources of pollution have been completed or are underway, including closing and scaling back plantations and agricultural runoff, construction of ungulate fencing in upper watershed areas, increased wastewater reuse, construction of sediment retention basins, improved use of construction and erosion control BMPs and increased public awareness and community action;

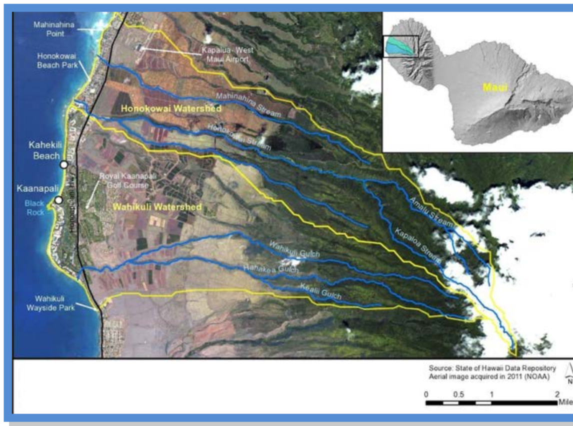
(e) Community-based marine resource management efforts are getting underway around Maui, including at community managed makai areas (CMMAs) and have international and Hawaii-based experience and lessons to build upon;

(f) Lay gill net ban (administrative only; no legislation) success;

(g) Ballast water rule success;

(h) Opportunity to build sustainability measures into Maui County Ordinances, including within the General Plan; and

(i) Development of watershed plans and conservation action plans for Kahekili area and a watershed plan for Kīhei watersheds.



Kahekili (top) and Kīhei (right) watersheds

Photo Credit: West Maui Ridge to Reef Initiative and Southwest Maui Watershed Project

[This page intentionally left blank]

Appendix Four – The Case for Action

Maui's coral reefs face multiple impacts, and the significance of specific threats varies by location. However, evidence locally and from around the world indicates an ominous and all too familiar pattern: excessive fishing alters the food web and allows algae to thrive and smother coral, runoff and sewage-contaminated ground water supports algal growth and diseases of coral, sediment from runoff directly smothers corals, and rising sea-surface temperatures cause coral bleaching and trigger coral diseases. Below we examine case histories of both coral reef collapse and recovery, to emphasize the point that actions taken in a timely fashion can save coral reefs and foster their recovery back to health. Secondly, we provide a concise overview of the range of threats to Maui's coral reefs within each case history, as a rationale for action to protect and recover them.

Dead zone off Kahekili Reef in Kaʻanapali

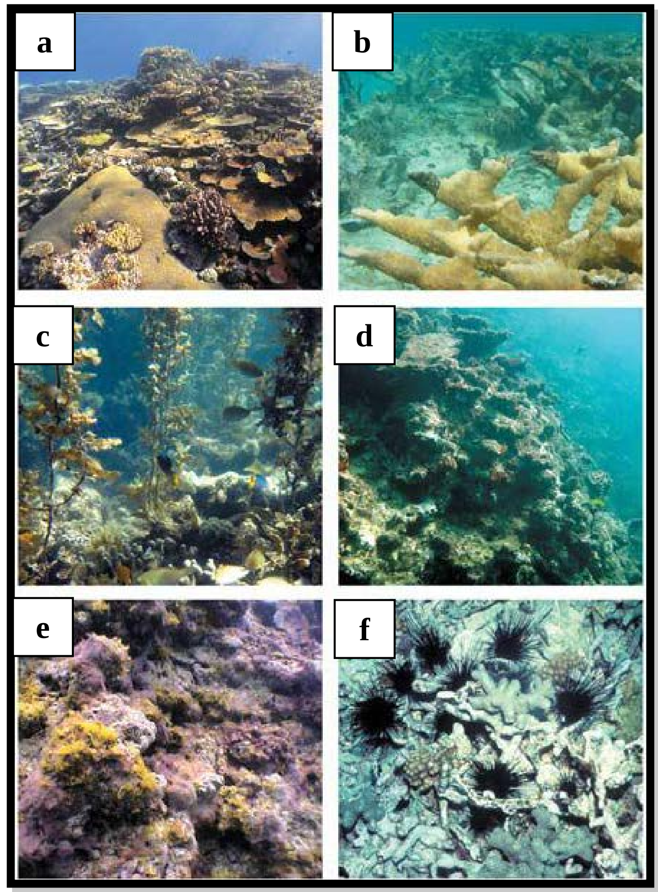
Photo Credit: Darla White

Coral Reef Demise: Māʻalaea Bay, Maui **–** In 1972, Māʻalaea coral reefs were described as being striking in their diversity and containing rare coral species. As late as 1993, estimated coral cover was 50- 75% close to the site where cover is now 8% (DAR and HCRI, 2008). Between 1996 and 1998, coastal vegetation was removed during the construction of commercial development in the area, resulting in the introduction of large sediment loads and other pollutants on Māʻalaea reefs (Jokiel and Brown, 1998). In just a few decades, the Māʻalaea reef has transformed from a healthy and diverse ecosystem into a badly degraded habitat overgrown by algae and with little surviving coral (DAR and HCRI, 2008). One consequence of severe loss of living coral is that degrading reefs change from being actively-growing and structurally-complex habitats, into eroding and relatively flat areas which do not support abundant marine

Coral in Māʻalaea being smothered by invasive algae

Photo Credit: DAR

life or biological diversity. That process is well advanced in Māʻalaea. Fish stocks are now in very poor condition, dominated by small wrasse, triggerfish and puffers. Given that the Māʻalaea reef is now a poor habitat for most grazing fishes, and that existing blooms of macroalgae will continue to inhibit new coral growth, even in the best of circumstances (elimination of water pollution and fishing impacts), recovery of Māʻalaea would likely take many years (DAR and HCRI, 2008). Such coral reef demise is being observed throughout Maui County, including on Molokaʻi (Field *et al*., 2008).



Six characteristic reef states : a) "Healthy reef", b) "stressed", c) macro algae, d) or turf, e) heterotrophic, f) barren. Images from sites on the Great Barrier Reef (a, c, d, e) and in the Caribbean (b, f)
Image credit: Bellwood 2004.

Coral Reef Demise: The Caribbean – The collapse of many Caribbean coral reefs was long preceded by dwindling stocks of fishes and increased nutrient and sediment runoff from land. On overfished reefs, the prevention of macroalgal blooms was increasingly dependent on a single species of sea urchin, *Diadema antillarum* (Bellwood *et al*., 2004). In the 1980s a disease outbreak heavily impacted the sea urchin population and precipitated macroalgal blooms destructive to corals. Today what remains of coral populations are further affected by increasingly prevalent coral diseases and climatically-induced coral bleaching. Several studies have documented phase changes from coral- to algal-dominated states on Caribbean reefs (Hoegh-Guldberg *et al*., 2007). The loss of sea urchins meant that the health of corals depended mostly on the grazing of algae by herbivorous fishes that were already overfished. Similar conditions occur in the main Hawaiian Islands.

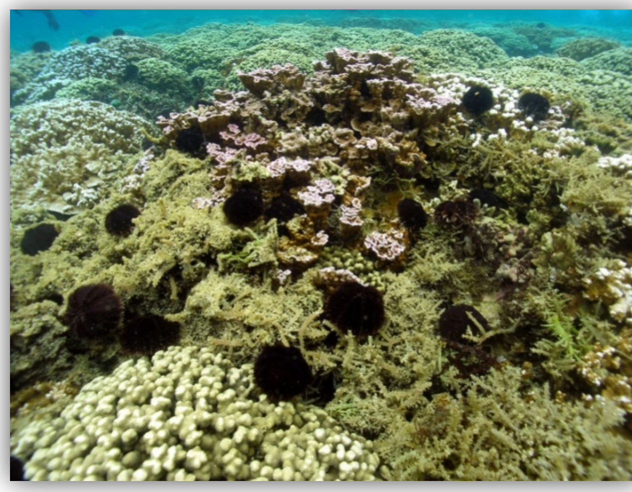
Coral Reef Revival: Kahoʻolawe **–** Overgrazing by goats led to massive erosion on the island of Kahoʻolawe. The Kahoʻolawe situation was corrected with the complete eradication of over 20,000 goats in 1990 (Jokiel *et al*., 1993). Elimination of the goats and efforts to reestablish vegetation on the island and stabilize its soils appear to be having a positive effect on the reefs. Sediment deposits are being winnowed off the reefs by wave action faster than new sediments are being deposited. Following conservation measures, rapid recruitment of new coral colonies onto the recently uncovered reef surfaces was noted at all sites around the island. The reefs appeared to be undergoing recovery. Similar responses of coral reefs to prevention of sediment damage have also been observed on the islands of Hawaiʻi (Grigg, 1995) and Kauaʻi (Jokiel *et al*., 2004; Jokiel, 2008).

Coral Reef Revival: Kāneʻohe Bay, Oʻahu -- Starting in the early 1960s, raw sewage discharged into the south basin of Kāneʻohe Bay, Oʻahu had a dramatic effect on the reefs (Maragos, 1972; Banner, 1974; Smith *et al*., 1981; Hunter and Evans, 1995). High nutrient levels led to blooms of phytoplankton, which reduced water transparency and blocked light to the photosynthetic benthos. Massive mats of the native "green bubble algae" overgrew and choked out living corals. The benthic community became dominated by macroalgae and filter feeding invertebrates. Sediments became anoxic and seaweed washed ashore to form large rotting berms of organic matter. Removal of sewage outfalls in Kāneʻohe Bay in 1979 led to dramatic decrease in nutrient levels, turbidity and phytoplankton abundance (Smith *et al*., 1981) and a rapid recovery of reef coral populations (Maragos *et al*., 1985). A major reef kill occurred in Kāneʻohe Bay in 1965 due to heavy rains acting upon soil instability (Banner, 1968). However, conditions of heavy sewage pollution prevented recovery of the reefs until after sewage abatement in 1979. The same coral reefs were subjected to a similar reef kill in late 1987, but showed substantial recovery within 5 years (Jokiel *et al*., 1993). It appears that coral reefs can recover quickly from major natural disturbances, but not polluted conditions (Jokiel, 2008).

Sediment deposits on coral

Photo credit: Mike Field

What these and other case studies tell us is that coral reefs can recover from chronic disturbances, including human impacts *if* the stress on the ecosystem is greatly reduced or eliminated, although full recovery may take much longer than degradation took (Connell, 1997; USGS, 2009). However, if conservation action is not taken in time, coral reefs can fail to regenerate and instead undergo a rapid shift to an alternate degraded state (e.g., dominance by fleshy seaweed) that may be impossible to reverse (Bellwood *et al*., 2004).



Native collector sea urchins graze on invasive algae in Kāneʻohe Bay. By augmenting the native urchin population, the *Kappaphycus* is effectively managed and the reef was kept clear of the smothering growth.

Photo credit: University of Hawaii

[This page intentionally left blank]

Appendix Five – Targets, Standards, and Measuring Success

A. Biological Recovery Targets

Targets are the specific biological resources and socio-cultural conditions that are being restored (i.e. the "what" is being restored). The primary biological targets to be restored under this recovery plan are:

(a) Coral reef habitat;
(b) Associated coral reef fish and invertebrate populations; and
(c) Adjacent coastal wetlands, estuaries, and shoreline habitat.

Increasing the abundance (percent cover), diversity (species richness), age range, and health of reef building corals is one of the primary targets for recovery. Coral reef habitat protection will focus on mitigating stressors such as excess nutrients, pollutants, excess sediment, and overfishing. Restoration efforts such as urchin restocking, invasive algae removal, and coral propagation and transplantation could be done concurrently, but fewer resources would be dedicated to these projects compared to protection.

Photo credit: Mark Deakos

Coral reef fishes in Hawaiʻi represent a diverse group that includes over 500 species ranging in size from small gobies and blennies that are only a few cm in length to large sharks and *ulua* (jacks) that exceed a meter and can weight > 100 lbs. Because of this broad diversity, there is no one single measure that can adequately characterize the entire assemblage. Typical measures of fish assemblage structure include the total number of species, the total number of individuals, and biomass or weight. However, coral reef fishes vary in what they eat, where they live, and their importance in cultural, recreational, commercial, and subsistence fisheries. In this plan, **biomass** will be the primary target in recovery.

Biomass is considered a good proxy of ecosystem function as it represents metabolic requirements and therefore energy fluxes in the ecosystem. Therefore fish biomass is often used as an important measure of fish assemblage structure and ecosystem health. Based on an analysis of multiple datasets, fish biomass around the main Hawaiian Islands ranged from 1.28 t ha^{-1} on

Kahoʻolawe (Friedlander and DeMartini, 2002) to 0.4 t ha^{-1} on Oʻahu (Friedlander *et al*., 2008). Fish biomass on Maui was 0.65 t ha^{-1}, was similar to Kauaʻi and slightly lower than Hawaiʻi Island. However, separating biomass into fished ("targeted") and un-fished groups help to examine the effects of fishing compared with other potential impacts such as habitat degradation. For example, Williams *et al*. (2008) showed that declines in fish biomass for targeted species around the main Hawaiian Islands correlated with increasing human populations, while non-targeted biomass did not change. Therefore, fishing pressure rather than habitat quality was affecting the abundance of fishes observed.

Photo credit: Fernando Lopez Arbarello

Total fish abundance and the number of species present can be indications of fish assemblage health. These measures, however, are extremely habitat dependent and relative trends over time are therefore a better indication of "health" and recovery rather than absolute values. For example, basalt boulder habitats harbor fewer fish species compared to coral rich habitats because the latter provides a greater diversity of habitats and "pukas" or holes.

Kaʻonoulu Gulch outlet wetland at high tide
Photo credit: Sarah McLane

Coastal wetlands are among the most productive, valuable, and yet most threatened ecosystems in the world due to their desirability for human habitation. They provide a variety of functions that reduce the impact of land-based storm flow and associated stressors on the coastal zone, such as slowing the flow of water from the mountains to the sea, trapping of sediments, and retaining or transforming nutrients (Bruland, 2008). At one time Hawaiʻi contained an estimated 59,000 acres of wetlands (Fabricius, 2005). Although the remaining wetlands cover less than three percent of Hawaiʻi's surface area, they are extremely important because they support a suite of plant and animal species found only in the Hawaiian Islands. Hawaiʻi's wetlands are inhabited by five endangered endemic water bird species, including the Hawaiian duck, Hawaiian stilt, Hawaiian moorhen, Hawaiian goose and the Hawaiian coot. A major contributing factor to declining populations of these species is the loss of wetland habitats due to coastal development (Hawaii Wetland Joint Venture, 2007).

Land-based pollution is causing degradation of coral reefs and fisheries on the Island of Maui (DAR and HCRI, 2008). Numerous studies (Fabricius, 2005) have reported that increased soil erosion and nutrient export from land-based management are threatening estuaries, coastal zones, and adjacent coral reef ecosystems. Coastal wetlands are located at a critical interface between the terrestrial and marine environments and are ideally positioned to reduce impacts from land-based sources (Bruland, 2008).

Federal biologist Terrell Erickson stated that more than half of south Maui's coastal wetlands have been lost to development in the past 40 years. Kīhei had 199 wetland acres in 1965. That number shrunk to 83 acres in 2001 and still continues to drop.

Wetlands collect sediment prior to reaching the reef
Photo credit: Mia Charleston

Due to the high amounts of rainfall and steep slopes of the Pacific Islands' landscape, researchers at the University of Hawaiʻi contend that all lands should be classified and treated as coastal lands (Bruland, 2008).

The MCRT and peer reviewers also considered including the following biological targets once the recovery plan had been implemented and experienced success, but agreed that it would be important to first focus on the three previously stated targets above:

(a) Deep water corals;
(b) Gorgonians;
(c) All inshore habitat; and/or

(d) Pelagic waters.

B. Socio-Cultural Recovery Targets

The primary socioeconomic and cultural targets to be restored are:

(1) Sustainable commercial and recreation fisheries; and
(2) Traditional knowledge and customary management practices.

Photo credit: Paul Hanada

A goal of recovery would be to integrate traditional knowledge into modern resource management. Our communities today must rely upon existing knowledge of marine resources to find a balance between human harvesting and resource replenishment. Elders in the community and members with extensive knowledge of specific locations should be brought into the process of setting new limitations for consumption in their respective communities.

C. Recovery Standards

The standards of recovery are the benchmarks against which the progress of the targets in their restoration is to be measured (i.e., "to what" the targets will be restored).

The ultimate outcomes desired from achievement of this plan include:

(1) Fish and coral are abundant, diverse, and resilient;
(2) Coral reef ecosystems are balanced;
(3) The economic value is recognized and used fairly in decision-making;
(4) Cultural practices and activities thrive;
(5) The reef supports local jobs and sustainable harvesting; and
(6) There is a widely-exercised ethic of coral reef protection.

Signs of coral ecosystem recovery at two sites over ten years include:

(a) Increase in coral cover;
(b) Increase in fish abundance and biomass;
(c) Decrease in algal cover (invasive or otherwise);
(d) Increase in coral recruitment;
(e) Larger and older fish; and
(f) Increased recruitment events and survivorship.

Recovery standards for reproductive and recruitment success include:
(1) Stable or relative increase in coral settlement rate of 10% within 10 years;
(2) Relative increase in abundance of 10% for target female fish of reproductive size within 10 years; and

(3) Relative increase in abundance of 5% for target fish recruits within 10 years.

In the case of fish species, larger, older individuals typically have exponentially greater reproductive output and the larvae of these individuals often have substantially better survival potential than do larva from younger fishes. Fishing disproportionately targets larger individuals, but these individuals are the most important for the reproductive success and sustainability of the population. We need to focus on protecting the larger or older individuals of long-lived fish species rather than concentrating on regulating the total numbers harvested from the population. For example, Hawaiians traditionally harvested intermediate-sized *moi* (*mana* and *pala moi*) rather than taking the juveniles or large reproductively important females (Poepoe, Bartram, and Friedlander, 2007).

Photo Credit: Mark Deakos

Information on the relative abundance of the newly recruited fishes should allow for assessment of the future health and population dynamics of the assemblage. Monitoring recruitment can help inform future management decisions.

Recovery standards for the fish assemblage include:
(1) Relative increase in fish species richness of 5% within 10 years;
(2) Relative increase in fish abundance of 10% within 10 years; and
(3) Relative increase in fish biomass of 50% within 10 years.

Robin Knox, water quality expert, collects water samples for a monitoring program.
Photo Credit: Watershed Advisory Group

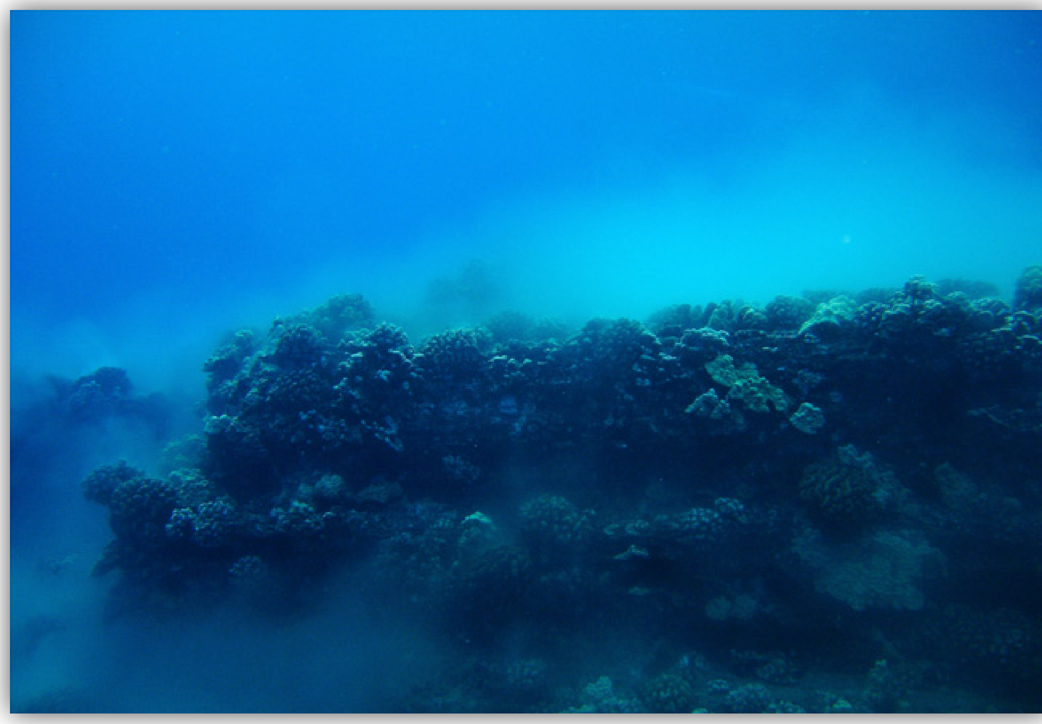
In terms of standards for ecological function, the recovery plan can look to large apex predators, such as sharks and jacks that exert a strong top-down control on the ecosystem. They structure prey population sizes and age distributions and strongly influence the reproductive and growth dynamics of harvestable fishes as well as smaller-bodied, lower-trophic-level fishes. In addition to the direct effect on the abundance of these species, apex predators indirectly affect the structure and function of the entire ecosystem through top-down control. Based on a meta-analysis of fish count data around the main Hawaiian Islands, apex predators only accounted for 4% of the total fish biomass observed.

In contrast, apex predators accounted for > 50% of the biomass on reefs in the northwestern Hawaiian Island (Friedlander and DeMartini, 2002). Within the main Hawaiian Islands, apex predator biomass ranges from 19% on Kahoʻolawe to < 1% on Oʻahu. Overall apex predator biomass on Maui is 3%.

Water quality and native stream restoration standards also apply under this plan. This restoration plan will apply the State of Hawaii, Department of Health water quality standards as targets for water quality improvements. Hawaiʻi's standards for nutrients and turbidity are relatively stringent, but are not based specifically on coral reef protection. However, in the absence of coral-based targets, the Hawaiʻi water quality standards are a starting point and would mark significant improvements for many of Maui's coastal waters.

Water and substratum quality must be restored to levels allowing for successful reproduction and recruitment of corals, fishes and invertebrates. Success of coral recruitment is a useful target for assessing the adequacy of water quality improvement. The sensitive stages of coral reproduction include reproductive synchronization among individuals of the same species (chemical cueing), successful egg-sperm interactions leading to fertilization of eggs and development of embryos, survivorship of embryos as they develop in the water column, the ability of competent larvae to detect and respond to chemical cues responsible for site selection and subsequent metamorphic induction, and in the case of coral larvae, their ability to recognize and take up the proper clades of symbiotic zooxanthellae when needed.

Another useful indicator of water quality conditions is the prevalence of nuisance macroalgal blooms. We seek to reduce nutrient loads to the point where the standing stocks of *Hypnea*, *Ulva*, *Cladophora* and other nuisance blooms are reduced in extent and frequency. Macroalgae can overgrow and smother coral reefs due to this increased nutrient input as well as from a



Coral spawn event

Photo Credit: Pauline Fiene

reduction in herbivore abundance. There is a strong positive correlation between high herbivore (surgeonfishes and parrotfishes) biomass and reduced cover of macroalgae. In locations around Maui where herbivore biomass was greater than 0.2 t ha^{-1}, macroalgae cover, on average, was less than 10%. Targeting a reduction in macroalgal blooms through improved water quality and protection of herbivore fish populations should in turn, have positive effects on coral reef communities.

Recovery standards for the benthic habitat quality and quantity include:
(1) Stable or relative increase in percent coral cover of 10% within 10 years;
(2) Relative increase in coral species richness of 10% within 10 years;
(3) Relative decrease in macroalgae percent cover of 10% within 10 years; and
(4) Stable or relative decrease in disease frequency of 10% within 10 years.

In terms of climate change adaptation standards, ecosystems that are more "intact" are more resistant and resilient to episodic natural disturbances such as hurricanes as well as potential long-term chronic perturbations such as climate change. Reefs lacking the full complement of ecosystems components will be less stable and more susceptible to these large-scale changes.

D. Measuring Success

The monitoring and evaluation of coral reef recovery efforts will require incorporation of recovery standards into existing measures and data collection efforts. This plan will take an adaptive management approach to monitoring coral recovery performance. Development of adaptive management actions will occur concurrently.

Reef Monitoring
Photo Credit: Megan Dailer

The specific measures and methods used will be identified once an implementation activity work plan has been developed following the approval, adoption, and implementation of this plan. During 2012, the MCRT began the process of developing a draft implementation activity work plan. Once finalized, appropriate measures of success underlying the specific objectives and associated activities will be identified and proposed for measurement.

Monitoring of both the status of the targets and the management effectiveness of recovery actions will occur periodically throughout the implementation of the recovery plan. Status measures periodically track changes in the both the biological and social targets. Status measures will be used to document ecosystem response to actions taken under practices within restoration strategies. Implementation of performance diagnostics, with community inputs, will occur at demonstration sites. Performance measures will be evaluated to periodically track progress being made against recovery standards and intended goals and objectives. Targeted, site-specific monitoring and evaluation plans will be implemented at each demonstration site, and will use available data sources already under collection.

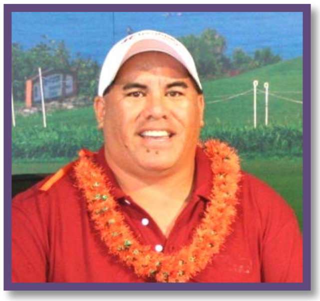
[This page intentionally left blank]

Maui Coral Reef Recovery Team

Thorne Abbott (Coastal and Natural Resource Planning and Policy)

Thorne is an experienced coastal manager and environmental planner. His efforts to improve proposed developments by capitalizing on innovative natural resource conservation have led to worldwide experience including efforts in Asia, Polynesia, Australia, Turkey and Hawaii, among others. His background integrates four broad topical areas including; constructed wetlands, water quality and watershed planning; shoreline, beach and coastal management; protected areas, species of special concern and sanctuary's; and policy, permitting and law. Thorne has worked in the government, non-profit, education and research, and private sectors. Based on that experience, he has served as a shoreline and coastal resources expert and has helped develop cross-jurisdictional, multi-sector approaches to solving complex coastal and environmental problems. He seeks innovative methods to balance competing interests and promote sustained use within the coastal zone. He is active in the coastal community and presently serves on the Hawaiian Islands Humpback Whale National Marine Sanctuary Advisory Committee, Hawaiʻi Audubon Society Board of Directors, and the Legacy Land Conservation Commission by Governor appointment.

Kaʻau Abraham (HI Humpback Whale National Marine Sanctuary)



Kaʻau Abraham is the Maui Island Coordinator for the Hawaiian Islands Humpback Whale National Marine Sanctuary. In his capacity he works with staff, volunteers, partners and community members. Born and raised on the island of Oʻahu, Kaʻau has always had a passion for taking care of the marine environment learning about mālama ʻāina and mālama kai. After leaving the airline industry in 2001 he was employed by several marine conservation and education organizations. Giving back to communities and organizations has been a high priority to Kaʻau, in 2003 he began also volunteering the sanctuary's Maui site. Prior to joining the sanctuary program in 2010 Kaʻau worked as a marine naturalist at the Maui Ocean Center and then become the sixth Education Manager at the aquarium. He continues to support the sanctuary program and its mission and goals to provide a place to explore the marine environment, serve communities, teach the children and preserve maritime and cultural heritage.

Eric Brown (National Park Service)

Eric is the Marine Ecologist for Kalaupapa National Historical Park on Molokaʻi. He received his B.S. in Marine Biology from Occidental College, his M.S. in Biology from Texas A&M University and his Ph.D. in Zoology from the University of Hawaii. His Ph.D. research focused on coral reef community ecology, specifically spatial and temporal trends in community structure at six reefs on Maui. After moving to Hawaiʻi in 1986, Eric worked with the Pacific Whale Foundation, documenting the recovery and general biology of humpback whales and other endangered marine mammals. In 1989, he branched out into coral reef research and served as principal investigator, for nine years, on Maui's Threatened Reef project with the Foundation. This project was done in conjunction with Earthwatch Institute, based in Watertown, Massachusetts. His current research focus, at Kalaupapa and across the state, examines coral recruitment dynamics, long-term trends in coral community structure, and watershed activities in relation to the condition of the marine environment.

Jay Carpio (Fisherman, Wailuku CMMA)

James "Jay" Carpio holds a Bachelor's Degree in Horticulture from UH Hilo. He is an avid fisherman, hunting guide, farmer, and sheep rancher, along with an Ahupuaʻa Steward. Jay is also Lawaiʻa, Mahiʻai and program manager for Wailuku CMMA, is a Cub Scout leader, and Chair of the Abundance of Fishes Committee for the MNMRC.

Rhiannon Tereari'i Chandler (UH Richardson School of Law)

Rhiannon has been a member of the MNMRC since 2009. She has a B.A. in Ethnic Studies, with an emphasis in Hawaiian Studies, from the University of Hawai`i at Mānoa. Rhiannon formerly served on the Maui County Cultural Resources Commission and served as the Executive Director of the environmental non-profit organization Community Work Day Program d.b.a. Mālama Maui Nui. Rhiannon currently attends the William S. Richardson School of Law.

Mia Charleston (Maui Restoration Group)

Mia was born in landlocked Pennsylvania but fell in love with the ocean watching Jacques Cousteau and reading Eugenie Clark books. She completed her B.S. degree in Oceanography from the University of West Florida. Mentors include professors Dr. Edward Petuch (Geosciences), the late Dr. Ray McAllister (Ocean Engineering) and the late Dr. Peter Lutz from Florida Atlantic University. Mia has worked in the marine and environmental fields for over 20 years including positions with the Fl. Dept. of Environmental Protection, MNMRC, and is currently working with the Maui Restoration Group and Leeward Haleakalā Watershed Restoration Partnership.

Eric Conklin (The Nature Conservancy)

Eric Conklin is the Marine Science Director of TNC-Hawaiʻi's Marine Program. His areas of expertise include coral reef ecology and restoration, reef resilience, invasive species, monitoring, and community-based management. The team he supervises focuses on ensuring that TNC's marine conservation strategies are informed by the best available science and that the effectiveness of those strategies is critically evaluated through focused monitoring and research projects. Eric has a Ph.D. in zoology from the University of Hawai`i at Mānoa.

Mark Deakos (Hawai'i Association for Marine Education and Research)

Mark was fortunate to experience living in various countries around the globe during his early years. A common thread in his life has always been water. His chosen career working in wildlife biology and marine research is an extension of his passion for the natural world and his marvel of the ocean environment. Mark obtained his Biology degree from the University of Waterloo. At the University of Hawaii, he completed his master's degree studying humpback whale behavior and his doctoral degree focused on manta ray ecology. In 2004, Mark founded The Hawaiʻi Association for Marine Education and Research, a not-for-profit corporation with the mission of better understanding and protecting Hawaiʻi's marine resources.

Alan Friedlander (UH-Adjunct Associate Professor)

Alan Friedlander is currently the assistant leader of the Hawaiʻi Cooperative Fishery Research Unit and associate professor in the Department of Zoology at the University of Hawaiʻi at Mānoa. He holds a Ph.D. from the University of Hawaiʻi and was a National Research Council Postdoctoral Associate with the Pacific Fisheries Environmental Laboratory in Pacific Grove, California. Alan was as a fisheries extension officer in the Kingdom of Tonga in the early 1980s and for nearly 30 years he has conducted coral reef fisheries and ecosystem-based research throughout the Indo-Pacific and Caribbean regions. His work incorporates ecology, remote sensing and GIS technologies, along with traditional resource knowledge to better understand coral reef ecosystem function and how best to conserve and manage these resources for future generations. He has authored or co-authored 65 peer-reviewed publications and 15 book chapter over the course of his career.

Elia Herman (HI Humpback Whale National Marine Sanctuary)

Elia Herman is the State Co-Manager of the Hawaiian Islands Humpback Whale National Marine Sanctuary at the State of Hawaiʻi's Department of Land and Natural Resources. She received her Master's degree in Environmental Management from Duke University and has spent many years conducting research on humpback whales and other marine mammals in Hawaii. Elia also has extensive national experience, having worked on marine conservation issues at National Geographic; as a legislative fellow with the U.S. Congress developing aquaculture, energy, and ocean education policy; and as the manager of a campaign at the Pew Charitable Trusts that focused on strengthening U.S. international environmental policy. Elia has written for magazines and journals, broadcast on the radio, and developed public service announcements on a range of environmental and community management issues. She grew up in Honolulu, HI and received her B.A. in History from Brown University in 2001.

Robin Knox (Coordinator – Southwest Maui Watershed Plan)

Robin Knox is the Owner and Principal Scientist of Water Quality Consulting, Inc., an environmental services firm specializing in Clean Water regulation and policy, water quality management and aquatic ecosystem restoration. She has close to 30 years of experience including project management, water quality monitoring, coastal biogeochemistry, wastewater treatment, watershed planning, water quality modeling, total maximum daily loads, coastal restoration, the Clean Water Act, and National Pollutant Discharge Elimination System (NPDES) permitting. For the past six years, Robin has been supporting local communities around Maui Island to address and resolve clean water issues for both human and coral reef health, and is a recognized expert in water quality management, monitoring, and regulatory compliance for Maui. She serves as the Coordinator of the Southwest Maui Watershed Plan and a member of the University of Hawaiʻi interdisciplinary research team investigating the impacts of injection wells on Maui's water quality and coral reef ecosystems. She is a member of the Maui Nui Marine Resource Council, and served as a founding member of the Council's Clean Water Committee and Turbidity Task Force. She served on the County of Maui Community Wastewater Working Group appointed by Mayor Charmaine Tavares. She serves on the Hawaiian Islands Humpback Whale National Marine Sanctuary (HIHWNMS) Water Quality Working Group and serves as science advisor to the Sanctuary's Citizen Science program.

Ekolu Lindsey (Maui Cultural Lands, Polanui Hiu CMMA)

Edwin "Ekolu" Lindsey is the President of Maui Cultural Lands, Inc whose mission is to stabilize, protect, and restore Hawaiian cultural resources. He is also one of the founders of the Polanui Hiu Community Managed Makai Area (CMMA). Ekolu believes in the ʻōlelo noʻeau: He aliʻi ka ʻāina, he kauā ke kanaka (The land is chief and we are its servants).

Manuel Mejia (The Nature Conservancy)

Manuel is the Hawaiʻi Community-Based Marine Program Manager with The Nature Conservancy. His background is in biodiversity conservation and received his Master's degree in environmental science and policy from Columbia University. Manuel is passionate about marine conservation and has worked toward sustainable fisheries, conservation finance, habitat restoration and capacity building for conservation across the Asia-Pacific region for many years. Manuel believes that investing in our marine environment and the next generation of Hawaiʻi's future leaders are critical to ensuring sustainable resource management, food security and self-reliance for island communities. Indeed, as communities, we need to take care of our blue realm, in order for us to be green and thrive.

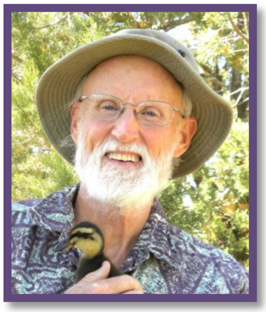
Robin Newbold (Maui Nui Marine Resource Council, Chair)

Robin Newbold, Chair of the Maui Nui Marine Resources Council (MNMRC) co-found the Council with *Kupuna* Ed Lindsey in 2007, and succeeded him as Chair. Robin is a former professor of marine biology and oceanography at Saddleback College in California and is an active SCUBA diver and spokesperson for Maui's reefs. Beginning in 1995 Robin participated in coral reef research efforts around Maui Nui and spearheaded the introduction of REEF to Hawaiʻi in 1999 to foster a sense of reef awareness and stewardship among Maui's residents. Robin is the Maui representative to the Hawaiian Islands Humpback Whale National Marine Sanctuary's advisory council and recently chaired the Sanctuary's Water Quality Working Group during the management plan review process. Robin was recently appointed to the Natural Area Reserves System (NARS) Commission. She has made over a thousand research- oriented SCUBA dives throughout the Pacific and recently participated in the Palau-Hawaiʻi learning exchange in Palau. Robin is committed to involving the community in restoration of our reefs through the Community Managed Marine Areas (CMMA) effort.

Dan Polhemus (US Fish & Wildlife Service)

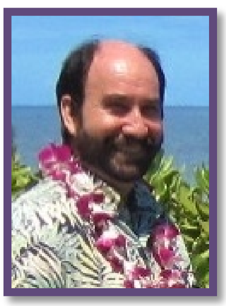
Dr. Polhemus is an administrator for the Pacific Islands US Fish & Wildlife Service on Oʻahu. Dr. Polhemus also served as an Administrator of the Division of Aquatic Resources at the Hawaiʻi State Department of Land and Natural Resources and a Research Associate at the Bishop Museum in Honolulu, Hawaiʻi. Dan has been conducting research on the semi-aquatic insects (*Heteroptera*) and Damselflies (*Odonata*) of the Pacific region for over 20 years, with a particular concentration of survey effort on New Guinea and adjacent island arc systems. His major interest is in attempting to integrate patterns of species richness and phylogenetic evolution in freshwater aquatic biotas with evolving earth history models to understand the zoogeographic development of the Asia-Pacific region during the last 70 million years. Dan has authored over 120 scientific papers and several books, and is a world authority on the taxonomy and systematics of aquatic and semi-aquatic insects (*Heteroptera*), and Pacific basin Damselflies (coenagrionid *Zygoptera*). He has participated as a member of the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve Advisory Council, and aided in the creation of the Papahānaumokuākea Marine National Monument, serving as their Chair of the Monument Management Board.

Tony Povilitis (Life Net Nature)



Tony Povilitis directs LifeNetNature, a nonprofit conservation organization promoting wildlife research, citizen science, and progressive public policies. He has a B.S. in entomology from the University of Maine, received his M.S.P.H. from the University of North Carolina in environmental science. In 1979 Tony acquired a Ph.D. Colorado State University in wildlife biology. Tony has worked around the world as a Conservation director, American Wildlands, Montana; Border Impacts Program coordinator, National Park Service, Organ Pipe Cactus National Monument, Arizona; Earthwatch principal investigator (PI), Chile, and co-PI, Ecuador; Director, Fish and Wildlife Department, Pueblo of Zuni, New Mexico and as the acting director for the Division of Natural Resources, Pueblo of Zuni.

Bob Richmond (UH – Principal Investigator)



Professor Bob Richmond is a Pew Fellow in Marine Conservation, President of the International Society for Reef Studies and a Leopold Fellow in Environmental Leadership. He has a Ph.D. from SUNY at Stony Brook, in Biological Sciences and has been an acting Director and Research Professor for the Kewalo Marine Laboratory of the University of Hawaiʻi at Mānoa. He has been on the Organizing Committee for the International Coral Reef Symposiums and now serves as the Pacific Scientific Representative for the U.S. Coral Reef Task Force as well as a member of the University of the Virgin Islands NSF-EPSCoR Program Review Committee. He also served as the Associate Editor, for the *Marine Biology* journal. His recent research has been focusing on reproduction and coral recruitment, and looking at cellular diagnostics as a way to measure coral reef decline.

Celia Smith (UH- Marine Botanist)

Dr. Smith is a Ph.D. from Stanford University in Botany, and is a professor at the University of Hawaiʻi-Mānoa (UHM). Smith was involved in saturation diving research projects using the National Oceanic and Atmospheric Administration's Florida-based Aquarius research station, where she and a team of colleagues from five other institutions studied the ecology of two species of *Halimeda* (Genus of green macroalgae). While heading her own laboratory at the UHM, Smith continues to play integral roles in various phycologically-based areas such as native algae, invasive alien algae, and biofouling research. Dr. Smith contributes her expertise in the genus *Halimeda* and other algae in Hawaiʻi towards a better understanding of deep water algal assemblages in Hawaii.

Russell Sparks (Maui Division of Aquatic Resources)

Russell Sparks received his B.S. in Biology from Oregon State University. He received his M.S. in Marine Biology from University of Hawaiʻi at Mānoa in 1996. Since 1998 Russell has worked as the Education Specialist for the State of Hawaiʻi, Department of Land and Natural Resources, Division of Aquatic Resources, Maui, Hawaii. He is responsible for designing and instituting educational programs intended to increase public awareness about conservation and responsible use of our aquatic resources. Other duties include leading the design, implementation, and overall management of all the Maui marine resource assessment and monitoring projects.

John Summers (Maui County Planning Department)

John Summers is the Administrator for the Long-Range Planning Division of the Maui County Planning Department. Prior to taking on the Long Range Division, John was responsible for the Planning Department's legislative policy development and redevelopment programs. Before joining the County of Maui, John was a senior Planner and Policy Analyst with the State of Hawaiʻi's Office of State Planning. John has a MURP in Urban and Regional Planning from the UH Mānoa and a B.S. in Business Economics.

Brian Tissot (Washington State University- Marine Ecologist)

Brian is a Professor in the School of the Environment at Washington State University in Vancouver. Professor Tissot runs the WSU Vancouver Benthic Ecology Laboratory which is focused on the ecology and conservation of marine invertebrates and fishes. They investigate issues at the interface between conservation science, management, and policy, using quantitative statistical approaches combined with geospatial tools to explore the ecology of physical and biological components of habitat for commercially important fishes with an emphasis on structure-forming invertebrates. In his work in West Hawaii, he helped improve the management of an aquarium fishery along the Kona coast by being a part of a collaborative research program with state biologists and policy makers, Sea Grant extension, and the local community.

Darla White (Maui Division of Aquatic Resources)

Darla White is the Special Projects Coordinator for the Hawaiʻi DLNR Division of Aquatic Resources on Maui and is part of the Marine Monitoring Team that looks at near shore fish populations and coral health. She is also the Eyes of the Reef Network Coordinator for Maui Island, and is an Ex-officio member of the Maui Nui Marine Resources Council. Darla attended the University of Hawaiʻi at Hilo, where she received a Bachelor's degree in Marine Science and a Master's of Science Degree in Tropical Conservation Biology and Environmental Science. She has been a research diver in Hawaiʻi since 2000, and has had the rare privilege to dive on scientific expeditions to nearly all of the islands in the Hawaiian Archipelago. Her experience and interests are wide ranging, including fishes, coral reef ecology, climate change, marine disease, ocean acidification, water quality, harmful algal blooms, ciguatera, marine ecosystem monitoring, anthropogenic impact assessment, reef resilience and network marine reserves.

Wendy Wiltse (Environmental Protection Agency)

Wendy Wiltse, a Senior Environmental Scientist in Region 9's Wetlands Office, has broad experience with EPA working in Boston, San Francisco, Hawaii, and the Pacific Islands. Based in Hawaiʻi for the last 20 years, she works on a range of EPA's water quality management and enforcement programs, with a emphasis on coral reef and wetlands protection. Wendy came to Hawaiʻi in 1993 from EPA Region 9 in San Francisco to coordinate a community-based watershed management project in West Maui to address nuisance algal blooms and improve coastal water quality. Wendy has a Ph.D. in Marine Ecology from the University of Massachusetts and completed a postdoctoral fellowship at Woods Hole Oceanographic Institute.

Tegan Hammond (MNMRC Coral Reef Recovery Plan Coordinator)

Tegan is experienced in implementing collaborative community based marine conservation strategies in partnership with local community members, scientists and government agencies. As a program manager for Mālama Maunalua, she gained experience in marine resource management in Hawaiʻi serving as a key leader for both makai and the mauka programs. She has a natural love and proven track record of developing and nurturing partnerships with community, local businesses, and government partners. Tegan's love of the ocean took hold diving at the Channel Islands off the coast of California when she was eleven; she was absolutely captivated by what she saw and experienced. She was first exposed to how resource management is deeply engrained in Hawaiian traditions and values while earning a degree at UH Mānoa in Hawaiian Language. Whether diving, surfing or paddling canoe, the ocean is a place of refuge for Tegan and she is very excited to be a part of an exceptional team working toward the preservation of these special places.

Amy Hodges (MNMRC Operations and Programs Coordinator)

Amy is committed and passionate about working toward a healthy and sustainable future for Maui. She supports numerous community groups working to restore Maui's native marine and terrestrial ecosystems, using both traditional ecological knowledge and modern science. Through her work with the Council, Amy has learned the critical importance of community participation and input in effective conservation and restoration efforts on Maui. Amy is originally from Maine and graduated from Bowdoin College with a degree in Art and Biology.

John Parks (Marine Management Solutions)

For twenty years, John Parks has worked with local communities, indigenous leaders, resource users, government agencies, and non-governmental organizations to employ marine resource management solutions that strengthen the environmental and civil security in coastal communities around the world. During this time, John has served in a number of non-government and government organizations, including as a federal officer with the U.S. National Oceanic and Atmospheric Administration and as senior staff with the Nature Conservancy, World Wildlife Fund, and the World Resources Institute. John assists government and non-governmental clients around the world design and implement marine management solutions, including for fisheries management, marine protection, maritime enforcement, and climate change adaptation. John earned his undergraduate and graduate degrees from the University of Miami in Florida, with a dual focus on tropical coastal ecology and human behavior. He is a member of the IUCN World Commission on Protected Areas, and has been a contributing or lead author on numerous books, peer-reviewed journal articles, and other publications.

References

Banner, Albert H. *A fresh-water "kill" on the coral reefs of Hawaii*. Honolulu (HI): Hawai'i Institute of Marine Biology, University of Hawai'i. Report No.: 15. 1968.

---. "Kaneohe Bay, Hawaii, Urban pollution and a coral reef ecosystem." *Proceedings of the Second International Symposium on Coral Reefs*. Vol. 2. 1974.

Bellwood, David R. T.P. Hughes, C. Folke and M. Nyström. "Confronting the coral reef crisis." *Nature* 429.6994 (2004): 827-833.

Bishop, Richard C., David J. Chapman, Barbara J. Kanninen, Jon A. Krosnick, Bob Leeworthy, and Norman F. Meade. 2011. Total Economic Value for Protecting and Restoring Hawaiian Coral Reef Ecosystems: Final Report. Silver Spring, MD: NOAA Office of National Marine Sanctuaries, Office of Response and Restoration, and Coral Reef Conservation Program. NOAA Technical Memorandum CRCP 16. 406 pp. Available at: http://coralreef.noaa.gov/aboutcrcp/news/featuredstories/oct11/hi_value/resources/protecting_restoring_hawaiian_cre.pdf, 2011.

Bruland, Gregory L. "Coastal wetlands: function and role in reducing impact of land-based management." *Coastal Watershed Management. WIT Press, Southhampton, UK* (2008): 85-124.

Byrne, Robert H., S. Mecking, R. A. Feely, and Xuewu Liu. "Direct observations of basin-wide acidification of the North Pacific Ocean." *Geophysical Research Letters* 37.2 (2010): L02601.

Choat, J. Howard, William D. Robbins, and Kendall D. Clements. "The trophic status of herbivorous fishes on coral reefs." *Marine Biology* 145.3 (2004): 445-454.

Chuenpagdee, Ratana, Julia Fraga, and I. Jorge. "Progressing toward co-management through participatory research." *Society and Natural Resources* 17.2 (2004): 147-161.

Chuenpagdee, Ratana, and Svein Jentoft. "Step zero for fisheries co-management: what precedes implementation." *Marine Policy* 31.6 (2007): 657-668.

Connell, Joseph H. "Disturbance and recovery of coral assemblages." *Coral reefs* 16.5 (1997): 101-113.

County of Maui, Hawaii. Department of Planning. *Maui Island Plan General Plan 2030 Draft*. Wailuku, HI: County of Maui, 2009.

Dailer, Meghan L., R.S. Knox, J.E. Smith, M. Napier, and C. Smith. "Using δ^{15}N values in algal tissue to map locations and potential sources of anthropogenic nutrient inputs on the island of Maui, Hawaiʻi, USA." *Marine Pollution Bulletin* 60.5 (2010): 655-671.

DAR and CRAMP (Division of Aquatic Resources and Coral Reef Assessment and Monitoring Program). Trends in Coral Cover: Maui. State of Hawaii. Department of Land and Natural Resources. 2012.

[DAR and HCRI] Division of Aquatic Resource and Hawaiʻi Coral Reef Initiative. (2008) *Status of Maui's Coral Reefs*. State of Hawai'i, Department of Land and Natural Resources, Division of Aquatic Resources (DAR) and Hawaii Coral Reef Initiative (HCRI). 2 pp. Web. http://cramp.wcc.hawaii.edu/Downloads/Publications/TR_2008_Maui_Reef_Declines.pdf

Dulaiova, Henrieta, and Carl Berg. "Comments to EPA on the value of pH in the listing of impaired waters under Section 303(D)". In response to Clean Water Act Section 303(d): Notice of Call for Public Comment on 303(d) Program and Ocean Acidification. Environmental Protection Agency (EPA). May 21, 2010.

Fabricius, Katharina E. "Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis." *Marine pollution bulletin* 50.2 (2005): 125-146.

Feely, Richard A., S.C. Doney, and S.R. Cooley. "Ocean acidification: present conditions and future changes in a high-CO2 world." *Oceanography* 22.4 (2009).

Feely, Richard A., Christopher L. Sabine, Taro Takahashi, and Rik Wanninkhof. "Uptake and storage of carbon dioxide in the ocean." *Oceanography* 14.4 (2001): 18.

Field, Michael E., Cochran, Susan A., Logan, Joshua B., and Storlazzi Curt D., eds., 2008, The coral reef of south Moloka`i, Hawai`i; portrait of a sediment-threatened fringing reef: U.S. Geological Survey Scientific Investigations Report 2007-5101, 180 p. [http://pubs.usgs.gov/sir/2007/5101/].

Firing, Yvonne L., Mark A. Merrifield, Thomas A. Schroeder, and Bo Qiu. "Interdecadal sea level fluctuations at Hawaii." *Journal of Physical Oceanography* 34.11 (2004): 2514-2524.

Friedlander, A.M., G. Aeby, E. Brown, A. Clark, S. Coles, S. Dollar, C. Hunter, P. Jokiel, J. Smith, B. Wals, h, I. Williams, and W. Wiltse. 2005. The State of Coral Reef Ecosystems of the Main Hawaiian Islands. pp. 222-269. In: J. Waddell (ed.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005. NOAA Technical Memorandum NOS NCCOS 11. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 522 pp.

Friedlander, A.M., G. Aeby, R. Brainard, E. Brown, K. Chaston, A. Clark, P. McGowan, T. Montgomery, W. Walsh, I. Williams and W. Wiltse. 2008. The State of Coral Reef Ecosystems of the Main Hawaiian Islands. pp. 219-261. In: Waddell, J.E. and A.M. Clarke (eds.), *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States.* NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 2008. 569 pp.

Friedlander, Alan M., and Eric Brown. "Marine protected areas and community-based fisheries management in Hawaii." *Status of Hawaii's coastal fisheries in the new millennium (AM Friedlander, ed.). Proceedings of the 2001 fisheries symposium sponsored by the American Fisheries Society, Hawaii Chapter. Honolulu, Hawaii. 2004.*

Friedlander, Alan M., Eric K. Brown, and Mark E. Monaco. "Coupling ecology and GIS to evaluate efficacy of marine protected areas in Hawaii." *Ecological Applications* 17.3 (2007): 715-730.

Friedlander, Alan M., and Edward E. DeMartini. "Contrasts in density, size, and biomass of reef fishes between the northwestern and the main Hawaiian islands: the effects of fishing down apex predators." *Marine Ecology Progress Series* 230 (2002): 253-264.

Friedlander, Alan M., J.M. Shackeroff, and J.N. Kittinger. (In Review). Traditional marine resource knowledge and use in contemporary Hawaiʻi. *Pacific Science*.

Goreau, T. J. "Case study: Waste nutrients: Impacts on coastal coral reefs and fisheries, and abatement via land recycling." *Proceeding of United Nations Expert Meeting on Waste Management in Small Island Developing States*. 2003.

Grigg, R. W. "Coral reefs in an urban embayment in Hawaii: a complex case history controlled by natural and anthropogenic stress." *Coral Reefs* 14.4 (1995): 253-266.

Hamnett, M.P., M. Liu, and D.B. Johnson. *Fishing, Ocean Recreation, and Threats to Hawaii's Coral Reefs: Results from a December 2004 Household Survey*. Honolulu: 2004. Web. http://www.hcri.ssri.hawaii.edu/files/education/fishingbrochure.pdf.

Hansen, J. E. and M. Sato. "Paleoclimate Implications for Human-Made Climate Change. NASA Goddard Institute for Space Studies and Columbia University Earth Institute, New York. 2011.

Hawaii Tourism Authority. "Visitor Satisfaction and Activity Report.". *Hawaii Tourism Authority*. 2010. Web. 9 Dec. 2012. http://www.hawaiitourismauthority.org/default/assets/File/reports/visitorsatisfaction/201%20VSAT%20Report%20%28FINAL2%29.pdf.

Hawaii Wetland Joint Venture. "Building Partnerships for Hawaii's Wetlands." *Hawaii Wetland Monitor* Nov. 2007: 1.1.

Hobson, Edmund S. "Feeding relationships of teleostean fishes on coral reefs in Kona, Hawaii." *Fish. Bull* 72.4 (1974): 915-1031.

Hoegh-Guldberg, Ove, P. J. Mumby, A. J. Hooten, R. S. Steneck, P. Greenfield, E. Gomez, C. D. Harvell *et al*. "Coral reefs under rapid climate change and ocean acidification." *Science* 318, no. 5857 (2007): 1737-1742.

Hoegh-Guldberg, Ove, and John F. Bruno. "The impact of climate change on the world's marine ecosystems." *Science* 328.5985 (2010): 1523-1528.

Hoeke, Ron K., Paul L. Jokiel, Robert W. Buddemeier, and Russell E. Brainard. "Projected changes to growth and mortality of Hawaiian corals over the next 100 years." *PloS One* 6.3 (2011): e18038.

Hughes, Terence P. "Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef." *Science* (1994): 1547-1547.

Hunt, C.D., Jr., and Rosa, S.N., 2009, A multitracer approach to detecting wastewater plumes from municipal injection wells in nearshore marine waters at Kihei and Lāhainā, Maui, Hawaii: U.S. Geological Survey Scientific Investigations Report 2009-5253, 166 p.

Hunter, Cynthia L., and Christopher W. Evans. "Coral reefs in Kaneohe Bay, Hawaii: two centuries of western influence and two decades of data." *Bulletin of Marine Science* 57.2 (1995): 501-515.

Jokiel, P. L., K. S. Rodgers, W. J. Walsh, D. A. Polhemus, and T. A. Wilhelm. "Marine resource management in the Hawaiian archipelago: the traditional Hawaiian system in relation to the western approach." *Journal of Marine Biology* 2011 (2010).

Jokiel, Paul L. "Biology and ecological functioning of coral reefs in the main Hawaiian Islands." *Coral Reefs of the USA* (2008): 489-517.

Jokiel, Paul L., Eric K. Brown, Alan Friedlander, S. Rodgers and William R. Smith. "Hawai'i coral reef assessment and monitoring program: Spatial patterns and temporal dynamics in reef coral communities." *Pacific Science* 58.2 (2004): 159-174.

Jokiel, Paul L., and E. Brown (1998) Coral Baseline Survey of Mā'alaea Harbor for Light-Draft Vessels, Island of Maui. Submitted to U.S. Army Corps of Engineers, Honolulu, Hawaii in fulfillment of Contract No. DACW83-96-P-0216.

Jokiel, Paul. L., C. L. Hunter, S. Taguchi, and L. Watarai. "Ecological impact of a fresh-water "reef kill" in Kaneohe Bay, Oʻahu, Hawaii." *Coral Reefs* 12, no. 3 (1993): 177-184.

Karl, David M., and Roger Lukas. "The Hawaii Ocean Time-series (HOT) program: Background, rationale and field implementation." *Deep Sea Research Part II: Topical Studies in Oceanography* 43.2 (1996): 129-156.

Kelly, Ryan P., M. M. Foley, W. S. Fisher, R. A. Feely, B. S. Halpern, G. G. Waldbusser, and M. R. Caldwell. "Mitigating local causes of ocean acidification with existing laws." *Science* 332.6033 (2011): 1036-1037.

Kittinger, J.N. Participatory fishing community assessments to support coral reef fisheries co-management. *Pacific Science (In review)*.

Littler, Mark M., and Diane S. Littler. "Models of tropical reef biogenesis: the contribution of algae." Prog. Phycol. Res., 3. (1984): 323-364.

LMMA (Locally Managed Marine Network). *2010 Annual Report: Defining Our Future*. Aug. 2011. Web. http://www.lmmanetwork.org/files/annual_reports/LMMA2010AR.pdf

Maragos, James E. *A study of the ecology of Hawaiian reef corals*. University of Hawaii. (Oceanography), 1972.

Maragos, James E., C. Evans, and P. Holthus. "Reef corals in Kaneohe Bay six years before and after termination of sewage discharges (Oʻahu, Hawaiian Archipelago)." *Proceedings of the fifth international coral reef congress, Tahiti 27 May- 1 June 1985*. Vol. 4. 1985.

Maunupau, Thomas. *Ancient Hawaiian Civilization: A Series of Lectures Delivered at the Kamehameha Schools*, E.S. Craighill Handy, ed. (Rutland, Vermont: Charles E. Tuttle Company, (1965) 110-111.

McClanahan, Timothy R., Michael J. Marnane, Joshua E. Cinner, and William E. Kiene. "A comparison of marine protected areas and alternative approaches to coral-reef management." *Current Biology* 16.14 (2006): 1408-1413.

McClenachan, Loren, and John N. Kittinger. "Multicentury trends and the sustainability of coral reef fisheries in Hawaiʻi and Florida." *Fish and Fisheries* (2012).

Meehl, Gerald A., Aixue Hu, and Benjamin D. Santer. "The mid-1970s climate shift in the Pacific and the relative roles of forced versus inherent decadal variability." *Journal of Climate* 22.3 (2009): 780-792.

Merrifield, M. A., S. T. Merrifield, and G. T. Mitchum. "An anomalous recent acceleration of global sea level rise." *Journal of Climate* 22.21 (2009): 5772-5781.

National Research Council: Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations. *Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia*. National Academy Press, 2011.

[NMFS] National Marine Fisheries Service. *Recovery plan for the humpback whale (Megaptera novaeangliae)*. National Marine Fisheries Service (NMFS) Silver Springs, MD. 1991.

Nicholls, Robert J., and Anny Cazenave. "Sea-level rise and its impact on coastal zones." *Science* 328.5985 (2010): 1517-1520.

Nicholls, Robert J., Natasha Marinova, Jason A. Lowe, Sally Brown, Pier Vellinga, Diogo de Gusmão, Jochen Hinkel, and Richard SJ Tol. "Sea-level rise and its possible impacts given a 'beyond 4^0 C world' in the twenty-first century." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 369.1934 (2011): 161-181.

Oki, Delwyn S. *Trends in streamflow characteristics at long-term gaging stations, Hawaii*. US Department of the Interior, US Geological Survey, 2004.

Poepoe, Kelson, Paul Bartram, and Alan Friedlander. *The use of traditional Hawaiian knowledge in the contemporary management of marine resources*, Haggan, N., Neis, B., and Baird, I., eds., Fishers' knowledge in fisheries science and management: Oxford, Blackwell Publishing (2007), p. 114–144.

Povilitis, T. *An evaluation of conservation efforts related to the coral reefs of Maui Island, Hawaii*. Maui Coral Reef Recovery Team. Maui Nui Marine Resource Council. Maui, Hawaii, 2011.

Rignot, E., I. Velicogna, M. R. Van den Broeke, A. Monaghan, and J. Lenaerts. "Acceleration of the contribution of the Greenland and Antarctic ice sheets to sea level rise." *Geophysical Research Letters* 38.5 (2011): L05503.

Roberts, Callum M., Colin J. McClean, John EN Veron, Julie P. Hawkins, Gerald R. Allen, Don E. McAllister, Cristina G. Mittermeier *et al*. "Marine biodiversity hotspots and conservation priorities for tropical reefs." *Science* 295.5558 (2002): 1280-1284.

Rogers, Caroline S. "Responses of coral reefs and reef organisms to sedimentation." *Marine ecology progress series. Oldendorf* 62.1 (1990): 185-202.

Selig, Elizabeth R., Kenneth S. Casey, and John F. Bruno. "Temperature-driven coral decline: the role of marine protected areas." *Global Change Biology* (2012).

Smith, Jennifer E., John W. Runcie, and Celia M. Smith. "Characterization of a large-scale ephemeral bloom of the green alga Cladophora sericea on the coral reefs of West Maui, Hawai'i." *Marine Ecology Progress Series* 302 (2005): 77-91.

Smith, Stephen V., William J. Kimmerer, Edward A. Laws, R. W. Brock, and Ted W. Walsh. "Kaneohe Bay sewage diversion experiment: perspectives on ecosystem responses to nutritional perturbation." *Pacific Science* 35.4 (1981).

Soicher, A. J., and F. L. Peterson. "Terrestrial nutrient and sediment fluxes to the coastal waters of west Maui, Hawai'i." *Pacific Science* 51.3 (1997): 221-232.

State of Hawaii. *Hawai'i Coral Reef Strategy: Priorities for Management in the Main Hawaiian Islands 2010-2020.* Honolulu, HI. 2010.

State of Hawaii. Hawaii Department of Health. *2012 State of Hawaii Water Quality Monitoring and Assessment Report: Integrated Report to the U.S. Environmental Protection Agency and the U.S. Congress.* Honolulu, HI. 2012.

Steneck, R. S. "Crustose corallines, other algal functional groups, herbivores and sediments: complex interactions along reef productivity gradients." *Proceedings of the 8th International Coral Reef Symposium*. Vol. 1. Panama: Smithsonian Tropical Research Institute, 1997.

Storlazzi, C. D., & Field, M. E. (2008). *Winds, waves, tides, and the resulting flow patterns and fluxes of water, sediment, and coral larvae off West Maui, Hawaii*. US Geological Survey.

Titcomb, Margaret. *Native Use of Fish in Hawaii: With the Collaboration of Mary Kawena Pukui*. Avery Press, 1952.

United States Congress. S. 46--112th Congress: "Coral Reef Conservation Amendments Act of 2011". GovTrack.us (database of federal legislation). 2011. December 9, 2012. http://www.govtrack.us/congress/bills/112/s46

[USFWS] U.S. Fish and Wildlife Service. "Revised recovery plan for Hawaiian forest birds." *US Fish and Wildlife Service, Region* 1 (2006).

USGS (U.S. Geological Survey). Science-based strategies for sustaining coral ecosystems: U.S. Geological Survey Fact Sheet 2009-3089 (2009), 4 p.

Vecchi, Gabriel A., Brian J. Soden, Andrew T. Wittenberg, Isaac M. Held, Ants Leetmaa, and Matthew J. Harrison. "Weakening of tropical Pacific atmospheric circulation due to anthropogenic forcing." *Nature* 441.7089 (2006): 73-76.

Veron, John E. N., O. Hoegh-Guldberg, T. M. Lenton, J. M. Lough, D. O. Obura, P. Pearce-Kelly, C. R. C. Sheppard, M. Spalding, M. G. Stafford-Smith, and A. D. Rogers. "The coral reef crisis: the critical importance of <350 ppm CO_2." *Marine Pollution Bulletin* 58.10 (2009): 1428-1436.

West Maui Watershed Management Advisory Committee. *West Maui watershed owners' manual*. Report prepared for Hawaii Department of Health, U.S. Environmental Protection Agency, National Oceanographic and Atmospheric Administration, and the West Maui community. (1997). 104 pp.

Williams, Ivor D., W. J. Walsh, R. E. Schroeder, A. M. Friedlander, B. L. Richards, and K. A. Stamoulis. "Assessing the importance of fishing impacts on Hawaiian coral reef fish assemblages along regional-scale human population gradients." *Environmental Conservation* 35.3 (2008): 261.

Williams, Ivor. D., W. J. Walsh, A. Miyasaka, and A. M. Friedlander. "Effects of rotational closure on coral reef fishes in Waikiki-Diamond Head Fishery Management Area, Oʻahu, Hawaii." *Marine Ecology Progress Series* 310 (2006): 139-149.

Williams, Ivor D., and Nicholas Polunin. "Large-scale associations between macroalgal cover and grazer biomass on mid-depth reefs in the Caribbean." *Coral Reefs* 19.4 (2001): 358-366.

Wolanski, Eric, Jonathan A. Martinez, and Robert H. Richmond. "Quantifying the impact of watershed urbanization on a coral reef: Maunalua Bay, Hawaii." *Estuarine, Coastal and Shelf Science* 84.2 (2009): 259-268.

Wootton, J. Timothy, Catherine A. Pfister, and James D. Forester. "Dynamic patterns and ecological impacts of declining ocean pH in a high-resolution multi-year dataset." *Proceedings of the National Academy of Sciences* 105.48 (2008): 18848-18853.

Xie, Shang-Ping, Clara Deser, Gabriel A. Vecchi, Jian Ma, Haiyan Teng, and Andrew T. Wittenberg. "Global Warming Pattern Formation: Sea Surface Temperature and Rainfall." *Journal of Climate* 23.4 (2010): 966-986.

Glossary

Biodiversity — The term 'biodiversity' (i.e., biological diversity) refers to the variability among living organisms, from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part, including diversity within species, between species, and within the ecosystem, as a whole.

Coral – The term 'coral' refers to any species of the phylum *Cnidaria*, which produces a stony exoskeleton or forms sclerites, including:

(a) All species of the orders *Antipatharia* (black corals), *Scleractinia* (stony corals), *Gorgonacea* (horny corals), *Stolonifera* (organpipe corals and others), *Alcyonacea* (soft corals), and *Helioporacea* (blue coral) of the class *Anthozoa*; and
(b) All species of the families *Milleporidea* (fire corals) and *Stylasteridae* (stylasterid hydrocorals) of the class *Hydrozoa*.

Coral reef – The term 'coral reef' refers to the hard or unconsolidated carbonate structures and their associated natural formations and biological communities, composed of living organisms (being dominated by zooxanthellate stony corals (Class *Anthozoa*, Order *Scleractinia*), soft corals (Class *Ahnthozoa*, Subclass *Alcyonaria*), zooanthids (Class *Anthozoa*, Order *Zoanthiniaria*), algae (both fleshy and calcareous) or sea grasses) and which often include: echinoderms, mollusks, crustaceans, fishes, sponges and annelids. Coral reefs may include associated sand, mud, rock, sea grass and/or mangrove habitats, and their physical, chemical, trophic and/or ecological interactions and integration. For the purposes of this recovery plan, coral reefs are generally restricted to shallow (< 500 feet depth) tropical and subtropical estuarine, coastal and/or oceanic waters.

Coral reef component – The term 'coral reef component' refers to any part of a coral reef, including individual living or dead corals, and their associated vertebrates (e.g., fish), invertebrates (e.g., crustaceans, echinoderms) and marine plants, including any adjacent or associated sea grasses.

Coral reef ecosystem – The term 'coral reef ecosystem' refers to the system of coral reefs and geographically-associated species, habitats and dependent environmental linkages, including any adjacent or associated aquatic habitats (e.g., wetlands and sea grasses), as well as the processes that control their dynamics. Such systems are significantly influenced by neighboring terrestrial (upland) and atmospheric systems, such as watersheds, drainage systems, atmospheric and sunlight considerations, or any other natural system contributing to the health of a coral reef. Coral Reef Ecosystems include the physical, chemical, trophic and ecological interactions with all the surroundings that contribute to maintain the natural optimum functions and organisms represented.

Research – The term 'research' refers to *bona fide* scientific investigation on corals, the results of which are likely:

a) To be published (or be eligible for publication) in a peer-reviewed scientific journal;
b) To contribute to the basic knowledge of the biological or social sciences; and/or
c) To identify, evaluate, or resolve conservation problems, including status, effectiveness monitoring and evaluation.

Restoration – The term 'restoration' is defined as returning stable ecological functioning and health to systems that are damaged or no longer fully functional. This includes restoration of the natural capital, or ecosystem goods and services that are provided by a healthy and functional ecosystem. This definition recognizes that ecosystems naturally change over time, and that a return to "pre-contact" state is not possible, given global climate change.

Maui Coral Reef Recovery Team in February 2011: (From Left to Right, Top Row) Rhiannon Chandler, Jay Carpio, Robin Newbold, Russell Sparks, John Parks, Dan Polhemus, John Summers, Wendy Wiltse, Darla White, Robin Knox, Mark Deakos, Bob Richmond, Mia Charleston, and Brian Tissot. (Bottom row) Eric Brown, Tony Povilitis, Alan Friedlander, and Celia Smith.

Photo credit: John Parks

Relevant Further Reading

Caillaud, Anne, *et al*. "Tabus or not taboos." *How to use traditional environmental knowledge to support sustainable development of marine resources in Melanesia. SPC Traditional Marine Resource Management and Knowledge Information Bulletin* 17 (2004): 14-35.

Dailer, Meghan L., *et al*. "Algal δ^{15}N values detect a wastewater effluent plume in nearshore and offshore surface waters and three-dimensionally model the plume across a coral reef on Maui, Hawai ʻi, USA." *Marine Pollution Bulletin* (2012).

Dailer, Meghan L., Jennifer E. Smith, and Celia M. Smith. "Responses of bloom forming and non-bloom forming macroalgae to nutrient enrichment in Hawai ʻi, USA." *Harmful Algae* (2012).

DeMartini, Edward E., and Alan M. Friedlander. "Predation, endemism, and related processes structuring shallow-water reef fish assemblages of the NWHI." *Atoll Research Bulletin* 543 (2006): 237-256.

Jimenez-Badillo, L. "Management challenges of small-scale fishing communities in a protected reef system of Veracruz, Gulf of Mexico." *Fisheries Management and Ecology* 15.1 (2008): 19-26.

Manu, M. *Hawaiian Fishing Traditions*. Kalamaku Press. Honolulu, HI. 1992.

Randall, John E. *Shore fishes of Hawai'i*. University of Hawaii Press, 2010.

Rodríguez-Martínez, R. E. "Community involvement in marine protected areas: The case of Puerto Morelos reef, México." *Journal of environmental management* 88.4 (2008): 1151-1160.

Sparks, R., Kristy Stone, and Darla White. "Maui and Lānaʻi Monitoring Report: Updated to Include Data Collected between 10/2006 – 09/2010." DAR and DLNR, 2010. Web. 9 Dec. 2012.http://cramp.wcc.hawaii.edu/Downloads/Publications/TR_2010_Maui_DAR.pdf

Tanji, M. Healing Maui watersheds: Pollutants, Runoff studied. *The Maui News* (2004, December 6). Maui, HI.

Photo Credit: Don McLeish

MAUI NUI

Marine Resource Council

Mahalo to the partners of the Maui Coral Reef Recovery Plan

Mayor's Office of Economic Development Maui County

National Fish and Wildlife Foundation NFWF

Harold K.L. Castle Foundation

Marine Management Solutions

National Marine Sanctuaries Hawaiian Islands Humpback Whale

The Nature Conservancy Protecting nature. Preserving life.

Tri-Isle RC&D

University of Hawaii Mānoa 1907

Water Quality Consulting, Inc.

Maui Cultural Lands Education Archaeology Reforestation

Coastal Planners, LLC www.coastalzone.com

United States Environmental Protection Agency

HAMER

Maui Watershed

Pacific Whale Foundation Protecting our oceans through science and advocacy

Life Net

U.S. Fish & Wildlife Service Department of the Interior

DAR Hawaii Division of Aquatic Resources

FernandoLopezArbarello Photography | www.TheReefAlive.com