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The Coral Reef of South Moloka‘i, Hawai‘i

Portrait of a Sediment-Threatened Fringing Reef

Scientific Investigations Report 2007-5101

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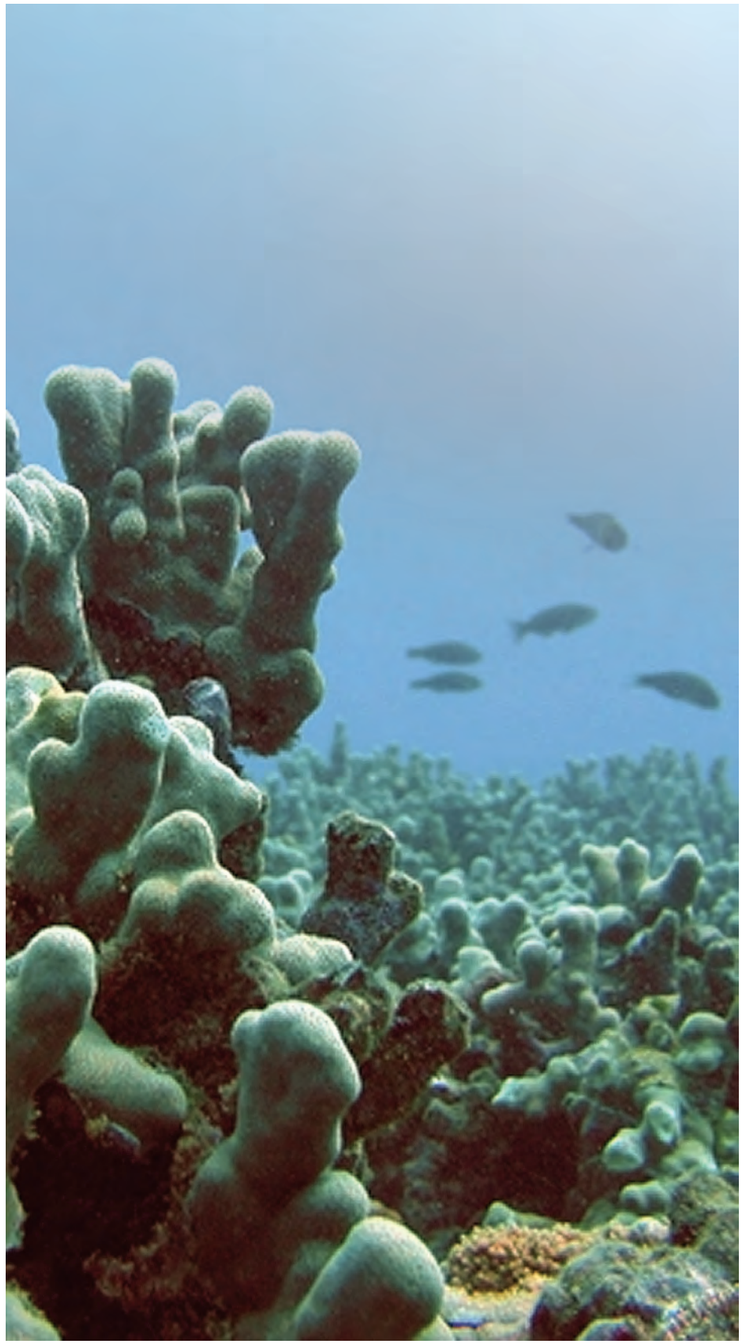
Portrait of a Sediment-Threatened Fringing Reef

Edited by Michael E. Field, Susan A. Cochran, Joshua B. Logan, and Curt D. Storlazzi



Scientific Investigations Report 2007–5101

U.S. Department of the Interior
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CONTENTS

FOREWORD

Molokaʻi, with the most extensive coral reef in the main Hawaiian Islands, is especially sacred to Hina, the Goddess of the Moon. As Hinaalo, she is the Mother of the Hawaiian people; as Hinapukuʻa, she is the Goddess of Fishermen; and in the form Hinaʻopuhalakoʻa, she is the Goddess who gave birth to coral, coral reefs, and all spiny marine organisms. Interdependence between the reef's living resources, the people, and their cosmology was the basis for management of Molokaʻi's coastal waters for over a thousand years.

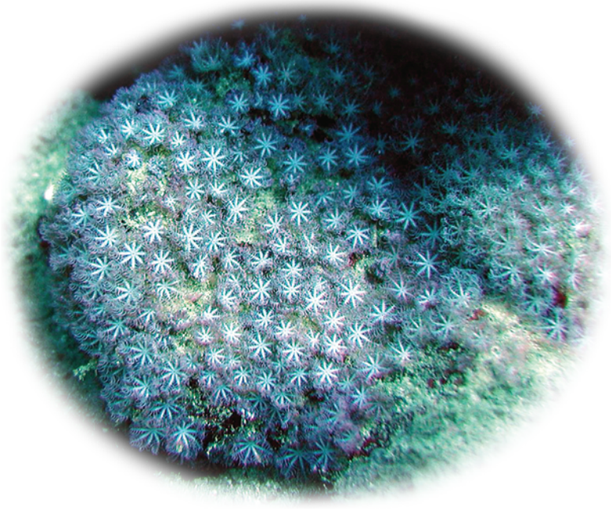
The ancient residents of Molokaʻi built the greatest concentration of fishponds known anywhere, but their mastery of mariculture, something needed now more than ever, was lost after near genocide from exotic Western diseases. Subsequent destruction of the native vegetation for exotic cattle, goats, pigs, sugar cane, and pineapple caused soil erosion and sedimentation on the reef flat. This masterful volume clearly documents that soil washing into the sea is the major threat to the reef today. Abandoned fishponds, choked with sediment, now act as barriers and mud traps, making damage to corals less than it would otherwise would have been.

The role of mud and freshwater from land in preventing coral reef growth, clearly articulated in Charles Darwin's first book, The Structure and Distribution of Coral Reefs, is the major theme of this book. All around the tropics, coral reefs have died from huge increases in terrestrial sedimentation that resulted from destruction of hillside forests for cash-crop agriculture and pastures in the colonial era, especially in Latin America, Asia, and the islands of the Caribbean and Indo-Pacific. It is obvious that one cannot manage the coastal zone as a unit separate from the watersheds that drain into it. Yet there has been surprisingly little comprehensive scientific study of these impacts.

In this landmark volume, U.S. Geological Survey researchers and their colleagues have developed and applied a remarkably integrated approach to the reefs of Molokaʻi, combining geology, oceanography, and biology to provide an in-depth understanding of the processes that have made these reefs grow and that now limit them. They have joined old fashioned natural history of marine animals and plants with study of the geological evolution of the island, hydrology, meteorology, and land-use history, to an arsenal of new methods of remote sensing, including aerial photography, laser ranging, infrared thermal mapping, seismic reflection, in-situ instrumentation to measure chemical parameters of water quality, and direct measurements of the physical driving forces affecting them—such as wave energy, currents, sedimentation, and sediment transport. They provide a level of documentation and insight that has never been available for any reef before.

A remarkable feature of this book is that it is aimed at the people of Molokaʻi to inform them of what is happening to their reef and what they might do to preserve their vital resources. The scientific data and interpretations are expressed in unusually clear and comprehensible language, free of the professional jargon that makes most technical publications impenetrable to the public that most needs to know about them, yet without loss of scientific rigor.

Here readers will see clearly explained the whole path of soil loss, from the impacts of wild pigs and goats at higher elevations, deforestation of the hills for cattle pasture at lower levels, and denudation of low lands for cash crops. The resulting biological impoverishment has bared the soils, which wash away in flash storms, smothering the inshore reefs, whose growth was already limited because they had grown right up to sea level. The data in this book show that the mud doesn't get far if it is washed into the sea during a big storm with heavy waves. Afterwards this mud keeps getting stirred up by every succeeding storm, spreading and affecting corals over wider areas until it is finally washed out of the system—and that only happens if there is no more new mud washing onto the reef.



I saw this myself a few years ago in Pilaʻa Bay on Kauaʻi, where a bulldozed hillside of abandoned sugar cane fields had slumped right on top of a coral reef following exceptional rains. Years later, the algae species were zoned in a way that clearly mapped the distribution of nutrients washed into the bay, most likely from fertilizers bound to the eroded soils. That pattern closely mimics, on a small scale, that shown in Molokaʻi in this volume, where the inner reef is covered with algae, zoned by species in a way that points to land-based sources of nutrients, while the outermost reef slope is still coral dominated, and the deep algae seem to indicate deep-water nutrient upwelling.

What of the future? The Hawaiian Islands have been exceptionally fortunate to be spared the worst coral heatstroke death from high temperatures, at least to date. So far, the worst global warming impacts have luckily been small in this region, and the small number of people on Molokaʻi has kept population densities, and sewage pollution, low compared to the more developed islands. Nutrients from years of sugar and pineapple fertilization, and the washing of this soil onto the reefs, show clear influences on the pattern of algae on the reef. Even at very low levels of nutrients, well below that which drives algae to smother and kill coral reefs, more algae is present. Soil erosion control is therefore the key to better management of both nutrients and turbidity on Molokaʻi reefs. To that end land management actions mentioned in this book, such as suppressing wild fires and eliminating wild goats and pigs, could be made even more effective if supplemented by active erosion control using plants whose roots bind the soil effectively in place. Through all of these efforts, Hina and the people of Molokaʻi could be happy again!

Thomas J. Goreau, Ph.D.
President, Global Coral Reef Alliance

PREFACE

Two themes pervade this publication. One is the beauty, grandeur, and majestic resource that the fringing coral reef off south Moloka‘i represents to the people of Moloka‘i and Hawai‘i—and indeed to people everywhere. The other theme is the threats that face that same reef.

Hawaiian reefs, like other reefs worldwide, harbor an incredible diversity of plant and animal life, and that richness is reflected in the cultural traditions of native peoples and in prosperity from tourism. However, coral reefs are in decline worldwide (Hughes and others, 2003a), and Hawai‘i and Moloka‘i are no exception. An abundance of land-derived silt has washed from Moloka‘i’s slopes and threatens the health of the island’s reef by blocking light and choking the reef inhabitants. Conditions on Hawai‘i’s reefs vary from island to island and location to location (some areas show signs of improving), and the causes of degradation are both natural and human induced. Natural disturbance by large waves is being exacerbated by increased sediment runoff. Islands erode by natural processes, but the activities of humans—deforestation, agriculture, cattle and sheep farming, introduction of feral grazers, increased wildfires, construction —often cause the release of sediment at higher rates than occur naturally. Nowhere is this more evident than on the island of Moloka‘i. In 1979—a full two decades before U.S. Geological Survey (USGS) scientists visited Moloka‘i to study sediment on the reef—the famous ocean explorer Jacques-Yves Cousteau wrote:

> One of the most serious dangers to coral reefs is sedimentation. This threat is dramatically illustrated in Hawaii. With the arrival of Westerners, upland soil was plowed for sugar cane and pineapple. The impact of the resulting erosion has been tragic. Since 1897 the shoreline of Molokai has advanced as much as a mile and a quarter across the reef flat. Elsewhere off Molokai, the reef is overlaid with four to 27 inches of red-brown silt. (Cousteau, 1985, p. 191)

It is noteworthy that of all the troubled reefs in the world, Cousteau singled out Moloka‘i as the example for sedimentation on reefs.

Starting in 1999, the USGS, along with university and agency partners, initiated a study to map the reef off south Moloka‘i and describe the coral, analyze the sediment, and measure the processes that suspend and transport sediment on the reef. This publication reports the results of those endeavors.

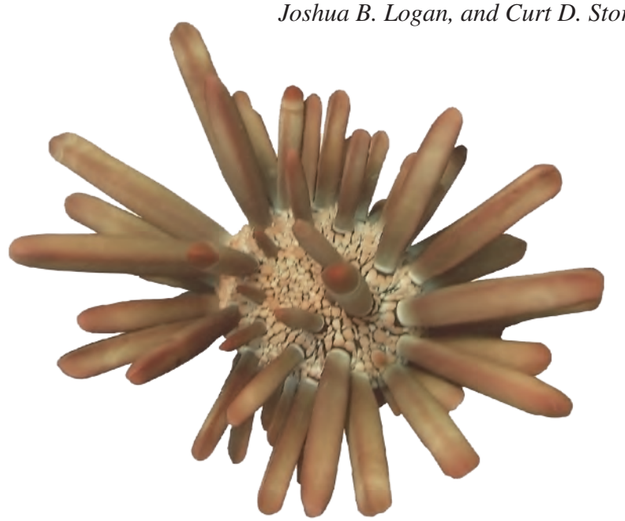
The importance of identifying and monitoring the effects of land-based pollution has become crucial within the United States, as evidenced by priorities set by the U.S. Task Force on Coral Reefs. One of the key topics in the April 2004 Report of the U.S. Commission on Ocean Policy (U.S. Commission on Ocean Policy, 2004) is the need for “an ecosystem and watershed-based management” approach to ocean pollution, and that report highlights “the astounding decline of coral reef ecosystems” and “an urgent need to address the identified, major factors causing coral declines.” In Hawai‘i, local representatives of the U.S. Coral Reef Task Force specifically developed and established a Local Action Strategy (LAS) and steering committee to address land-based sources of pollution and their impact on reefs. The LAS is essentially a locally-driven roadmap for collaborative and cooperative action among Federal, State, and nongovernmental partners to identify and implement priority actions needed to reduce key threats to valuable coral-reef resources. In the state of Hawai‘i, Moloka‘i was designated one of the key LAS sites. To protect and sustain coral reefs, broad understanding of the processes involved is necessary—how sediment is derived in upland regions, how it is transported through the watershed, and its fate on the reef. Many positive signs indicate that science and management are embracing that need for understanding.

This volume supports and augments those goals through presentation of new information on the behavior and fate of sediment on the Moloka‘i coral reef. The following chapters discuss the evolution of the reef, the natural processes that affect the reef, and the role of sediment in inducing change on the reef. This information is intended to help make decisions—on Moloka‘i and elsewhere—that can lead to sustaining healthy reefs.

We hope this volume will be of benefit first and foremost to the people of Moloka‘i. The fringing coral reef bordering the south shore of their island is perhaps the most magnificent coral reef in the Hawaiian Island chain. In addition to its intrinsic value as an important ecosystem, the reef holds a rich heritage of cultural and historical associations and meanings for the island residents. Today the Moloka‘i reef is at a crossroad—the evidence of damage from heavy land use is clear, and yet procedures for its protection through improved land-use practices are already underway. It is the people of Moloka‘i who will ultimately decide the fate of their coral reef. Measures to decrease sediment runoff, control fish collection, and establish protected zones are all actions they can take to help preserve the reef.

We hope this publication will also be of value to all coastal people living harmoniously with neighboring coral reefs. Some of the causes of reef degradation are global, but many remain local. It is largely through local decisions and local actions that protection of coral reefs can be assured for future generations.

Michael E. Field, Susan A. Cochran,
Joshua B. Logan, and Curt D. Storlazzi



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The information presented in this volume derives largely from research undertaken by the U.S. Geological Survey (USGS) to meet one of its principal goals—to establish the geologic framework of ecosystem function and structure. Some of the research was supported by our partners at the University of Hawai‘i and the National Oceanographic and Atmospheric Administration (NOAA). All of the authors and editors fully recognize that the success of their studies resulted in very large measure both through the technical expertise provided by our colleagues in Hawai‘i and on the mainland and from the assistance and friendship of the people of Moloka‘i.

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Captain Joe Reich and his boat, *Alyce C.*

Glossaries

Acronyms

ANOVA	analysis of variance (a statistical analysis procedure)
CCA	crustose coralline algae
CRAMP	Coral Reef Assessment and Monitoring Program
CRTF	United States Coral Reef Task Force
CTD	instrument that measures water conductivity (salinity), temperature, and depth
DAR	State of Hawai‘i Division of Aquatic Resources
DEM	digital elevation model
DLNR	State of Hawai‘i Department of Land and Natural Resources
DOC	dissolved organic carbon
DOI	United States Department of the Interior
ENSO	El Niño Southern Oscillation
ERM	effects range-median; a measurement of sediment toxicity
GIS	geographic information system
GLM	general linear model; a statistical analysis procedure
GPS	global positioning system
IRM	isothermal remanent magnetization; a technique to measure the magnetic properties of rock or sediment
LIDAR	light detection and ranging
MAB	meters above bottom
MMU	minimum mapping unit
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPWMA	Nu‘upia Ponds Wildlife Management Area (O‘ahu)
PAR	photosynthetically active radiation
PSU	practical salinity units
SAG	spur-and-groove
SGD	submarine ground-water discharge
SHOALS	scanning hydrographic operational airborne lidar survey
SSC	suspended sediment concentration
SWAPS	spectral wave prediction system
TIN	total inorganic nitrogen
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

Hawaiian Words

‘a‘ama crab
āholehole Hawaiian flagtail
ahupua'a smaller subdivision of moku which define watersheds
aku skipjack tuna
akule bigeye scad
ali‘i royalty
‘ama‘ama mullet
enenue chub
hā‘uke‘uke shingle urchin
halalū smaller sized akule
he‘e octopus
hieau sacred worship site or altar
hīnālea lauwili saddle wrasse
hoo‘ilo cooler and wetter weather season when winds are inconsistent
humuhumu hi‘u kole pink durgeon
humuhumu lei lei triggerfish
humuhumu nukunuku āpua‘a reef triggerfish
humuhumu‘ele‘ele black durgeon
kāhala amberjack
kala bluespine unicornfish
kapu ancient Hawaiian system of laws and regulations; forbidden
kau warmer and drier weather season when winds blow steadily
kawakawa wavy-back tuna
kole goldring surgeonfish
kūmū whitesaddle goatfish
laenihi razorfish
limu seaweed
limu ‘ele ‘ele a type of seaweed
limu kala a type of seaweed
limu kohu a type of seaweed
limu līpoa a brown algae
limu manauea a type of seaweed
limu pālahalaha a type of green seaweed
limu waiwai‘ole a green algae
loko i‘a fishpond
loko kuapā type of shoreline fishpond, fully enclosed except for a makaha
loko ‘ume iki low-walled fishpond with walled lanes leading in and out
lū‘au special occasion feast
lua wai water holes
mā‘i‘i‘i brown surgeonfish
mahimahi dolphinfish
makaha slotted gate in fishpond
makai toward the sea
manauea a type of seaweed
manini convict tang
mauka towards the mountains
moana kale blue goatfish
moana ukali a type of goatfish
moi Pacific threadfin
moku wedge-shaped parcels of land from mountain crest to shore
nabeta razorfish
nui large, big
‘oama juvenile goatfishes
ō‘io bonefish
ogo a type of seaweed
onaga long-tailed red snapper, also known as **‘ula‘ula koa‘e**
ono wahoo, delicious
‘ōpakapaka pink snapper
‘opihi limpets
palani eyestripe surgeonfish
pali cliff
pāpio juvenile jacks
pualu yellowfin surgeonfish
puka a depression, hole
roi peacock grouper
ta‘ape bluestripe snapper
taro staple starchy plant
to‘au blacktail snapper
uhu parrotfish
uhu uliuli spectacled parrotfish
uku green jobfish
ula spiny lobster
ula papa slipper lobster
‘ula‘ula red snapper
‘ula‘ula koa‘e long-tailed red snapper, also known as **onaga**
ulua jacks
uma-uma lei orangespine unicornfish
‘ū‘ū soldierfishes and squirrelfishes
weke goatfish

Fieldwork Activities

Fieldwork activities for the research reported in this volume were assigned identification numbers, to which all data are tied. InfoBank (http://walrus.wr.usgs.gov/infobank/) is the U.S. Geological Survey Coastal and Marine Geology Team's online data catalog of these activities and more. Fieldwork activity IDs for USGS work on the Molokaʻi reef and associated volume chapters are shown below.

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A-14-01-HW	http://walrus.wr.usgs.gov/infobank/a/a1401hw/html/a-14-01-hw.meta.html	January 2001	19, 20
A-2-01-MK	http://walrus.wr.usgs.gov/infobank/a/a201mk/html/a-2-01-mk.meta.html	April 2001	19, 20
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