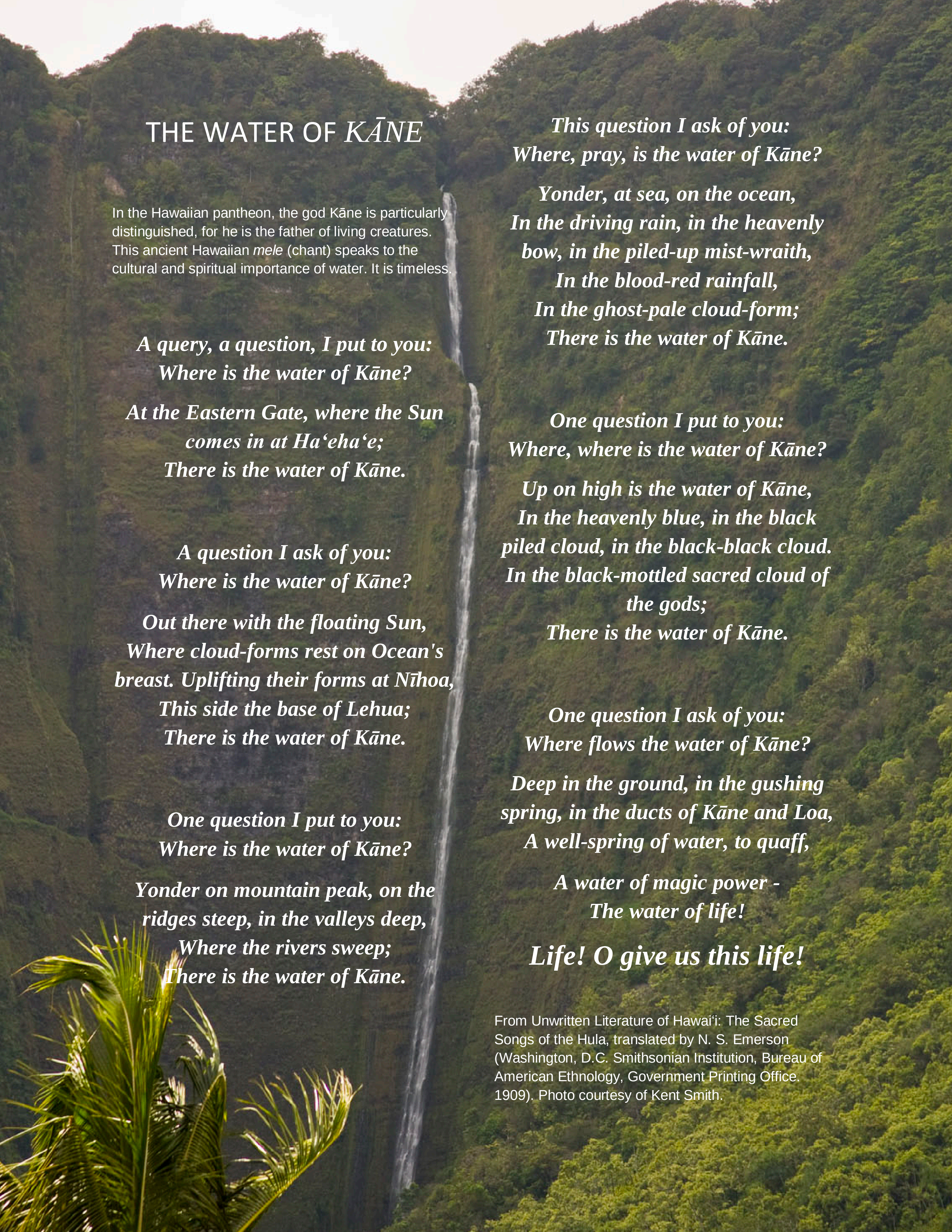
Hawaiʻi Forest Action Plan 2016

Department of Land and Natural Resources
Division of Forestry and Wildlife
Honolulu, Hawaiʻi
December 31, 2016

David Smith, State Forester



THE WATER OF *KĀNE*

In the Hawaiian pantheon, the god Kāne is particularly distinguished, for he is the father of living creatures. This ancient Hawaiian *mele* (chant) speaks to the cultural and spiritual importance of water. It is timeless.

A query, a question, I put to you:
Where is the water of Kāne?

At the Eastern Gate, where the Sun
comes in at Ha‘eha‘e;
There is the water of Kāne.

A question I ask of you:
Where is the water of Kāne?

Out there with the floating Sun,
Where cloud-forms rest on Ocean's
breast. Uplifting their forms at Nīhoa,
This side the base of Lehua;
There is the water of Kāne.

One question I put to you:
Where is the water of Kāne?

Yonder on mountain peak, on the
ridges steep, in the valleys deep,
Where the rivers sweep;
There is the water of Kāne.

This question I ask of you:
Where, pray, is the water of Kāne?

Yonder, at sea, on the ocean,
In the driving rain, in the heavenly
bow, in the piled-up mist-wraith,
In the blood-red rainfall,
In the ghost-pale cloud-form;
There is the water of Kāne.

One question I put to you:
Where, where is the water of Kāne?

Up on high is the water of Kāne,
In the heavenly blue, in the black
piled cloud, in the black-black cloud.
In the black-mottled sacred cloud of
the gods;
There is the water of Kāne.

One question I ask of you:
Where flows the water of Kāne?

Deep in the ground, in the gushing
spring, in the ducts of Kāne and Loa,
A well-spring of water, to quaff,

A water of magic power -
The water of life!

Life! O give us this life!

From Unwritten Literature of Hawai‘i: The Sacred Songs of the Hula, translated by N. S. Emerson (Washington, D.C. Smithsonian Institution, Bureau of American Ethnology, Government Printing Office. 1909). Photo courtesy of Kent Smith.

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Cover Photo: View from Kaʻala, the tallest point on Oʻahu looking west over the community of Waianae. Photo credit Ron Cannarella.

Acknowledgements

The Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW) is the lead agency in the development and update of the Hawaiʻi Forest Action Plan 2016 (FAP). The extensive work done in 2010 to develop the original FAP greatly facilitated the update process. Also, as was the case in 2010, many DOFAW staff, partners, organizations, and interested citizens helped develop and complete the plan. The authors of this 2016 update sincerely thank those who willingly shared their knowledge, comments, resources, time, and enthusiasm to ensure that this plan continues to be a comprehensive strategy for forest management by and for the people of Hawaiʻi.

Assistance was provided by various people and organizations at different stages of the process. To everyone involved, thank you for your time and talent. Special thanks go to the following people for providing guidance and information whenever asked: Sheri Mann, Irene Sprecher, Rob Hauff, Michelle Jones, Lance DeSilva, Ryan Peralta, Philipp LaHaela Walter, Dwight Matsuwaki, Josh Atwood, Emma Yuen, James Cogswell, Fern Duvall, Cynthia King, Nickolas Agorastos, Marigold Zoll, Maggie Sprock-Koehler, Christopher Mottley, Jason Misaki, Shane DeMattos, Aaron Lowe, David Smith, Steven Bergfeld, Scott Fretz, Galen Kawakami, Tanya Rubenstein, Maria Carnevale, Jeremy Kimura, Martha Yent, Jan Pali, Teresa Trueman-Madriaga, Colleen Carroll, Jolie Wanger, Clay Trauernicht, Elizabeth Pickett, Katie Friday, Flint Hughes, Christian Giardina, J. B. Friday, Nick Koch, and members of the Kaulunani Urban & Community Forestry Advisory Council, State Forest Stewardship Advisory Council, and the Hawaiʻi Wildfire Management Organization, who reviewed and provided input on program issues, initiatives, and strategies. We would also like to thank U.S. Forest Service Region 5 and the Institute of Pacific Island Forestry for their continued support, partnership, and guidance in the update of this plan and the implementation of forestry programs in the state of Hawaiʻi.

Finally, we would like to acknowledge all the citizens who participated in the review process and provided input at public meetings or through emails, letters, or faxes. Thank you for your dedication and commitment to the conservation of forest resources in Hawaiʻi and your willingness to participate in this process.

Because so much of the information in the 2010 version of this plan has been retained and is the foundation of this update, we also want to acknowledge those who were instrumental in developing the first edition of this plan. Their names can be found in the acknowledgement section of the *Hawaiʻi Statewide Assessment of Forest Conditions and Trends: 2010.*

Note from Hawai‘i State Forester

Aloha,

It is my pleasure to invite you to join DLNR DOFAW to continue the process of assessing the conditions of our forests, native species, forests products industry, and forest recreational opportunities and to plan our continuing strategy to protect, manage, and sustain these resources for current and future generations. The U.S. Secretary of Agriculture, as part of the 2008 Farm Bill, asked each state and territory to complete a Statewide Forest Assessment and Resource Strategy that will help inform our federal agency partners and national policymakers on where and how to direct natural resource funding and, more importantly, to guide our efforts here in the state to be more collaborative and productive. The original assessment and strategy was produced in 2010 and was called the *Hawai‘i Statewide Assessment of Forest Conditions and Trends.* Since then, the name of these plans has been changed to reflect more the intent of the document to identify current conditions and needed future management, and they are now called Forest Action Plans. The provisions of the program require that each state’s plan be periodically updated, and now is a good time to do so to keep current on recent advances in forest conservation and watershed management, identify new threats that have emerged since 2010, and incorporate recent progress made with development of the forest products industry and planning on climate change. The basic requirements of this planning effort remain the same:

- Identify present and future forest conditions, trends, and threats on all land ownerships.
- Identify any issues, areas, and regions of the state that are a priority.
- Identify any multi-state areas or issues that are a regional priority.
- Incorporate existing forest management plans, including state wildlife action plans and community wildfire protection plans.

As in 2010, the current update effort involves all landownership—state, private, and federal, and views forests and trees as a whole and not by programs. It will enable DOFAW to continue to seek and base funding on landscape-scale management and not only on narrow program mandates and to integrate the many programs we work on together under one document. We have an opportunity to demonstrate the value of our forests and trees to the state and nation, and to describe our strategy to work together to protect our forests from harm and conserve forests in a working landscape. We hope that this information will continue to be used, as it is now, to influence our communities, our state and national legislators, and our other government leaders to invest in Hawai‘i’s forests for the future.

Mahalo for joining us in this effort; thank you for your participation, assistance, and support.

David G. Smith
Hawai‘i State Forester

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List of Acronyms and Other Abbreviations

Acronym	Meaning
AAA	Aloha Arborists Association
APHIS	Animal and Plant Health Inspection Service
BISC	Big Island Invasive Species Council (Island of Hawai‘i)
BRD	Biological Resources Division (of the U.S. Geological Survey USGS)
BWS	Board of Water Supply
C&C	City and County of Government of Hawai‘i
C&CH	City and County of Honolulu
CAO	Carnegie Airborne Observatory
CAR	Community at Risk (from wildland fire)
CELCP	Coastal Estuarine Land Conservation Program
CERT	Community Emergency Response Training
CGAPS	Coordinating Group on Alien Pest Species
CE	Conservation Education
CPB	Customs and Border Protection (Department of Homeland Security)
CFP	Cooperative Fire Protection
CREP	Conservation Reserve Enhancement Program
CWCS	Comprehensive Wildlife Conservation Strategy
CWPP	Community Wildfire Protection Plan
CWRM	Commission on Water Resources Management
CZARA	Coastal Zone Act Reauthorization Amendments
CZM	Coastal Zone Management
DAR	Division of Aquatic Resources
DFWG	Dryland Forest Working Group
DHHL	Department of Hawaiian Homelands
DHS	U.S. Department of Homeland Security
DLNR	Department of Land and Natural Resources
DOD	State Department of Defense
DOFAW	Division of Forestry and Wildlife
DOH	State Department of Health
DOT	State Department of Transportation
DPCH	Department of Planning for County of Hawai‘i
DPCK	Department of Planning for County of Kaua‘i
DPCM	Department of Planning for County of Maui
EE	Environmental Educational
ELP	Environmental Literacy Plan
EPA	U.S. Environmental Protection Agency

Acronym	Meaning
EQIP	Environmental Quality Incentive Program (a program of the NRCS)
ETS	emission trading scheme
FAO UN	Food and Agriculture Organization of the United Nations
FEMA	Federal Emergency Management Agency
FGDC	Federal Geodata Data Committee
FH	Forest Health
FHMP	Forest Health Monitoring and Protection
FLIR	forward-looking infrared
FSP	Forest Stewardship Program (both State & Federal programs)
FLP	Forest Legacy Program
Friends	Friends of Urban Forests
FRPP	Farm and Ranchland Protection Program
FRS	Forest Reserve System
FS	U.S. Forest Service
FSA	Farm Service Agency
FSCG	U.S. Forest Service Competitive Grants
FSP	Forest Stewardship Program
FWSR	U.S. Fish and Wildlife Service Refuge
GIS	geographic information system
GMA	Cooperative Game Management Area
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HACD	Hawai'i Association of Conservation Districts
HARC	Hawai'i Agriculture Research Center
HAWP	Hawai'i Association of Watershed Partnerships
HCA	Hawai'i Conservation Alliance
HCEI	Hawai'i Clean Energy Initiative
HCRI-RP	Hawai'i Coral Reef Initiative Research Program
HDOA	Hawai'i Department of Agriculture
HEAR	Hawai'i Ecosystem At Risk
HEEA	Hawai'i Environmental Education Alliance
HETF	Hawaii Experimental Tropical Forest
HFIA	Hawai'i Forest Industry Association
HFRA	Healthy Forest Restoration Act
HIGAP	Hawai'i Gap Analysis Project
HISC	Hawaii Invasive Species Council
HP-WRA	Hawai'i-Pacific Weed Risk Assessment
HRPRG	Hawai'i Rare Plant Recovery Group
HTA	Hawai'i Tourism Authority

Acronym	Meaning
HUD	U.S. Department of Housing and Urban Development
HWMO	Hawai‘i Wildfire Management Organization
I&E	Information and Education
ICAC	Interagency Climate Adaptation Committee
ICAP	Island Climate Adaptation and Policy
ICS	Incident Command System
IPCC	Intergovernmental Panel on Climate Change
IPIF	Institute of Pacific Islands Forestry
ISC	Invasive Species Committee (there are five ISCs operating at an island level for Kaua‘i, O‘ahu, Moloka‘i, Maui, and the Big Island)
KISC	Kaua‘i Invasive Species Committee
LICH	Landscape Industry Council of Hawai‘i
LiDAR	Light Detection and Ranging
LLCP	Legacy Land Conservation Program
LSR	Landscape Scale Restoration
LWCF	Land and Water Conservation Fund
MAA	Mutual Aid Agreement
MCZAC	Marine and Coastal Zone Advocacy Council
MISC	Maui Invasive Species Committee
MoISC	Moloka‘i Invasive Species Committee
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NAH	State Na Ala Hele Trails and Access Program
NASA	National Aeronautics and Space Administration
NPS	National Park Service
NAPP	Natural Area Partnership Program
NARF	Natural Area Reserve Fund
NARS	Natural Area Reserve System
NASF	National Association of State Foresters
NIMS	National Incident Management System
NGO	nongovernmental organization
NOAA	National Oceanic and Atmospheric Administration
NRAG	Natural Resources Advisory Group (to Hawai‘i Tourism Authority)
NRCS	Natural Resources Conservation Service
NWHI	Northwestern Hawaiian Islands
OCCL	Office of Conservation and Coastal Lands
OHA	Office of Hawaiian Affairs
OISC	O‘ahu Invasive Species Committee

Acronym	Meaning
ORMP	Ocean Resources Management Plan
OP	Office of Planning
PBIN	Pacific Biodiversity Information Node
PICCC	Pacific Islands Climate Change Cooperative
PIER	Pacific Island Ecosystems at Risk
P.L.	Public Law
PR	Pittman-Robertson Funds
PSWRS	Pacific Southwest Research Station
RC&D	Research, Conservation, and Development
RLA	Recovery Land Acquisition Program
ROD	Rapid ‘Ōhi‘a Death
S&PF	State and Private Forestry organization (FS)
SAF	Society of American Foresters
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SOEST	University of Hawai‘i School of Ocean and Earth Science and Technology
SOPAC	Secretariat of the Pacific Applied Geoscience Commission
SPC	The Secretariat of the Pacific Community
SPREP	South Pacific Regional Environmental Program
STAC	State Technical Advisory Committee (NRCS)
STDP	Special Technology Development Program
STP	Smart Trees Pacific
SWAP	State Wildlife Action Plan
SWCD	Soil and Water Conservation District
T&E	threatened and endangered (species)
TAT	Transient Accommodation Tax administered by HTA
THTIRC	Tropical Hardwood Tree Improvement and Regeneration Center
TNC	The Nature Conservancy
TPL	Trust for Public Lands
UAV	Unmanned Aerial Vehicle
UFICEM	Urban Forestry Incident Command Engagement Model
UH	University of Hawai‘i
UH/SOEST	University of Hawai‘i School of Ocean and Earth Science and Technology
UH/CTAHR	University of Hawai‘i College of Tropical Agriculture and Human Resources
UHHERO	University of Hawai‘i Economic Research Organization
UNFAO	United Nations Food and Agriculture Organization
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture

Acronym	Meaning
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USTI	U.S. Tropical Island
UTC	Urban Tree Canopy Assessment
UXO	unexploded ordinance
WFLC	Western Forestry Leadership Coalition
WHIP	Wildlife Enhancement Incentive Program
WP	Watershed Partnership
WRA	Weed Risk Assessment
WUI	Wildland-Urban Interface
YCC	Youth Conservation Corps

Glossary

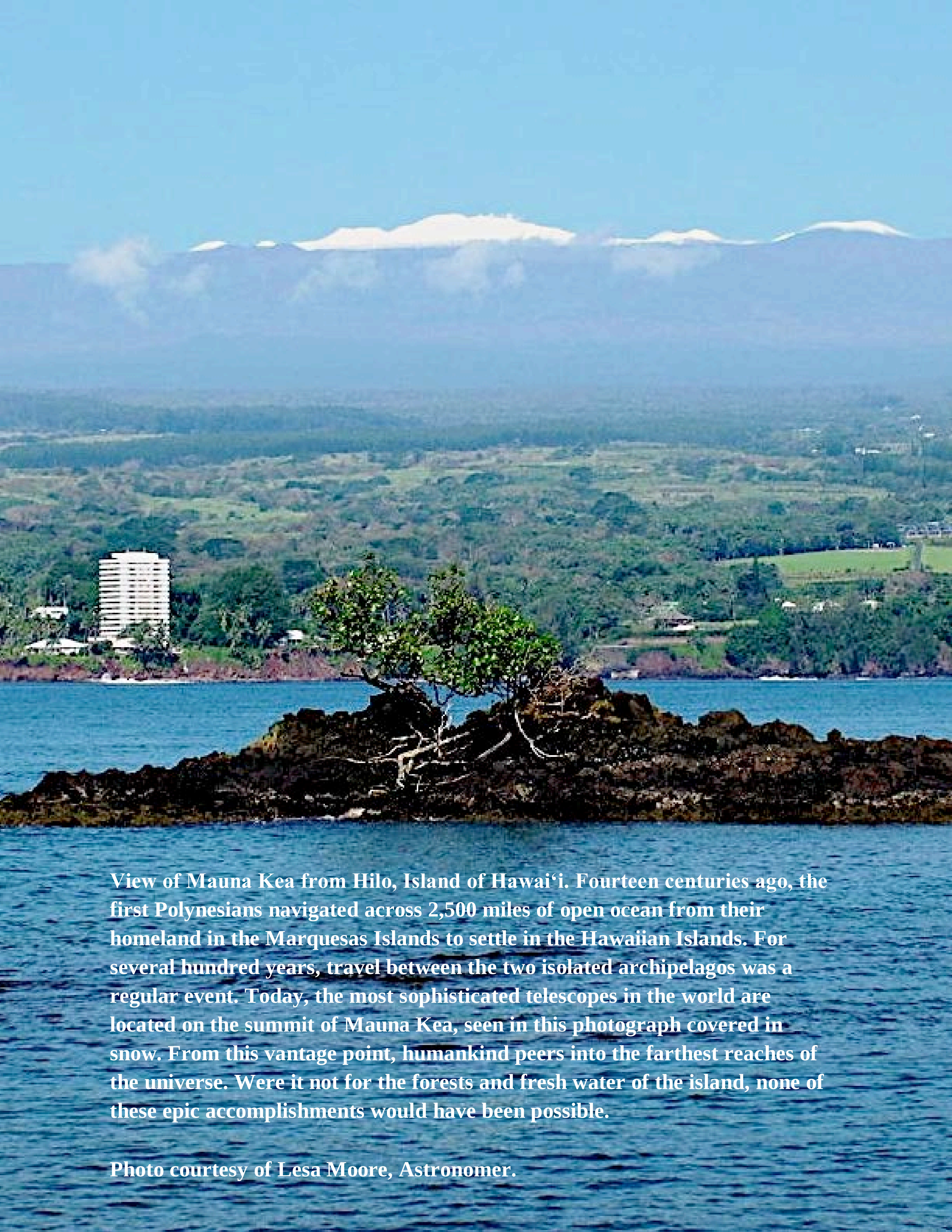
Hawai‘i is unique for many reasons. It is the only state with two official languages, Hawaiian and English. Regrettably, the use of the Hawaiian language has been nearly lost over the last 100 years and English has become the dominant language of government, education, mass media, and general use.

Today, there is a renewed interest in reviving and expanding the use of the Hawaiian language and reaffirming the values of the native Hawaiian culture and language in everyday life. In 1978, Hawaiian was reestablished as an official language of the State of Hawai‘i and, in 1990, the federal government of the U.S. adopted a policy to recognize the right of Hawai‘i to preserve, use, and support its indigenous language. To this end, Hawaiian language and culture are being taught in Hawaiian immersion schools, Hawaiian language broadcasts on public television and radio, and in continuing education programs developed by the Hawai‘i Department of Education.

The authors of this document share the aspirations of native Hawaiian speakers to restore the use of spoken and written Hawaiian language to its former status as a primary language spoken in these Hawaiian Islands. At this time, however, we do not have the resources to produce this document in both English and Hawaiian. Throughout this document, we have italicized Hawaiian words (except for proper nouns) to highlight these and inform the reader that glossary definitions may be available for these words.

The following glossary table provides English translations of Hawaiian words, from Pukui and Elbert (1986). Hawaiians today may use more contemporary meanings for some of the words; these words are translated to current meanings, marked with “(common),” and any other text is from Pukui and Elbert (1986).

Hawaiian Word	English Translation
‘aha moku	A system of best practices based on indigenous resource management practices; enacted within specific *moku* (district) boundaries to sustain the resources and the community of that *moku*. Also, a series of district councils that would manage land and natural resources for tenants and the community through the implementation of site-specific cultural conservation efforts coupled with utilitarian practices.
ahu	Altar of stones (common).
ahupua‘a	Land division usually extending from the uplands to the sea, so called because the boundary was marked by a heap (*ahu*) of stones surmounted by an image of a pig (*pua‘a*), or because a pig or other tribute was laid on the altar as tax to the chief.
‘āina	Land (common).
aloha	Love, affection, compassion.
‘auwai	Ditch, canal, water conveyance channels.
ea	Independence (common).
heiau	Pre-Christian place of worship, shrine; some *heiau* were elaborately constructed stone platforms, others simple earth terraces. Many are preserved today.
hula	To dance the hula (a form of dance).
i ka pono	Through righteousness, justice, or virtue (common).
kai	Ocean.
kapu	Taboo, prohibition.
kauna	Placement, hanging, appearance; Count (title or nobility)
kona	Leeward sides of the Hawaiian Islands.
kupuna	Elders (common). Grandparent, ancestor, relative or close friend of the grandparent’s generation, grandaunt, granduncle.
limu	Seaweed, algae (common).
mahalo	Gratitude. Respect.
makai	Ocean-ward (common).
mauka	Landward (common).
mo’olelo	The storytelling oral tradition of native Hawaiians.
ua mau	Steadfast, solid, forever.
wai	Water (common).
wao akua	A distant mountain region, believed inhabited only by spirits (*akua*).
wao kanaka	An inland region where people may live or occasionally frequent, usually considered below the *wao akua*.



View of Mauna Kea from Hilo, Island of Hawai‘i. Fourteen centuries ago, the first Polynesians navigated across 2,500 miles of open ocean from their homeland in the Marquesas Islands to settle in the Hawaiian Islands. For several hundred years, travel between the two isolated archipelagos was a regular event. Today, the most sophisticated telescopes in the world are located on the summit of Mauna Kea, seen in this photograph covered in snow. From this vantage point, humankind peers into the farthest reaches of the universe. Were it not for the forests and fresh water of the island, none of these epic accomplishments would have been possible.

Photo courtesy of Lesa Moore, Astronomer.

Executive Summary

This is Hawai‘i's Forest Action Plan 2016 (FAP). It is an update of the 2010 *Hawai‘i Statewide Assessment of Forest Conditions and Trends* produced by Hawai‘i Department of Land and Natural Resources, Division of Forestry and Wildlife (DLNR DOFAW), to fulfill a mandate of the U.S. Forest Service (FS) State and Private Forestry (S&PF) organization. The requirement to produce this document and periodic updates is part of a suite of provisions in the Forestry Title of the 2008 Farm Bill (Public Law 110-234).

This document meets the legal requirements set forth by the 2008 Farm Bill and it directly addresses the National Themes of the S&PF Redesign to: (1) conserve working landscapes, (2) protect forests from harm, and (3) enhance public benefits associated with trees and forests. We have used this process as an opportunity for DOFAW to continue the collaborative efforts among the many agencies, institutions, and landowners actively involved in the stewardship of Hawai‘i's natural resources, begun in the 2010 planning effort.

In this update, DOFAW reached out internally to its professional staff and to watershed and invasive species conservation partners, outdoor recreation partners, the State Forest Stewardship Advisory Committee, the State Kaulunani Urban and Community Forestry Council, the Hawai‘i Wildfire Management Organization, and FS's Institute of Pacific Islands Forestry for program updates, coordination, and integration. A specific effort was made to more closely integrate with the recently updated State Wildlife Action Plan. To build on the momentum begun in 2010, we kept the format and layout of the 2010 plan, which identified nine conservation and management issues, but updated and expanded on those as needed. We particularly identified any new threats, new opportunities, and new initiatives not previously covered. For each issue, we updated the current conditions, trends, threats, and benefits, and updated maps and strategies for addressing the issues where needed. This updated FAP will meet the needs of the forest management program for the next 5 to 10 years, and we hope will be of use to our agency staff, conservation partners, and other state and federal agencies in the future.

The Aloha Act of 1986

As in 2010, perhaps the most important outcome of this effort will be the sum of the relationships we have established and renewed, and the enhancement of capabilities of our staff and partners to use the many tools, data, and plans compiled and developed. We have renewed our commitment to the cultural values and land stewardship ethic that we have inherited from the native Hawaiians: the passing of knowledge from one generation to the next, a deep respect for the *‘āina* (the land that sustains us), the *aloha* spirit that binds us as a community, and a commitment to doing our part as responsible stewards of the 21st century *ahupua‘a*.[1] All of these concepts are discussed at length throughout this document.

Anyone who comes to Hawaiʻi will experience the Aloha Spirit for themselves. It permeates every aspect of life in these islands. Section 5-7.5 of the Hawaiʻi Revised Statutes made the Aloha Spirit the law of the land, and set the standard of conduct for public servants in all three branches of the Hawaiʻi state government. In preparing and implementing this plan, we fulfilled the requirements of the 2008 Farm Bill and renew our commitment to conducting ourselves according to the values in our state law.

THE ALOHA ACT
HAWAIʻI REVISED STATUTES § 5-7.5

§ 5-7.5 "Aloha Spirit". (a) "**Aloha** Spirit" is the coordination of mind and heart within each person. It brings each person to the self. Each person must think and emote good feelings to others. In the contemplation and presence of the life force, "**Aloha**", the following **unuhi laulā loa** may be used:

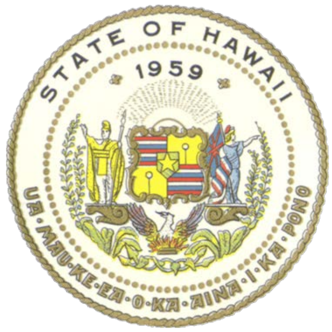
"**Akahai**", meaning kindness to be expressed with tenderness;
"**Lōkahi**", meaning unity, to be expressed with harmony;
"**ʻOluʻolu**" meaning agreeable, to be expressed with pleasantness;
"**Haʻahaʻa**", meaning humility, to be expressed with modesty;
"**Ahonui**", meaning patience, to be expressed with perseverance.

These are traits of character that express the charm, warmth and sincerity of Hawaii's people. It was the working philosophy of native Hawaiians and was presented as a gift to the people of Hawaiʻi. "**Aloha**" is more than a word of greeting or farewell or a salutation. "**Aloha**" means mutual regard and affection and extends warmth in caring with no obligation in return. "**Aloha**" is the essence of relationships in which each person is important to every other person for collective existence. "**Aloha**" means to hear what is not said, to see what cannot be seen and to know the unknowable.

(b) In exercising their power on behalf of the people and in fulfillment of their responsibilities, obligations and service to the people, the legislature, governor, lieutenant governor, executive officers of each department, the chief justice, associate justices, and judges of the appellate, circuit, and district courts may contemplate and reside with the life force and give consideration to the "**Aloha** Spirit". [L 1986, c 202, § 1]

The Hawaiʻi State Motto and Land Stewardship

Ua Mau Ke Ea, O Ka ʻĀina I Ka Pono
"The life of the land is perpetuated in righteousness"



This Hawaiian language maxim was designated as the official state motto soon after Hawaiʻi became a U.S. state in 1959. The official English translation is "The life of the land is perpetuated in righteousness," but there is a much deeper meaning to our state motto. These words were first spoken by King Kamehameha III on July 31, 1843, in a speech of gratitude on the day that sovereignty was restored to the Kingdom of Hawaiʻi by British Navy Admiral Richard Thomas. Months earlier, the captain of another British warship had unilaterally seized control of Hawaiʻi and claimed it as a territory of Great Britain. Upon hearing this news, Queen Victoria was outraged and directed Admiral Thomas to restore sovereignty of the Kingdom of Hawaiʻi. In his speech of gratitude, the King proclaimed "*Ua mau ke ea o ka ʻāina i ka pono,*" meaning that the Kingdom's *ʻāina* (land), was once again *ea* (independent) *ua mau* (steadfast, solid, forever), *i ka pono* (through righteousness, justice, or virtue).

The Hawaiian language is rich and poetic. Every chant and proverb has hidden within it a double or triple entendre, or *kauna*. The King chose his words carefully; there are dozens of words he could have chosen for "land," but he chose the word *'āina* for that word has a special connotation. The root of the word *ʻāina* is *ʻai* (to feed), thus, the *ʻāina* is a term of endearment for the land that feeds and sustains us. The word *pono* is also significant, for it carries a connotation of doing the right thing, doing what is fair or just. Today, many residents of Hawaiʻi, be they native Hawaiian or not, often use the words *ʻāina* and *pono* in every day speech because there simply isn't a word in English that means just that.

So a less formal, but more meaningful, translation of the King's words into English might be: "Our independence will forever be sustained by our precious life-giving land if we do what is good and just." At DOFAW, we do not simply hang this motto on the wall; in cooperation with our partners and volunteers we strive every day to do the right thing, to ensure that the land is cared for and preserved into perpetuity.

Background

Purpose of This Document

The first version of this plan, the 2010 Hawai‘i Statewide Assessment of Forest Conditions and Trends, was initiated in response to a mandate from FS contained in the Forestry Title of the 2008 Farm Bill (P.L. 110-234). The assessment was developed in a collaborative style by the staff of DOFAW with the assistance of our partners and stakeholders and in accordance with national direction issued jointly by FS and the National Association of State Foresters (NASF).

Statewide assessments were a key component of the FS S&PF Redesign Initiative that was launched in 2008. The assessments provided a science-based foundation to assist state forestry agencies and their partners in: (1) identifying the areas of greatest need and opportunity for forests across their states and (2) developing a subsequent long-term strategy to address them.

By encouraging states to collaboratively work with their partners in identifying and addressing priorities, the U.S. Congress and FS hoped to ensure that S&PF funds were invested in those areas where funding would make the most significant difference for both the state and the nation.

In Hawai‘i, DOFAW and our partners used the state assessment and the associated geographic information system (GIS) data layers as tools to identify where opportunities existed to facilitate forest management across jurisdictional boundaries and quantify the full scale of actions and resources needed to address Hawai‘i’s forest health challenges.

U.S. Forest Service State and Private Forestry Redesign Initiative

The S&PF branch of FS provides technical assistance and cost-share funding to every state in the nation in support of issues related to wildland fire, insects and disease, forest stewardship, and community forestry on nonfederal land. In Hawai‘i, this funding is received and distributed primarily by DOFAW.

The S&PF Redesign Initiative was conceived in 2008 by state and federal partners in response to increasing pressures on our nation’s forests and decreasing availability of resources and funds. In the face of those challenges, FS and state foresters determined that more progressive, large-scale strategies were needed to sustain our nation’s forest resources.

The purpose of the Redesign Initiative was “to shape and influence forest land use on a scale and in a way that optimizes public benefits from trees and forests for both current and future generations.” In designing the initiative, state foresters worked closely with FS to:

- Examine current conditions and trends affecting forest lands.
- Review existing S&PF programs to determine how best to address threats to forests on a meaningful scale.
- Develop a strategy to deliver a relevant and focused set of S&PF programs and opportunities.

Those efforts continue with the update of this plan.

National Objectives

The redesign approach and current update focuses on three consensus-based national themes with accompanying strategic outcomes:

1. Conserve working forest landscapes
    1.1. Identify and conserve high-priority forest ecosystems and landscapes.
    1.2. Actively and sustainably manage forests.
2. Protect forests from harm
    2.1. Restore fire-adapted lands and reduce risk of wildfire impacts.
    2.2. Identify, manage, and reduce threats to forest and ecosystem health.
3. Enhance public benefits from trees and forests
    3.1. Protect and enhance water quality and quantity.
    3.2. Improve air quality and conserve energy.
    3.3. Assist communities in planning for and reducing wildfire risks.
    3.4. Maintain and enhance the economic benefits and values of trees and forests.
    3.5. Protect, conserve, and enhance wildlife and fish habitat.
    3.6. Connect people to trees and forests.
    3.7. Manage and restore trees and forests to mitigate and adapt to global climate change.

Since 2008, a portion of S&PF funding has been, and will continue to be, allocated through a competitive process guided by these national themes. To ensure that proposals for this funding are being focused on high-priority areas with the greatest opportunity to achieve meaningful outcomes, each state or territory that wants to receive S&PF funding must work in collaboration with FS and other key partners to develop, implement, and report on an FAP.

The Forest Action Plan provides an analysis of forest conditions and trends in the state, and delineates priority rural and urban forest landscape areas. It also provides long-term strategies for investing state, federal, and other resources to manage priority landscapes identified in the assessment, focusing on areas in which federal investment can most effectively stimulate or leverage desired actions and engage multiple partners.

States that receive S&PF funds also will be asked to submit an annual report that describes how such funds were used to address the opportunities identified in the action plan, including the leveraging of funding and resources through partnerships.

According to the 2008 Farm Bill, each state is required to complete the initial assessment and strategy by June 18, 2010, which was done, and to periodically update it in order to qualify for most S&PF funds. This document represents Hawaiʻi's continuing efforts to be in compliance with these requirements.

National Guidance for Statewide Forest Resource Assessments

The development of statewide FAPs provides a valuable and unique opportunity to highlight the full scale of work needed to address priorities in the forests of each state and potentially across multiple states. At a minimum, each FAP must:

- Describe forest conditions and threats on all ownerships in the state.
- Identify forest-related benefits and services consistent with the national themes.
- Delineate priority forest landscapes or otherwise identify issues and opportunities that will emphasize and address the Statewide Forest Resource Strategy.
- Identify any multi-state areas that are a regional priority.
- Incorporate existing statewide plans as appropriate.

The national guidance recommends that states base their plans on publicly available geospatial data, but it allows states to use a combination of qualitative, quantitative, and geospatial sources to provide information relevant to key state issues and national themes. In addition, non-geospatial information can be used in combination with geospatial data to identify priorities. States may identify separate priority areas for different programs and issues.

In developing a statewide plan, each state forestry agency is directed to coordinate with the State Forest Stewardship Advisory Committee, State Technical Advisory Committee, the State Urban Forestry Council, state wildlife agency, and applicable federal land management agencies to ensure that the assessment addresses the rural-to-urban landscape continuum and identifies opportunities for program coordination and integration. State forestry agencies also are asked to involve other key land management and natural resource partners as appropriate to ensure the state's assessment integrates, builds upon, and complements other natural resource plans. This was done extensively in the 2010 initial version of the plan, and much was repeated in this 2016 update.

Process for Development of Hawai'i's 2010 Statewide Assessment and the 2016 Forest Action Plan Update

Scope

The state of Hawai'i consists of two distinctly different geographical regions; the Main Hawaiian Islands and the Northwestern Hawaiian Islands. (*See "Hawai'i's Forests: The Historical Context," for more detail.*) The Northwestern Hawaiian Islands do not support forests, and are managed as the Papahānaumokuākea Marine National Monument. This assessment therefore pertains only to the forested Main Hawaiian Islands from Ni'ihau to the Island of Hawai'i, as shown in Figure 1.

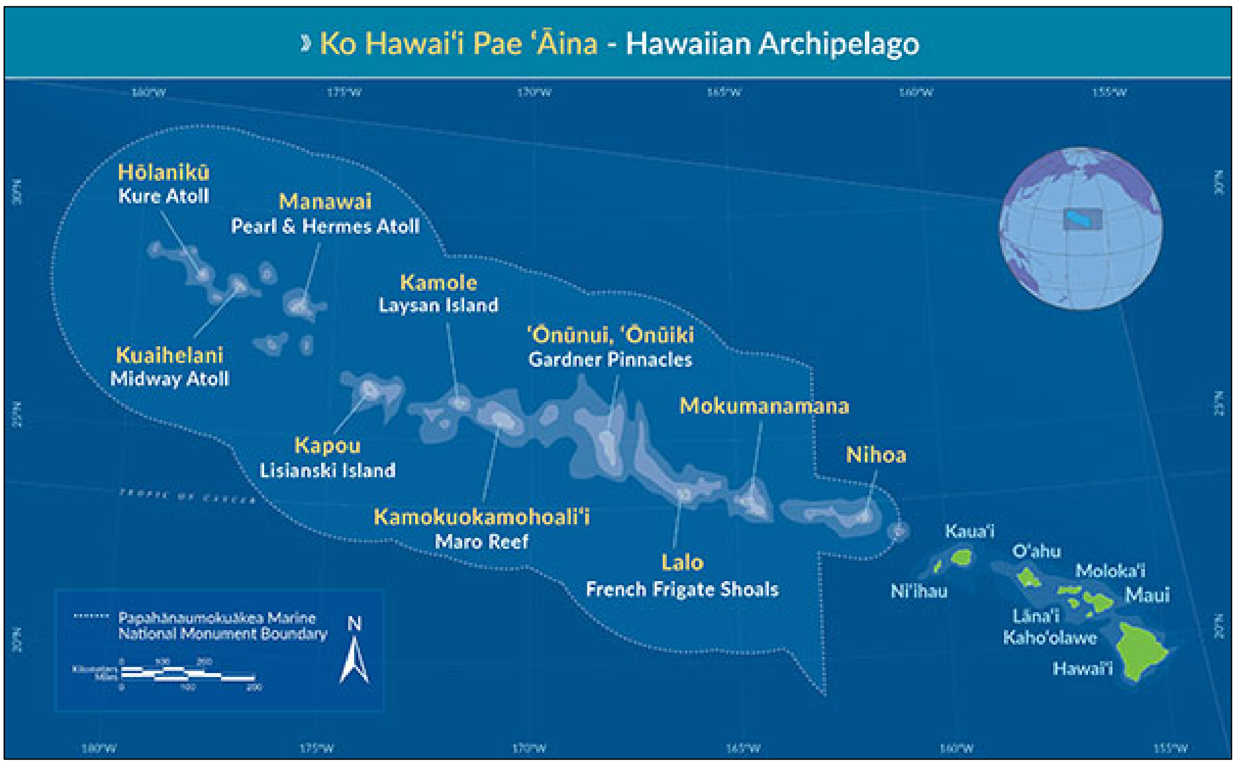


Figure 1. The state of Hawai'i, including the Main Hawaiian Islands addressed in this plan and the Northwestern Hawaiian Islands, which are not addressed.

The reader should be familiar with several characteristics that are unique to the State of Hawai'i in order to fully grasp some of the issues in this document:

- When referring to people, the term "Hawaiian" is reserved for people of native Hawaiian descent. Residents of the state of Hawai'i are referred to as "residents," "locals," or "the people of Hawai'i," and may or may not be of native Hawaiian ancestry.
- Hawai'i has a governor, and the Main Hawaiian Islands are divided into four counties, each with a county council and a mayor who is elected by popular vote. Each inhabited

island has a county seat, but these communities are not incorporated. The state does not have a municipal level of government. Because Hawaiʻi does not have municipalities with defined boundaries, the Kaulunani Urban and Community Forestry Program faced a challenge of when mapping its priority areas. Table 1 clarifies the relationship between island names, county names, named communities, and county seats.

Table 1. The relationship between county names, island names, and population centers for the islands addressed by this document.

County Name	Islands Composing the County (and County Seat)
County of Hawaiʻi	Hawaiʻi (Hilo)
County of Maui	Maui (Wailuku), Lānaʻi (Lānaʻi City), Molokaʻi (Kaunakakai), Kahoʻolawe (uninhabited). Legally, a fifth county exists on the Island of Molokaʻi, named Kalawao, which was formerly the leper colony of Kalaupapa, established by Saint Damien of Molokaʻi to care for native Hawaiians with Hansen’s Disease (leprosy). The original Kalaupapa settlement is now managed by the National Park Service as The Kalawao National Historical Park. As of the census of 2000 there were 147 residents with Hansen’s disease still living at Kalaupapa.
City and County of Honolulu	Oʻahu (“Honolulu” generally refers to the Honolulu urban core between Kalihi Valley and Kahala)
County of Kauaʻi	Kauaʻi (Lihue), and Niʻihau (privately owned)
County of Hawaiʻi	Hawaiʻi (Hilo)

The entire island of Oʻahu comprises the City and County of Honolulu. The terms “Oʻahu,” and “City and County of Honolulu” are used interchangeably throughout this document. Generally speaking, “Honolulu” refers to the urban core on the south side of the island. Portions of the island of Oʻahu are rural and these areas are distinctly different from the urban core. Again, “cities” on the island of Oʻahu, such as Kāneʻohe, Kailua, and Wahiawā, are not incorporated.

Two of the Main Hawaiian Islands are entirely or largely privately owned: Niʻihau and Lānaʻi. Niʻihau is populated entirely by native Hawaiians whose principal language is Hawaiian. Access to Niʻihau is strictly controlled by the landowner, and there is very little interaction between the government and Niʻihau.

Eighty percent of the state's population lives on Oʻahu, with the greatest concentration in the Honolulu urban core. This population distribution is clearly reflected in the district boundaries for Hawaiʻi's two U.S. Congressional Districts (see Figure 2).

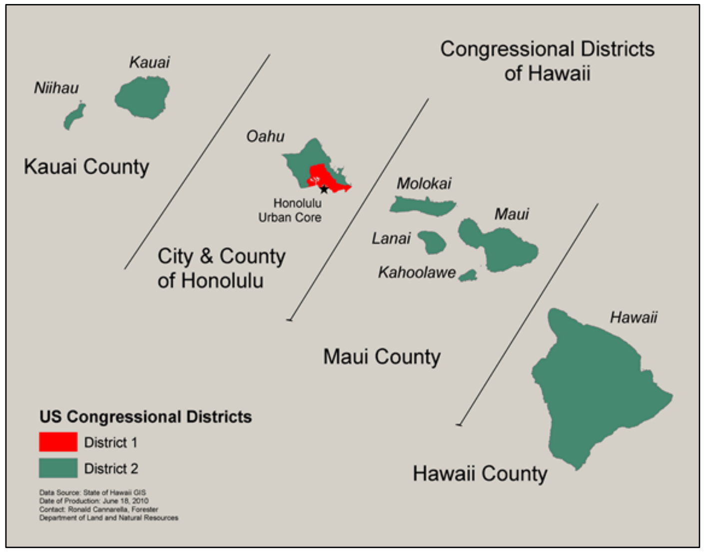


Figure 2. Congressional Districts of Hawaiʻi reflect the population concentrated in the Honolulu urban core.

Hawaiʻi's Issues for the 2016 Forest Action Plan Update

The states were given a good deal of leeway in how they identified relevant issues for their FAPs. For Hawaiʻi, we identified nine priority issues, listed below, using several questionnaires and online surveys and in collaboration with our partners. (*See "Appendix A: Stakeholder Involvement," for additional information on this process.*) DOFAW program managers developed the initial assessment, trends, threats, and strategies for issues relevant to their programs, and then all issues were reviewed by staff and our partners before incorporating them into the final document.

Hawaiʻi's Priority Issues are:

- Issue 1: Water Quality and Quantity
- Issue 2: Forest Health: Invasive Species, Insects, and Disease
- Issue 3: Wildfire
- Issue 4: Urban and Community Forestry
- Issue 5: Climate Change and Sea Level Rise
- Issue 6: Conservation of Native Biodiversity
- Issue 7: Hunting, Nature-Based Recreation, and Tourism
- Issue 8: Forest Products and Carbon Sequestration
- Issue 9: U.S. Tropical Island State and Territorial Issues

For the current update, DOFAW staff began assembling and updating the document in 2014, but with staff shortages and turnover, decided to seek additional assistance to complete the project. In 2015, DLNR asked H. T. Harvey & Associates to assist with revising content and drafting the update. The FAP team involved in the 2016 update includes DOFAW staff members who are directly involved in planning and implementing FAP projects, plus H. T. Harvey & Associates ecologists who have helped to write and revise the document.

Because so much of the 2010 plan remained relevant and a sound foundation on which to continue conservation efforts, the structure and content of that document was retained as much as possible. The content of the 2010 plan was reviewed and evaluated by the FAP team, program technical experts within DOFAW, advisory councils and conservation partners, management staff members who implement the plan, and staff members who use the plan for grant applications. This group worked together to identify the content and sections to be updated. Particular attention was paid to new information on threats and challenges, new or changing conservation or management strategies, new forest management initiatives, and development of forest products. Information on these topics were solicited from agency and conservation partners, species experts, and management experts via written requests and interviews.

The FAP team drafted revisions to the plan and provided a public review draft to DOFAW to review prior to distribution to the public. The draft update was released to the public for a 45-day review period, and a public information meeting was held on Oʻahu to present the plan and gather input from the public. The draft was also presented to the Board of Land and Natural Resources at a board meeting to brief the board on updated plan content, process, and public input. Comments from the public meetings, comments from the board, and any written comments submitted were addressed in the final version of plan, as appropriate.

Hawaiʻi's Forests: The Historical and Cultural Context

Summary[2]

Hawaiʻi is renowned as a tropical paradise, and anyone fortunate enough to visit or reside in these fair islands can attest to the beauty of our forests, beaches, waterfalls, and coral reefs. This is no accident; it is the result of centuries of land stewardship practices and cultural values that have perpetuated the land and sustained its people. Our values are rooted in the culture of the first people to populate these islands, the native Hawaiians. Over the centuries, the native Hawaiians developed a unique land stewardship system, the *ahupuaʻa* system, that functioned in harmony with the geography and climate of the Main Hawaiian Islands. The *ahupuaʻa* system was officially abolished in 1848 by King Kamehameha III and replaced with a system of private landownership based on American principles. However, within the last 40 years, we have learned through trial and error that watershed-level management produces the best results in Hawaiʻi. For this reason it is universally acknowledged that implementing a 21st century version of the *ahupua‘a* system is the path that will best serve the public interest.

Hawai‘i has a long tradition of comprehensive landscape-level planning for sustainably maintaining the natural resources upon which our livelihood, our economy, and our culture are based. This is the fourth statewide assessment and long-term strategy focusing on protecting our forests. The first assessment of the condition of Hawai‘i's forests was undertaken in 1902, and the strategy for addressing the serious threats to our forests and water supply resulted in the establishment of the Territorial Forest Reserve System in 1903. The second landscape-level plan was codified in the Hawai‘i State Land Use Law of 1961, which established a unique class of protected lands known as Conservation Districts. The third assessment of all of Hawai‘i's forested lands resulted in *The Hawai‘i Tropical Forestry Action Plan* (which did include private lands, but not urbanized areas) in 1994. In addition, the Hawai‘i Water Resources Regional Study of 1975 provided a thorough assessment of the benefits, threats and trends affecting Hawai‘i's water resources with a considerable emphasis on the role of our forests in sustaining water quality and quantity. This document is the fourth such statewide assessment of forest condition. The initial version of this plan was produced in 2010, as the *Hawai‘i Statewide Assessment of Forest Conditions and Trends*. Its title has since been shortened to *Hawai`i Forest Action Plan*, and this is the 2016 updated version of that plan.

In addition, three previous comprehensive statewide forestry plans have been produced evaluating only state-owned forest lands: *Multiple Use Program for the State Forest Lands of Hawai‘i* in 1962, *A Plan for the State Forest Lands of Hawai‘i* in 1975, and the *Hawai‘i Renewable Resources Research Plan for the Eighties*.

Through them all runs a common thread; our life in these islands is directly tied to the health of our forests and the role that they play in recharging our groundwater, springs, and streams.

The Hawaiian Archipelago: Isolated, Ancient, Continually Renewed

What we know today as the Hawaiian Archipelago actually consists of three distinct landforms all created by the same volcanic "hot spot," an apparently stationary feature in the middle of the Pacific tectonic plate (Figure 3). This hot spot pushes lava upward from deep within the earth's crust and over time forms a mountain that eventually reaches the surface of the ocean and continues to grow. Meanwhile, the Pacific plate slowly moves in a northwest direction away from the hot spot, carrying the landmass with it. In conjunction with this lateral movement, the sea floor actually sinks as it moves away from the hot spot. The combination of this sinking tendency and the powerful forces of erosion by wind, rain and sea begin to wear the young island down. Thus, the youngest islands are those at the southeast portion of the island chain, and the islands get progressively older as one travels west.

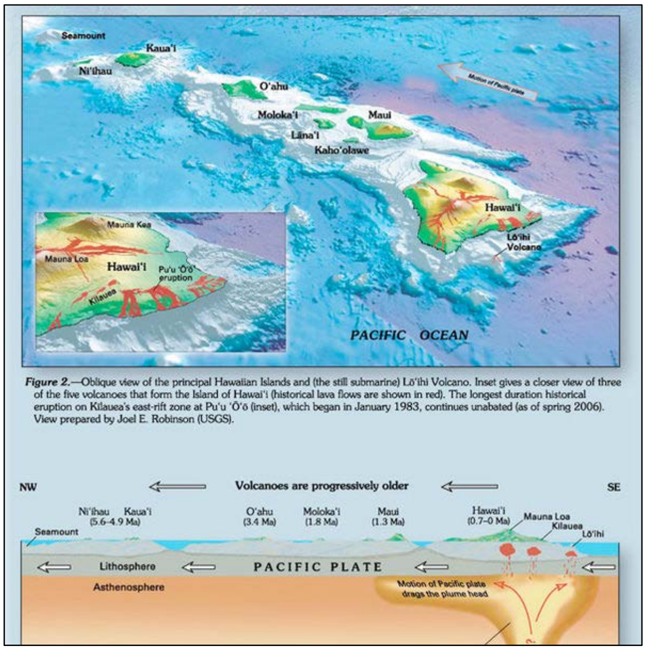


Figure 3. The Hawai'i hot spot. Image courtesy of the U.S. Geological Survey.

The process of creating new land from lava continues to this day. Kīlauea volcano in Hawaiʻi Volcanoes National Park has been continually erupting since 1983. Many visitors to Kīlauea are treated to a rare spectacle of molten lava pouring into the ocean. Kīlauea lies on the eastern flank of another volcano, Mauna Loa, which rises to 13,680 feet above sea level. When measured from the sea floor to the summit, Mauna Loa is one of the tallest mountain on the planet.

The High Islands

Those islands that have not been eroded down to sea level are known as "high islands." The Main Hawaiian Islands, which sustain human populations, are all high islands. In the millions of years that it takes for an island to move away from the hot spot, significant changes take place in soil chemistry and structure as the lava weathers and ages. Thus, soil fertility and the landscape itself are very different from island to island.

The Big Island is the youngest island in the archipelago. On the Big Island, Mauna Kea is the highest mountain in the state, rising gently from sea level to 13,796 feet (Figure 4). The Island of Hawaiʻi has rich, young volcanic soils, and many portions of the island are still so porous that they do not support perennial streams.

Figure 4. Hawai'i's tallest mountain, Mauna Kea, is often covered in snow from November to February.

At the western end of the high islands lies Kauaʻi; the oldest of the high islands. Kauaʻi has highly weathered and compacted soils. It supports many perennial streams and its highest peak is only 5,148 feet above sea level.

High islands also produce a precious commodity: water. As the trade winds approach a high tropical island, the air that has traveled thousands of miles over the open ocean rises and drops its cargo of rain. Trees on the forested peaks also capture fog from the misty clouds. This rainfall and fog drip are essential in sustaining life on the high islands. The wet northeastern portions of all of Hawai'i's high islands, known as the "windward sides," are wet and support rainforests and cloud forests.

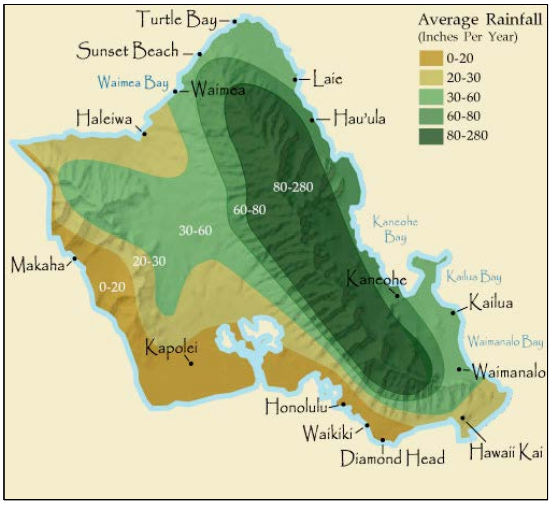


Figure 5. Average rainfall on O'ahu clearly shows the wet "windward" side and the dry "leeward" side found on all the islands. Image courtesy of Chris Spears.

As the winds cross the ridges, they lose most of their moisture, and so little rain falls. The dry southwest portion of each island is known as the "leeward side," or in Hawaiian, the *kona* side of the island. The forests of the *kona* sides of the islands are very different from those found on the windward sides. These tropical dry forests grow more slowly and are more prone to wildfire. This difference is clearly shown in Figure 5.

For this reason, Ralph Hosmer, Hawai'i's first forester, identified two types of forest in Hawai'i: "protection forests," defined as those on the wet windward slopes from which the most important product was water; and "commercial forests," defined as those from which the most important product was wood.

Throughout the world, the tropical dry forests are the most endangered, and Hawai'i's are no exception. The Pu'uwa'awa'a unit of the Hawaii Experimental Tropical Forest is highly degraded, and it is our hope that research and adaptive management of this area will provide insight into managing dry tropical forests throughout the world.

The Atolls of the Northwestern Hawaiian Islands

Once a high island has eroded to sea level, all that remains is the live coral reef that once ringed the island. Corals require sunlight for their survival, and grow at the rate of approximately 1 centimeter per year. As the Pacific plate continues its movement to the northwest, and as long as the corals can keep up with the sinking of the plate, a coral atoll forms. The state of Hawai'i includes these coral atolls, which are referred to as the Northwestern Hawaiian Islands. These atolls are not capable of sustaining human populations because they cannot capture rainwater as the Main Hawaiian Islands do. Nevertheless, they are rich in marine life, and support

"On the Island, we do it Island Style, From the mountain to the ocean from the windward to the leeward side."
Lyrics to a popular Hawaiian song by John Cruz.

huge populations of sea birds. They are also the habitat of the Hawaiian monk seal, one of the most endangered animals in the world.

For these reasons, the Northwestern Hawaiian Islands were designated as the Papahānaumokuākea Marine National Monument. The Papahānaumokuākea Marine National Monument is the single largest conservation area under the U.S. flag, and the largest marine conservation area in the world. It encompasses 582,578 square miles of the Pacific Ocean—an area nearly as large as the Gulf of Mexico (Figure 6).

Map of the USA with the Hawaiian Archipelago overlaid. Black outline shows the boundary of the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, which is 1200 Nautical Miles long by 100 Nautical Miles wide and has an area roughly the same size as Florida and Georgia combined, or 131,800 square statute miles.

Figure 6. The U.S. mainland with the state of Hawaiʻi overlaid, to show scale.

The First Hawaiians and the *Ahupuaʻa* System

The native Hawaiians developed a unique land stewardship system, called the *ahupuaʻa* system. In the *ahupuaʻa* system, the land was managed as a series of nested units. The most fundamental of these was the *ahupuaʻa*, which generally followed geographical watershed boundaries (Figure 6). The *ahupuaʻa* was managed as a single unit, from the mountain tops (in Hawaiian these areas are the *wao akua*, or realm of the gods) to the *wao kanaka*, or realm where people lived and tended their agricultural lands, and out to the reef.

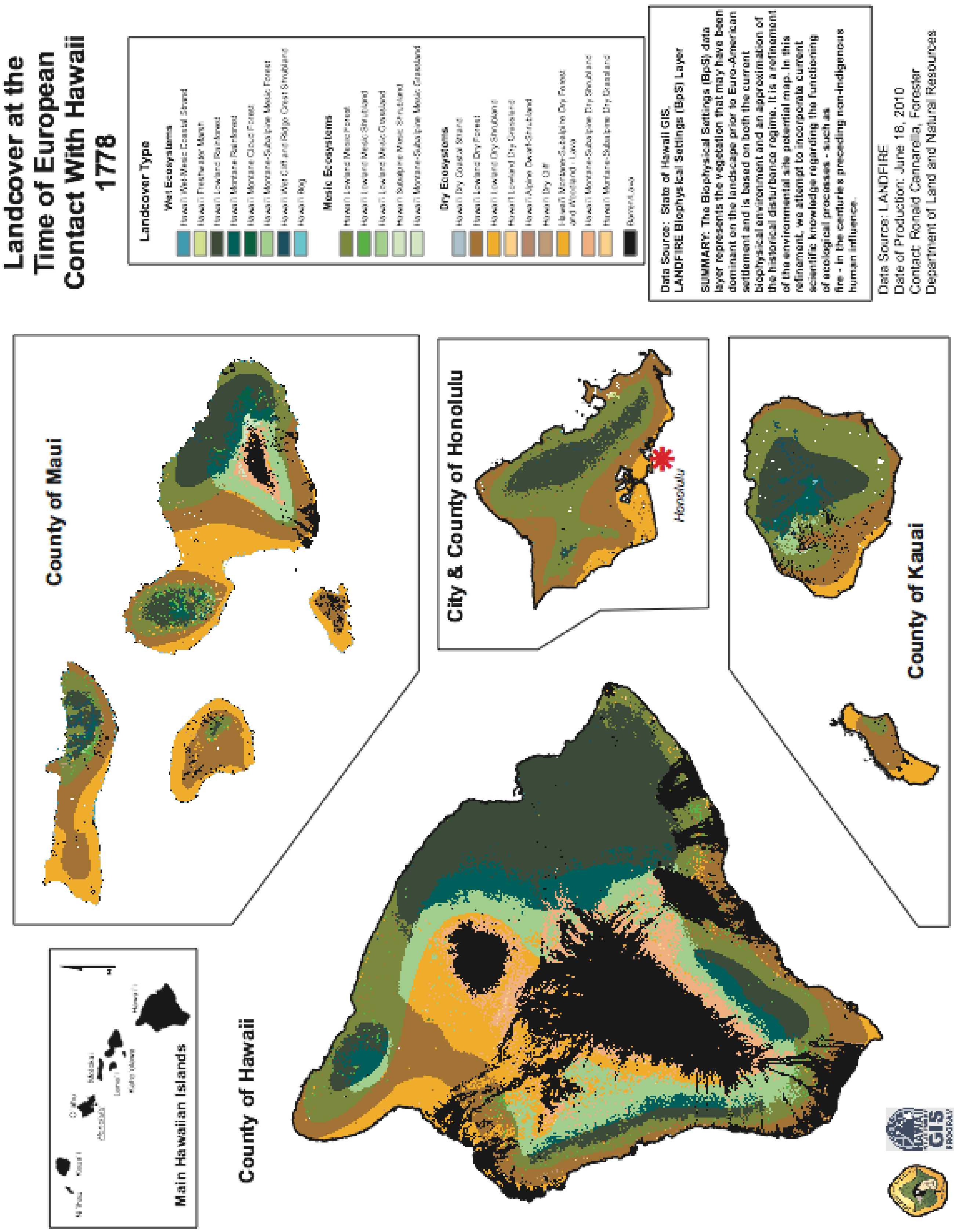
In 1778, the legendary explorer Captain James Cook happened upon the Hawaiian Archipelago on his third voyage of discovery. In Hawai‘i he encountered a large and thriving population and a healthy functioning ecosystem. Map 1 shows land cover at the time of European contact and Map 2 depicts only the forested lands at that time.

In the years that followed, change came swiftly to Hawai‘i as a result of introduced ideas, new technologies such as metal tools and firearms, introduced animals, and diseases to which the native Hawaiians had never been exposed. Honolulu with its deep water port, abundant natural resources, and friendly people soon became a favorite way station for whalers and traders crossing the Pacific Ocean.

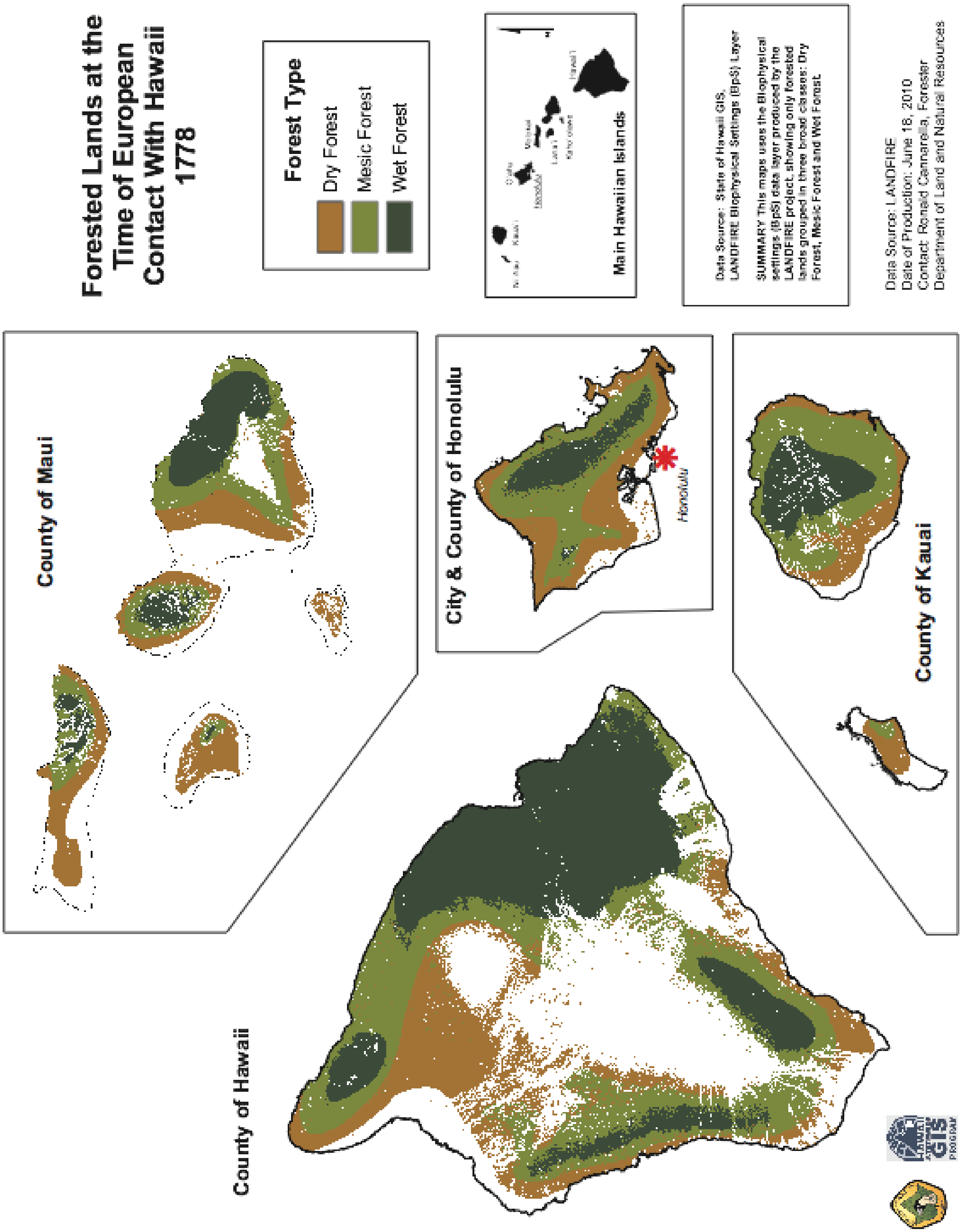
> ***"We are in trouble because we have no firewood and no la‘i [ti leaf], and no timber for houses, it is said in the law that those who are living on the land can secure the things above stated, this is all right for those living on the lands which have forests, but, we who live on lands which have no forests, we are in trouble. The children are eating raw potato because of no firewood, the mouths of the children are swollen from having eaten raw taro. We have been in trouble for three months, the Konohikis with wooded lands here in Kaneohe have absolutely withheld the firewood and la‘i and the timber for houses." (Letter from Hio et al. to House of Representatives, 1851)***
>
> Source: 2004 Paul F. Nahoa Lucas, "No Ke Ola Pono o Ka Lahui Hawaii" *Hulili: Multidisciplinary Research on Hawaiian Well-being*, Kamehameha Schools.

The Hawaiians adapted to these changes in remarkable ways. Within 15 years of Captain Cook’s first contact in 1778, King Kamehameha I transformed Hawai‘i from a number of warring island-states to a modern nation and eventually to a constitutional monarchy.

Soon thereafter, Christian missionaries, whalers, and entrepreneurs, mostly from the U.S., brought new ideas of religion and land tenure. Within two generations, in 1831, Queen Ka‘ahumanu officially outlawed the official state religion, known as the *kapu* system, and replaced it with Christianity as the new state religion. In a similar vein, the *ahupua‘a* system was officially abolished by the stroke of the pen in 1848 when King Kamehameha III (Kauikeaouli) instituted a new land tenure system similar to that of the U.S. in a process known as the Great Māhele. The Great Māhele divided all lands into one of three classes; privately owned fee simple, lands reserved for the government, and lands reserved for the Crown.



Map 1. Land cover at the time of first contact between Europeans and native Hawaiians.



Map 2. Forested lands at the time of first contact between Europeans and native Hawaiians.

The consequences of the Great Māhele were profound and yielded some unanticipated results. Instead of providing the native Hawaiians with the security of owning their own lands, many native Hawaiians were instead disenfranchised from their lands. Large agricultural interests, mostly owned by U.S. entrepreneurs, acquired large tracts of land, and the era of large-scale plantation agriculture began, based mostly on sugar cane. Private land was consolidated in the hands of a few large landowners, and laborers were imported from China, Japan, the Philippines, Korea, Puerto Rico, and Portugal to work the fields.

While a few large landowners grew wealthy, the condition of the forests of Hawaiʻi continued to deteriorate owing to the ever-increasing number of feral animals pushing farther into pristine ecosystems. Native Hawaiians suffered as well. Shortly after contact with Europeans, the native Hawaiian people, who had been self-sufficient for centuries, increasingly experienced homelessness, hunger, and disease. Thousands of native Hawaiians perished in mass epidemics as waves of new introduced diseases swept over the islands. Soon immigrants and non-Hawaiian locally born residents outnumbered the native Hawaiians. By the end of the 1800s, the economy of the Kingdom was faltering, and the large colonial powers of the era, England, Spain, France, and the U.S., all had their sights on Hawaiʻi and its most coveted asset: the deep water port of Pearl Harbor.

In 1893, a small group of American sugar planters unilaterally declared an end to the monarchy, proclaimed themselves the new Provisional Government of the Hawaiian Islands, and immediately sought the support of an American warship anchored in Honolulu's harbor. In that moment, the Kingdom of Hawaiʻi was abolished and Queen Liliʻuokalani, last reigning monarch of the Kingdom of Hawaiʻi, was imprisoned in the Royal Palace. The Queen realized that the native Hawaiian and remaining loyal Hawaiian subjects would be no match for the new American superpower, and so she called upon her people not to take up arms or shed blood trying to resist the new government, but instead to focus on protecting their families, preserving their culture, and surviving as a people.

In 1900, the U.S. officially annexed the Hawaiian Islands as the Territory of Hawaiʻi. All government lands and crown lands from the Great Māhele, collectively referred to as the Ceded Lands, were transferred to the U.S., which then entrusted the Territory with the stewardship of those lands. The status of the Ceded Lands is still being debated in the courts, in the Hawaiʻi Legislature, and in Congress. The native Hawaiian people are still not officially recognized by the federal government as a self-governing native people. This stands in stark contrast to the official government-to-government relationship that the federal government has with all remaining Native American tribes in the other 49 states.

One of the top priorities of the Territorial government, however, was to address the serious environmental problems that were affecting every citizen of the islands at the time. First and foremost was the crisis caused by deforestation and the resulting water shortages.

The Water Crisis of 1875 and Hawai'i's First Statewide Assessment and Resource Strategy: 1902

Prior to 1820, all of Honolulu's domestic drinking water was obtained from natural springs and the small river that runs through Nu'uanu Valley. The requirements of supplying whaling ships caused a waterfront storage tank to be installed at the lower end of Nu'uanu Street. The water for that tank came from a taro patch on Emma Street. The demand for drinking water from various springs and the Nu'uanu River spurred the development of a public water supply distribution system that, upon its completion in 1862, provided water to the residents and businesses in downtown Honolulu. The American writer Mark Twain was pleasantly surprised at how sophisticated Honolulu was when he first visited the islands in 1866. In his first essay written after arriving from San Francisco, he describes his first impressions of Honolulu: his hotel room, exotic trees like mango and tamarind, and the price of doing laundry. He specifically comments on the public water supply:

> "The water is pure, sweet, cool, clear as crystal, and comes from a spring in the mountains, and is distributed all over the town through leaden pipes. You can find a hydrant spurting away at the bases of three or four trees in a single yard sometimes, so plenty and cheap is this excellent water. Only twenty-four dollars a year supplies a whole household with a limitless quantity of it."[3]

Even as he wrote these words, native Hawaiians and long-term residents were expressing concern about two disturbing trends that seemed to somehow be linked; the destruction of upland forests by feral cattle, goats, boar, and sheep, and the observation of the drying up of springs and rivers. The rapid pace of forest destruction and increasingly frequent water shortages had outpaced the government's ability to respond.

Fortunately, during that same period, artesian (well) water was just being discovered on O'ahu. The discovery of this resource was completely unexpected. It had never occurred to anyone that an abundance of groundwater could be found on a tropical island. In 1889, the first commercial artesian well was dug on the 'Ewa plain of the island of O'ahu. Thus began the era when artesian wells were dug on all of the islands. Forward-thinking government officials, sugar planters, geologists, and water engineers quickly realized what the native Hawaiians had known for centuries: water and forests are inexorably linked. Destroy the forests, and water will disappear too.

By 1900, there was a general sense of panic among all residents of the islands as the springs and rivers that had sustained them for centuries dried up or became undrinkable due to sedimentation from denuded slopes. So the Territorial government turned to the U.S. Department of Agriculture (USDA) for help. USDA dispatched E. M. Griffith, a forester with the USDA Bureau of Forestry, to assess the condition and trends of Hawai'i's forests, and to recommend a long-term strategy for addressing the threats to the forests. Griffith completed his assessment and recommendations in 1902. Those findings and recommendations provide us with a reference point documenting conditions and trends at that time, and the strategy at that time to restore and protect essential forest cover in the State (see *Appendix G* for a copy of Griffith's report).

Establishment of the Territorial Forest Reserve System

Griffith's report was well received, and his recommended strategy was implemented. In 1904, Ralph S. Hosmer was hired as the first Territorial Forester. He immediately initiated a survey of those lands that should be designated as Forest Reserve and protected. By 1930, Hawai'i's Forestry agency was staffed with trained forest rangers, tree nurseries were established, and a Forest Reserve System was created that protected nearly 1,000,000 acres of public and private lands. Figures 7 and 8 show the results of the successful implementation of Griffith's strategy in in Nu'uanu Valley on O'ahu.

Figure 7. Nu'uanu Valley in 1929. The hillsides were almost devoid of any trees. The bare patch of ground is the O'ahu Country Club. Photo courtesy of Suzanne Case.

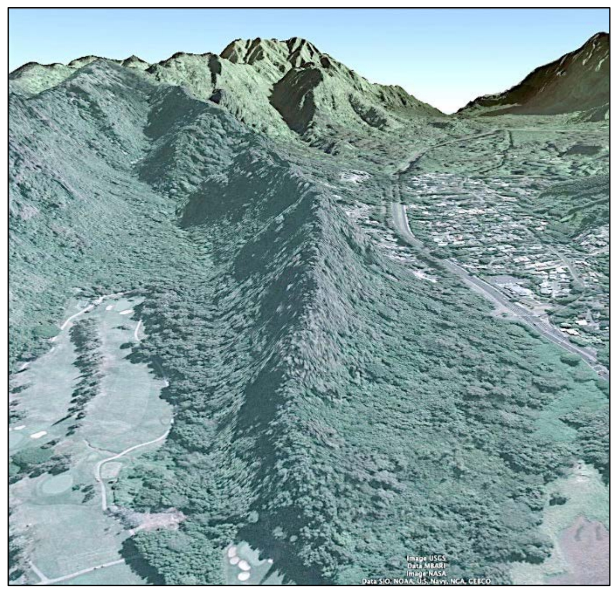


Figure 8. Nu'uanu Valley in 2010. Image courtesy of Google Earth.

The establishment of the Forest Reserve System was a true public-private partnership. All Territorial lands identified as important recharge areas were dedicated to the Reserve System, and private landowners volunteered their adjacent lands via "surrender agreements" with the Territorial government so that the Reserves could be managed as whole units regardless of ownership. Figure 9 shows the extent of the Forest Reserves in 1960 shortly after Hawai'i attained statehood. Tree propagation and planting were popular civic activities, and countless volunteers contributed to reforesting and protecting the Forest Reserves. That tradition continues to this day.

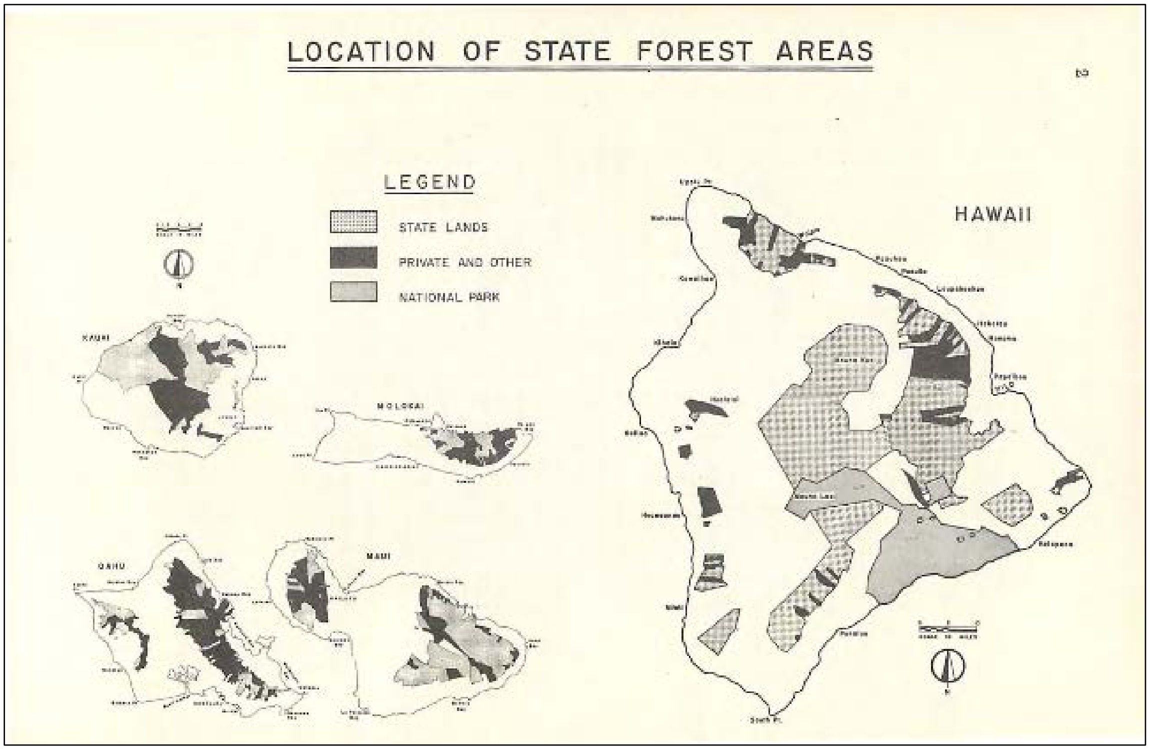


Figure 9. The Forest Reserves as they existed immediately after statehood, and prior to the passage of the State Land Use Law in 1961.

During this same period, the Boards of Water Supply on each island made it a policy to use artesian wells and forego the use of surface water or reservoirs. In 1932, Mr. Ohrt, Manager and Chief Engineer of the Honolulu Board of Water Supply, wrote "for the first time, the problem of Honolulu's water supply (can) be said to have been solved."[4] Today, nearly 100% of Hawai'i's public water is withdrawn from wells. See Figure 10 and the following quote from the U.S. Geological Survey regarding the importance of groundwater in Hawai'i:

> Ground water is one of Hawai'i's most important natural resources. It is used for drinking water, irrigation, and domestic, commercial, and industrial needs. Ground water provides about 99 percent of Hawai'i's domestic water and about 50 percent of all freshwater used in the State. Total ground water pumped in Hawai'i was about 500 million gallons per day during 1995, which is less than 3 percent of the average total rainfall (about 21 billion gallons per day) in Hawai'i. From this perspective, the ground-water resource appears ample; however, much of the rainfall runs off to the ocean in streams or returns to the atmosphere by evapotranspiration. Furthermore, ground-water resources can be limited because of water-quality, environmental, or economic concerns. Water beneath the ground surface occurs in two principal zones: the unsaturated zone and the saturated zone. In the

unsaturated zone, the pore spaces in rocks contain both air and water, whereas in the saturated zone, the pore spaces are filled with water. The upper surface of the saturated zone is referred to as the water table. Water below the water table is referred to as ground water.[5]

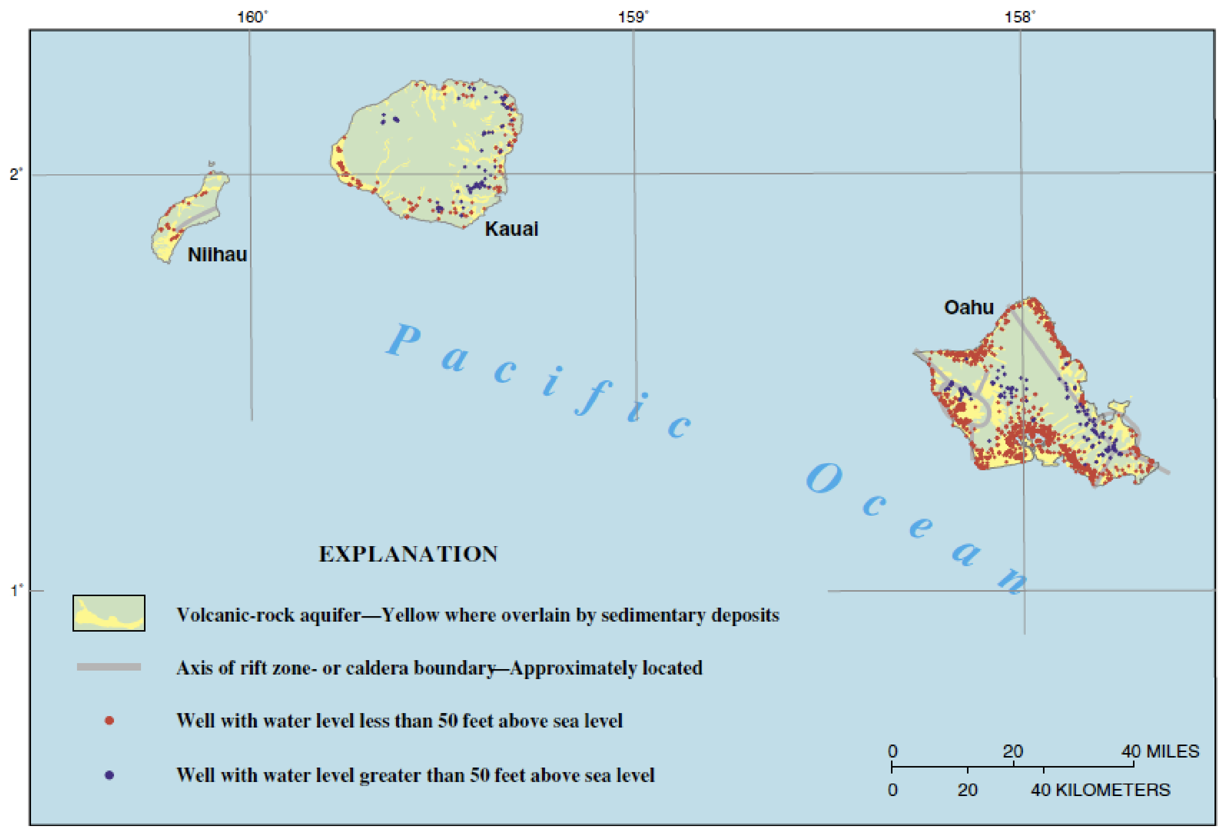


Figure 10. Location of artesian wells, which are the source of water for the public water supplies on Ni'ihau, Kaua'i, and O'ahu. Image courtesy of the U.S. Geological Survey.[5]

One Problem Solved, New Threats Emerge

In solving one major problem, how to reforest denuded slopes, the early generation of foresters unwittingly sowed the seeds of our greatest threat to Hawai'i's forests today: the introduction of highly invasive weeds, insects, and disease. Early in the process, foresters noted that most native Hawaiian tree species could not become established in the hard, eroded slopes that had once been thriving forests. So they began to search the world for species that they could effectively grow in mass quantities in tree nurseries and be planted in the field. The exotic and ornamental trees were chosen for being fast growing and capable of quickly colonizing the eroded slopes.

Today, our botanical gardens are filled with spectacular flowers and foliage plants that do not have to compete with the other plants, animals, insects, and diseases that evolved alongside them in their native habitats. Some of our most pernicious weeds, including *Miconia calvescens*, escaped from botanical gardens.

Like the water crisis of the 1880s, the problem of invasives snuck up on us, but now there is widespread consensus that introduced organisms threaten our land, our water, our streams, and our coral reefs. The first forestry plan developed specifically for State Forest Lands in 1962, entitled *Multiple Use Program for the State Forest Lands of Hawai'i,* identified the values of Hawai'i's forests and the threats to these values. The report identified only three threats to the forests: (1) the threat from fire, (2) the threat from insects and disease, and (3) the threat from animal damage.[6] The threat from invasive plants and the value of native biodiversity were not mentioned in the 1962 plan.

Since then, the rate of introduction for destructive new animals, plants, insects, and disease has increased dramatically with the advent of jet travel. The impact on our native species has been catastrophic. By 1992, a mere 30 years after that initial plan, it had become apparent that invasive insects, plants, algae, and vertebrates were some the most significant threats to our forests, streams, and coral reefs. Shortly after the passage of the Endangered Species Act, Hawai'i earned the nickname "extinction capital of the country," with approximately 35% of the federally listed threatened and endangered species. These topics are covered in depth in many of this plan's Issues sections.

Hawai'i's Second Statewide Assessment and Resource Strategy: 1961 Hawai'i State Land Use Law and the Establishment of the Conservation District

Shortly after Hawai'i became a state, the Hawai'i Legislature passed the Hawai'i State Land Use Law. All lands in the state were assigned to one of three "Districts," regardless of land ownership. The first and arguably most important district to be delineated was the "Conservation District." The main purpose for establishing the Conservation District was to ensure the protection our forested water recharge zones in perpetuity and to limit conversion of these lands to other uses. The boundaries of the Conservation District closely followed the original Territorial Forest Reserve Boundaries shown in Figure 9. Over time, the Conservation District has been further subdivided into subzones as the public and resource management agencies came to recognize the importance of protecting other values, such as cultural uses guaranteed to native Hawaiians by the state constitution, unique geological features, recreational opportunities, and exceptional native ecosystems.

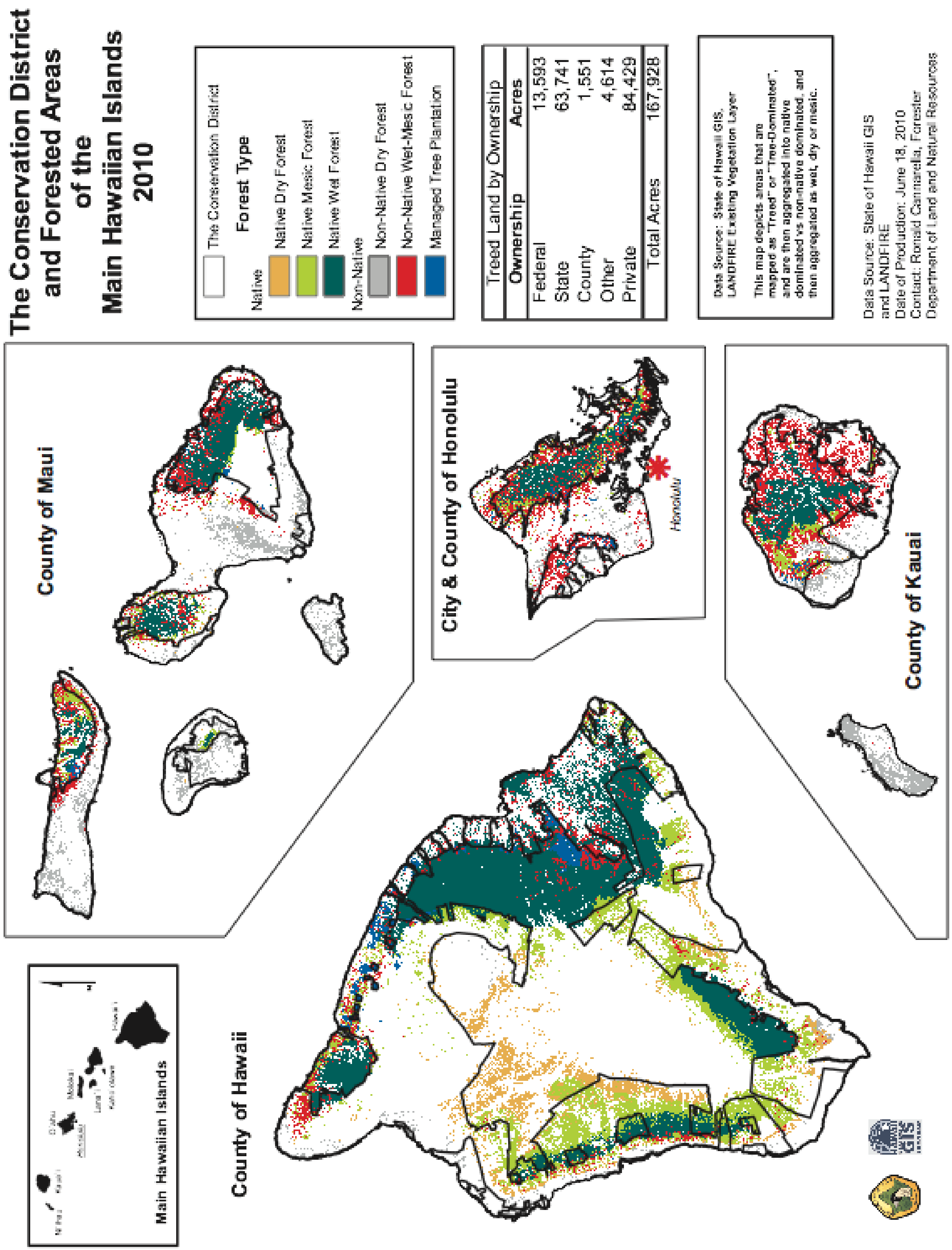
Once the Conservation District boundaries were established, the next District to be determined was the Urban District. The purpose of the Urban District was to direct urban growth to appropriate areas. This was significant for Hawai'i because the state does not have a municipal level of government. Lands not assigned to the Conservation District or the Urban District were lumped in a broad category called the Agricultural District, with little regard to their potential for agriculture. Several years later, the Legislature established the Rural District, with the purpose of preserving the quality of life for residents who choose to live in rural areas.

The Conservation District has been effective in preserving the regenerative capacity of our forested uplands. Since the enactment of the State Land Use Law, there have not been significant changes to the Conservation District. If anything, lands have been added to that district as the state has acquired private lands. However, there has been a tendency to reassign lands in the Agricultural District to the Urban District. This process has been exacerbated by the loss of Hawaiʻi's sugar cane and pineapple industries in the 1990s to countries where production costs for those crops are lower and environmental controls are less stringent. Nevertheless, the conversion of prime agricultural lands to residential communities and Oʻahu's "Second City" of Kapolei are of concern, because these lands will no longer be available for agriculture once developed.

Significance of the Conservation District

Planning and development in the Urban District, the Agricultural District, and the Rural District are regulated by the county governments. However, all activities within the Conservation District are regulated by DLNR. If a landowner wishes to undertake any actions on lands in the Conservation District, he or she must apply for a permit from DLNR. Thus, the Conservation District is essentially Hawaiʻi's Priority Landscape Area for conservation to ensure that those lands continue to provide vital ecosystem services in perpetuity.

Map 3 depicts the current boundaries of the Conservation District. It clearly shows that the Conservation District has prevented the conversion of forests to other uses, but it also underscores the fact that many of our forested areas are dominated by non-native species. This map does not capture what is happening in the understory, where the rate of spread of invasive plant species is increasing at an alarming level in many areas. Using *Miconia calvescens* as one example, if a single mature seed-bearing tree emerges from the understory, it will produce millions of seeds per year that will quickly be dispersed over the landscape by birds. A single mature *Miconia*, if left untreated, has the capacity to spread at an exponential rate and completely overtake all other overstory tree species, native or non-native.



Map 3. Lands in the Conservation District are permanently protected by state law to ensure that they continue to provide valuable ecosystem services in perpetuity. These lands are not at imminent risk of development, but they are increasingly dominated by non-native species.

The New Forest Reserve System: Unanticipated Consequences

With the implementation of the State Land Use Law, the definition of Forest Reserve changed. The State Forest Reserve System, which we currently have, includes only state-owned lands in the Conservation District. The Division of Forestry (which subsequently added wildlife management and was renamed the Division of Forestry and Wildlife, or DOFAW) was entrusted with management of the Forest Reserves, but had no jurisdiction over non-state lands that once composed the Territorial Forest Reserve system. Federal and privately owned lands in the Conservation District were still subject to permitting requirements by DLNR, but over time, management activities became less coordinated. Landowners and federal agencies managed their lands according to their own priorities or other mandates. New threats to the forested uplands emerged. With increased access to the Hawaiian Islands facilitated by jet travel and increased trade between the U.S. and Asia, the rate of introduction of dangerous invasive plants, insects, and disease increased significantly.

As awareness of environmental issues grew during the 1970s, the passage of federal and state Endangered Species Acts focused energy and resources on saving individual species from extinction. Hawaiʻi established a Natural Area Reserve System (NARS) in 1975 specifically for the preservation of native ecosystems and cultural resources. The state's Natural Area Reserves were created by withdrawing lands representing the best examples of intact native ecosystems from the State Forest Reserve System, and an independent Natural Area Reserve Commission was established to develop policy for the NARS. DOFAW established a new class of land managers specifically for the NARS. Although the NARS and Forest Reserve System staff work side by side, their mandates differ. NARS staff focuses primarily on conservation of biodiversity, and Forest Reserve staff focuses on management of the Forest Reserve System under a multiple-use mandate.

Additional programs were created or transferred to DOFAW in the 1970s and 1980s. The regulation of hunting was transferred from the Division of Fish and Game to the Division of Forestry to create DOFAW. In 1988, the state established the Na Ala Hele Trail and Access system to plan and maintain hiking trails and to provide access to public resources such as beaches, cultural sites, and scenic forest lands.

Federal agencies including the National Park Service, the U.S. Fish and Wildlife Service, and the U.S. Military, as well as conservation organizations such as The Nature Conservancy, acquired lands for the purpose of conservation. Over time, more and more lands were put into permanent conservation. Overall, the trend has been positive for conservation of our natural resource base. The conversion of our forest lands to other uses such as agriculture or urbanization was effectively managed. However, at the same time, management of land to protect our most precious resources of water, native species, and cultural resources, became incrementally fragmented and uncoordinated.

A similar scenario was evolving with Hawaiʻi's coastal waters. Conflicting activities increased as the visitor industry grew. Traditional native Hawaiian gathering rights, which are guaranteed by the state constitution, created conflicts between commercial fishermen, recreational uses such as surfing, and the use of motorized watercraft. Multiple state and federal agencies were charged with different mandates. At a national level, the same phenomenon was taking place.

Hawaiʻi's Recent Partnerships and Initiatives

More than a century after the establishment of the original Forest Reserve System, we have seen the voluntary establishment of several new public-private watershed partnerships and other resource management alliances to facilitate cooperation among various land management agencies for the benefit of all. The same values that we inherited from the native Hawaiians, a deep love of the land, respect for community, and a spirit of *aloha* and cooperation, has led to the establishment of these new successful and effective partnerships.

In addition to their ongoing activities, all of these stakeholder organizations were instrumental in helping DOFAW produce this document, and the authors of this document interact on a daily basis with these organizations:

The Hawaiʻi Conservation Alliance (HCA)

HCA is an alliance of 15 federal, state, Hawaiian, and not-for-profit organizations engaged in the stewardship and conservation of Hawaiʻi's natural resources. HCA has been a valued partner of DOFAW since its inception, and was instrumental in helping to produce this document. HCA is also helping the U.S. Fish and Wildlife Service to coordinate the establishment of its new Pacific Islands Climate Change Cooperative (PICCC). See *"Issue 6: Conservation of Native Biodiversity," and "Issue 5: Climate Change and Sea Level Rise," for more information.*

The Watershed Partnerships

Public and private landowners voluntarily came together to manage their lands for the purpose of recharging groundwater and surface water resources. After several watershed partnerships had established themselves, they came together to form an overall coordinating body, the Hawaiʻi Association of Watershed Partnerships (HAWP). DOFAW helps coordinate the various watershed partnerships, which have proven to be very effective at leveraging funding from various sources, both public and private. This issue is covered in more detail in *"Issue 1: Water Quality and Quantity."*

Hawaii Invasive Species Council (HISC)

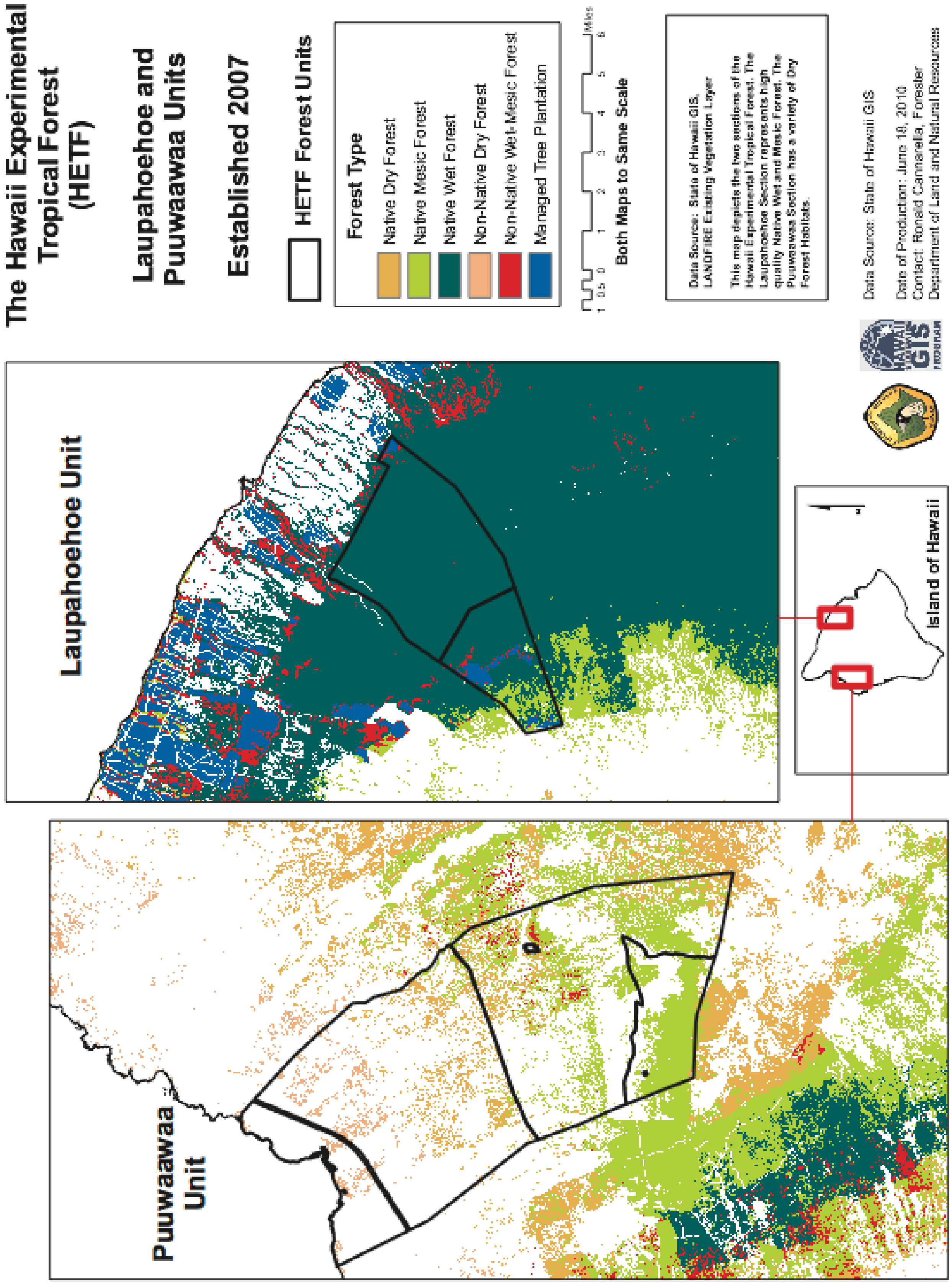
HISC is the statewide coordinating organization for addressing the threat of newly introduced invasive species. Public and private agencies have been working cooperatively for years on invasive species control activities; these groups include the Coordinating Group on Alien Pest Species (CGAPS) and the county-based invasive species committees (ISCs). HISC has been very effective at supporting these groups, leveraging funding for the control of invasive species, and coordinating the activities of agencies working to protect Hawai‘i from dangerous invasive species that continue to arrive by air, by sea, and on the wind.

The Ocean Resources Management Plan (ORMP) Working Group

ORMP was mandated by the Hawai‘i Legislature to provide a forum for coordinating the numerous agencies and organizations involved in the management and use of Hawai‘i’s ocean resources. Like HCA, the ORMP working group consists of representatives of many federal, state, county, and private organizations.

The Hawaii Experimental Tropical Forest (HETF)

A forest planning effort in Hawai‘i in 1994 produced *the Hawai‘i Tropical Forest Recovery Action Plan*. One of the most significant outcomes of the action plan was the recognized need for an experimental forest in Hawai‘i to provide research opportunities addressing tropical island forestry issues. Two distinct forested areas, one representing wet forest systems and one representing dry forests, were selected on the Big Island in 2007 (Map 4). HETF represents a cooperative partnership between FS Institute of Tropical Island Forestry and DLNR.



Map 4. The Hawaii Experimental Tropical Forest units.

Section References

[1] Hawai‘i Revised Statutes, Section 5-7.5, 1986.

[2] For a detailed timeline of forestry in Hawai‘i, refer to Appendix F.

[3] Day, A. G., editor. 1966. Mark Twain’s Letters from Hawaii. University of Hawai‘i Press, Honolulu.

[4] Staff of the Board of Water Supply, City and County of Honolulu. 1948. Conservation, Development and Protection of the Water Resources of the Honolulu Urban Area, Vol. 2.

[5] U.S. Geological Survey, Hawai‘i District. 2000. Ground Water in Hawaii. Publication FS126-00. Website: http://hi.water.usgs.gov/publications/pubs/fs/fs126-00.pdf.

[6] Staff of the Division of Forestry. 1962. A Multiple Use Program for the State Forest Lands of Hawaii.

Issue 1: Water Quality and Quantity

"In Hawai'i, the most valuable product of the forest is water, rather than wood."

Ralph S. Hosmer, First Territorial Forester

Figure 1.1. Water is our most precious resource, and healthy forests are essential for maintaining water quality and quantity. Photo courtesy of Chris Spears, Meteorologist; Waterfalls on Kaua'i.

Overview

Protection of forested watersheds to supply Hawai'i's fresh water (Figure 1.1) is a top priority for the Department of Land and Natural Resources (DLNR), and as such all programs that support watershed management or address watershed threats continue to be a high priority for the state, as attested by the two watershed protection plans begun over the past five years: *The Rain Follows the Forest: A Plan to Replenish Hawai'i's Source of Water,*[1] in 2011, and an expansion of that initiative, the *30 by 30 Watershed Forests Target,*[2] this year. As testament to the importance of this issue to the state, Governor Ige announced the watershed protection plans to the global conservation community in association with the International Union for the Conservation of Nature's World Conservation Congress, held in Honolulu in September 2016. As a part of Hawai‘i's World Conservation Congress Legacy Commitment, and the Sustainable Hawai‘i Initiative, the governor launched the *30 by 30 Watershed Forests Target* initiative and committed the State of Hawai‘i to protect 30% (253,000 acres) of the highest-priority watershed forests by 2030. This represents a significant advancement of watershed protection goals in the state. In 2011, when DLNR published its watershed plan, only 10% (approximately 90,000 acres) of the priority watershed forests identified in the plan areas were protected and managed to address the majority of watershed threats—a level of management that took 40 years to achieve.[1]

The initiative proposes to fence and remove nonnative hooved animals from targeted core areas, control invasive plants in priority native forests, prevent and control wildfires, combat forest diseases and pests, and plant native trees to protect watershed forests. These actions not only would restore watershed functions to replenish aquifers and surface water flows to secure the water supply needed for the future, but would increase Hawai‘i's resilience and ability to withstand impacts from climate change. To keep Hawai‘i on track to meet its 2030 goals, the initiative proposed watershed funding of $7.5 million per year for fence construction in Fiscal Year 2018–2019 to protect more than 18,000 acres of high-priority watershed forests and additional funding to control invasive plants and wildfires and to plant native trees.[2]

As of September 2016, the state had invested over $24 million for Fiscal Years 2013–2017 toward projects that protect these watershed forests from threats. DLNR distributes funds under this initiative through a competitive process open to public and private entities within the Watershed Partnership program, as well as directs funds to build organizational capacity to manage watersheds and water resources, and to support the expanded efforts of partnerships that highlight landscape-scale management. A majority of the state funds distributed through the Watershed Partnership program are additionally matched by federal, county, and private funds. DLNR works with the Hawai‘i Association of Watershed Partnerships (HAWP), an alliance of private and public partnerships, to coordinate and promote collaborative management across landscapes. Additional resources are needed to meet watershed management goals, with watershed partnerships even further leveraged, to address critical threats to the forests that are inextricably tied to Hawai‘i's water supply.

Brief History of Watershed Management in Hawai‘i

Before the discovery of high "perched aquifers" in the late 1800s, all of the public water systems in Hawai‘i relied on surface water from streams, springs, and reservoirs. Between 1779 and the last half of the 19th century, forests on all islands were nearly destroyed by wild cattle, sheep, and goats that had been introduced by the early European explorers and had been allowed to roam free. The intention was to allow wild animal populations to grow in order to provide game for the Hawaiian people, but the consequences of introducing these “feral ungulates” (hoofed grazing animals such as cattle, sheep, goats, deer, and pigs living in the wild) were disastrous for Hawai‘i’s forests. By 1890, everyone was experiencing the secondary effects of the destruction of the forests. Rivers and springs began to disappear in the dry season, and in the rainy season, flash floods carried rivers of mud out to sea, smothering reefs.

Soon after the discovery of freshwater aquifers, the public water systems switched from reliance on surface water to reliance on groundwater. At the same time, the Forest Reserve System was established in Hawai‘i to protect and restore the upland forests that are vital for recharge of groundwater aquifers and contribute to available surface waters.

Fog drip and the forests’ interactive role in evapotranspiration cycles are critical components of Hawai‘i’s watersheds’ ability to create and retain water. Fog and mist condensation on trees in higher-elevation forests can increase rainfall collection and absorption by as much as 30 to 40%. Forests support infiltration of rainfall into the water table, where water percolates through permeable rock into groundwater aquifers formed by volcanic rocks.

Native Hawaiians recognized the important link between water resources and terrestrial and aquatic systems, and designed a land tenure system within which *ahupua‘a*, land areas extending from the mountaintop to the shoreline and near-shore marine environments, were managed to provide all the natural resources needed to support the families and populations living within that watershed. (Watershed” is the term used to describe the geographic area of land that drains water from the surrounding mountain slopes, into its stream and river system, and out to a river, bay, or ocean.) Although the formal *ahupua‘a* system did not carry over into statehood, communities and resource managers in Hawai‘i still understand the connection between ecosystems found throughout the watershed and impacts on surrounding ocean resources. Since the first humans settled the Hawaiian Islands, people have recognized the importance of the links they share with the hydrologic systems. Watersheds are places, as geographer John Wesley Powell put it, “within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demands that they become part of a community.”

Hawai‘i’s watersheds are extremely diverse, containing forests that are dominated by both native and non-native plants and that represent a history of differing land management priorities. Many of Hawai‘i’s forests are rich in biological resources, represent unique ecosystems, and contain rare and endangered plant and animal species. These rare plants and animals live in varied habitats from windward sea cliffs to montane bogs, and from remnant dry forests to some of the wettest forests on earth. Native animal species include endemic birds, hoary bats, snails, and arthropods, all of which play a role in maintaining watershed health and productivity. The many stream systems that drain Hawai‘i’s watersheds are home to diverse native aquatic insects, fishes, crustaceans, and mollusks.

Hawaiʻi's watersheds are also rich in cultural history. Native Hawaiians recognized the importance of forests in water production and water quality, as reflected in the saying "*hahai nō ka ua i ka ulu lāʻau*" (the rains follow the forest). Ancient Hawaiians recognized the value of water—*wai*—because their very survival depended on it. In fact *waiwai*, the Hawaiian word for wealth, comes from water.[3] Native Hawaiians practiced wetland agriculture with taro in the fertile valleys, developed multi-story agroforestry systems known throughout the Pacific Island, and intensively cultivated other staple crops on many lower-elevation windward slopes. On the leeward sides of the islands, native Hawaiians practiced dryland agriculture and agroforestry, in some cases transporting water for miles to crops in ʻ*auwai* (human-made irrigation ditches or canals). Much later technological advances allowed for the development of complicated ditch and dam systems that supported vast sugar and pineapple plantations.

Today, water quantity and quality remain critically important for all populations, and water is affected significantly by human development and land use practices. As was recognized by the ancient Hawaiians and remains true today, our very survival in this island state depends on an abundant, clean, and sustainable supply of water. Hawaiʻi must be self-sufficient in its water production for all aspects of our quality of life. Best management practices both in upland and coastal watersheds are needed to ensure groundwater recharge for drinking water, provide for sufficient and clean water in stream systems to support aquatic life and sustain agriculture, protect habitat for threatened and endangered species, and support all island and near-shore hydrologic functions in general. In the urbanized areas, stream channelization and a high proportion of impervious surfaces in the densely populated areas contribute to flash flooding, which results in large discharges of fresh water with sediments and pollutants that negatively affect our near-shore ecosystems. These flash-flood events often overwhelm sewage treatment facilities, resulting in an overflow of raw sewage into our coastal waters that threatens public health and coastal zones. In addition, flash flooding events have caused substantial damage to infrastructure and homes when large debris is carried downstream by fast-moving water.

Our upland forests, urban areas, coastline, and near-shore environment are all closely linked, and this relationship is recognized in the Hawaiʻi Coastal Zone Management (CZM) program, established in 1977. In Hawaiʻi, the CZM area encompasses all land in the state and not merely the "coastal zone," which is how it is interpreted on the U.S. mainland. With no point of land more than 30 miles from the ocean, it was logical to designate the entire state as the CZM area, up to the summit of our highest mountain Mauna Kea (13,803 feet). What occurs on land, even on the mountains, will affect and influence the quality of the coastal waters and marine resources. (More information on Hawaiʻi's CZM program is available at http://planning.hawaii.gov/czm/.)

In addition to the CZM program, there are a variety of agencies and programs that are involved in forest management for water quantity and quality purposes. Each agency and program has a common goal to produce abundant and pure water for public use, but each agency and program may have a slightly different focus. The various programs involved in watershed management in Hawai‘i include[4]:

- DLNR Division of Forestry and Wildlife (DOFAW). DOFAW has a focus on watershed management for multiple benefits, including protecting and developing sources of water, ensuring adequate quantity of water for current and future public use, and managing resources to improve or enhance water quality. DOFAW contributes to watershed management through its management of public forest lands as well as the development of private-public partnerships to protect and manage resources across the Hawai‘i landscape.
- DLNR Commission on Water Resources Management. The Commission focuses on water conservation, protects ground and surface water resources, sets policy, and regulates uses.
- DLNR Office of Conservation and Coastal Lands (OCCL). OCCL focuses on protection of watersheds through regulation of land use activities in the state Conservation Districts and on protection of coastal shores, beaches, and marine environments.
- DLNR Division of Aquatic Resources (DAR). DAR’s mission is to manage, conserve, and restore the state’s unique aquatic resources and ecosystems for present and future generations. DAR developed the *Atlas of Hawaiian Watersheds & Their Aquatic Resources* to increase the knowledge base, strengthen the foundation for decision making, and ultimately provide the means for assuring the future survival of our unique native biota. The Atlas provides a snapshot of watershed health, stream conditions, and aquatic resources for watersheds across the state of Hawai‘i.
- Department of Business, Economic Development and Tourism, Office of Planning, CZM program. The Office of Planning has a focus on protection of coastal and marine resources and administration of the Coastal Nonpoint Pollution Control Program, which is related to protecting the quality of water resources.
- Department of Health, Clean Water Branch. The Clean Water Branch focuses on water quality protection programs to minimize pollutant discharge and polluted runoff and to protect drinking water supplies.
- Hawai‘i Association of Conservation Districts (HACD) and Soil and Water Conservation Districts (SWCDs). The HACD, founded in 1954, is an association of the 16 local SWCDs in Hawai‘i. HACD works to coordinate and facilitate local partners and governmental agencies in identifying and implementing projects and practices with cultural sensitivity to ensure the protection of Hawai‘i's environment. The SWCDs implement programs and provide assistance on preventing soil erosion, improving agricultural practices, encouraging use of best management practices, restoring wetlands, and protecting groundwater resources and water quality.
- Research, Conservation, and Development councils (RC&Ds). As a community of partnerships that values and conserves natural resources, the RC&Ds address economic,

environmental, and agricultural problems, including by providing technical assistance and training to landowners and managers to improve land management activities in order to reduce soil erosion and water loss in degraded watersheds.

- U.S. Environmental Protection Agency (EPA). EPA has a focus on protecting water quality, preventing water pollution, and providing clean water for ecosystem services and to ensure safe drinking water. It incorporates a comprehensive watershed protection approach strategy.
- U.S. Army Corps of Engineers (USACE). USACE has a regulatory role and focus on protecting surface water resources and wetland environments and on implementing projects related to water resources and watershed assessment and protection.
- U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA). USDA focuses on assisting private landowners with control of erosion, improved agricultural practices to address resource concerns, establishment and management of native forest and wetland resources, enhancement of water supplies, improvement of water quality, and implementation of programs for watershed- and landscape-scale management and conservation.
- County water departments. The four counties in Hawai‘i focus on providing an adequate quantity and quality of water for public uses, including for drinking and for industrial, tourism, and agricultural uses. Three of the four county water departments provide funding for watershed protection. The Honolulu Board of Water Supply (BWS) also analyzes production and supply in watersheds and prepares watershed management plans.
- Hawai‘i Association of Watershed Partnerships. HAWP is an alliance of private and public partnerships committed to protecting large areas of forested watersheds on private and public lands for water recharge and other multiple-use purposes. There are 11 watershed partnerships on five islands, with more than 71 public and private partners protecting over 2.2 million acres.
- Invasive Species Committees (ISCs). ISCs are island-based coalitions of government and nongovernmental entities, organized under the University of Hawai‘i’s Pacific Cooperative Studies Unit, that provide early detection and rapid response programs to eradicate or contain newly detected invasive species before they become irreversibly established. ISCs work closely with the watershed partnerships to detect, monitor, and control newly introduced and established invasive species pests that degrade watersheds. The ISCs include the Kaua‘i Invasive Species Committee, O‘ahu Invasive Species Committee, Maui Invasive Species Committee, Moloka‘i Invasive Species Committee, and Big Island Invasive Species Committee.
- Kaulunani Urban and Community Forestry Committee. This committee has a focus on management of forests and trees in urban areas, especially urban forests, for watershed protection, prevention of erosion, and water recharge. *(See “Issue 4: Urban and Community Forestry,” for more detail on this program.)*

Benefits

Conservation of water quality and quantity practiced at the watershed level creates benefits within and beyond the management area of interest, and these benefits can be magnified by economic policies that support conservation measures.[5] One of the most valuable ecosystem services related to water is the provision of a consistent supply that meets domestic, agricultural, industrial, and tourism needs. Important to this service are the forests that slow the flow of water from steep mountainsides to coastal and near-shore marine areas. This slow movement of water flowing through streams maximizes aquifer recharge and prevents flooding during heavy rains that cause topsoil erosion and sedimentation. Reefs are particularly vulnerable to smothering by fine sediment, which blocks the light necessary for their growth. Sediment deposition from streams and urban drainages is responsible for beach deterioration and reef degradation and, in some cases, death of the coral reef. Healthy forests, including riparian forest buffers along waterways, and functional hydrologic processes are critical to ensuring that our waters are fishable and swimmable, and that beaches and coastal watersheds are healthy, which is critical to food production and tourism, Hawai'i's largest industry.

Other ecosystem services provided by healthy watersheds and hydrologic functions are drought mitigation, traditional cultural resources, recreation, and preservation of unique native species. The cost of replicating any of these essential services through technology or engineering is staggering and often unnecessary if forethought and restraint are practiced against the enticement of quick economic gain.

There is a direct connection between forest quality and water quality.[5] In Hawai'i, the steep mountainous areas have long been recognized as crucial elements of a sustainable ecosystem. Beginning more than a century ago with the establishment of the Forest Reserve System, upland areas began to be set aside for protection of water resources. A 1999 study by the University of Hawai'i estimated that the Ko'olau Mountains on O'ahu alone provide benefits worth up to $14 billion[6] in economic and ecosystem services.

The lands currently zoned under State Land Use Law, Chapter 205, Hawai'i Revised Statute, as Conservation District, designated as Forest Reserve, and those within a watershed partnership or alliance are responsible for providing billions of gallons of water each year. The collaborative management of these lands for watershed health has the following advantages:

- Resource threats across landscapes and landowner boundaries are more efficiently and economically managed.
- Available funds are leveraged using federal, state, county, and private monies.
- Private landowners increase their capacity and desire to protect their forests.
- Resources and expertise are pooled to reduce redundancy.

Threats

There are many threats to sustaining water quality and quantity in the Hawaiian Islands. At the core of all of these threats are the impacts of human decisions or lack of action. A proactive approach to reducing long-term threats is necessary if we are to sustain our watersheds. Significant economic and ecological threats affecting our watersheds are discussed in detail below.

Need for Understanding of Hydrologic Functions

Watersheds are affected by humans through development and land use practices. To better inform the public and policymakers, there is a need to assess the health of, and distribute knowledge about, hydrologic functions and watershed sustainability.

Effects of Weeds on Hydrologic Processes

Habitat-modifying invasive plants often have negative impacts on the hydrologic processes of forested watersheds. Habitat-modifying invasive species shade out native understory species, exposing soil surface and contributing to erosion. Some alien invasive species, such as *Miconia* (*Miconia calvescens*), have been shown to be significantly less effective than native trees in allowing rain to slowly infiltrate watersheds, and instead create runoff.[7] The tendency for a number of invasive species to have shallow roots also reduces the ability of the forests to withstand erosion and rockfalls and to prevent landslides on steep hillsides.

There is also evidence that strawberry guava (*Psidium cattleianum*) has higher evapotranspiration rates than *ʻōhiʻa* (*Metrosideros polymorpha*) -dominated forest in some areas, but additional research is needed to fully documented this difference.[7] What has been well demonstrated for strawberry guava is that it reduces the proportion of rainfall that becomes available for groundwater recharge, when compared with native-dominated forests.[8] Further, some alien invasive species, such as strawberry guava or albizia (*Falcataria moluccana*), have been shown to significantly alter the microhabitat, rendering it less supportive of native species.

Wildfires that degrade watersheds are exacerbated by weeds. As discussed in "*Issue 3: Wildfire*," invasive fire-prone grass species such as fountain grass (*Pennisetum setaceum*) and buffel grass (*Pennisetum ciliare*) readily invade naturally open forests. The dry, dense biomass of grasses in the understory easily ignites, causing wildfires. With each subsequent fire, these invasive fire-adapted grasses proliferate, eventually displacing forested watersheds.

Urbanization and Conversion of Forests and Associated Water Pollution

The effects of urbanization and human activities, such as burning, logging, cattle grazing, large-scale agriculture and associated chemicals and fertilizers, and development, have already permanently altered many coastal and lowland forests. The demand for urban and residential development on accessible and easily developable lands continues to result in conversion of prime agricultural and forest lands in the lowlands to housing or small residential agricultural lots with increased human density, urban uses, impermeable surfaces, and urban pollutants.

In recent years, it has become increasingly clear that the nation's waters have serious water quality problems. Virtually everywhere, the problems result from what is commonly called polluted runoff or nonpoint source pollution. These terms refer to pollutants that enter a body of water as a result of precipitation or irrigation water flowing over land. Although polluted runoff results from natural causes, most results from people's activities on the land and water.

Common nonpoint source pollutants include soil, fertilizers, animal wastes, oil, grease, litter, and agricultural and household chemicals. These and other pollutants end up in public waters all across the country. In Hawaiʻi, land-based activities are the primary source of polluted runoff problems statewide.[9] The consequences of nonpoint source pollution are all too well known: increased risk of disease contracted during water recreation, algae blooms, fish kills, destroyed aquatic habitats, collapse of coral reef ecosystems, and turbid waters.

Impact of Feral Ungulates on Forests and Water Quality

The effects of Hawaiʻi's extreme isolation from other land masses are illustrated well by the absence of a single native mammalian herbivore. Hoofed grazing animals, a group of mammals present on islands and continents throughout most of the world, are completely absent from Hawaiʻi's evolutionary history. However, non-native feral ungulates like pigs, goats, sheep, deer, and cattle trample and consume vegetation and tear up the ground with their hooves, leaving the ground bare and exposed. This can result in increased erosion and allows the seeds of fast growing non-native species to germinate and thrive. The pressures associated with ungulates, such as trampling and heavy browsing and grazing, have, for many species, threatened species survival or the ability of the species to evolve and adapt to new evolutionary pressures, such as climate change. In some cases, the effects of ungulates have resulted in complete transformations of ecosystems.

Cattle

In 1793, Captain George Vancouver delivered domestic cattle (*Bos taurus*) as a gift to King Kamehameha I. A 20-year prohibition on their use, kapu, was issued, and they were allowed to proliferate across the landscape. During that time, the cattle caused heavy impacts on the native vegetation as well as cultivated crops.[10] Currently, most cattle grazing takes place on private and state-leased lands. However, wild cattle persist in many areas where inadequate or absent fencing has allowed them to wander into the forest in search of highly palatable foods. Unmanaged cattle are widely recognized as a major destructive agent in Hawaiʻi's ecosystems and have had a significant effect on montane mesic forests.[11]

Pigs

Initially introduced by the Polynesians was the relatively small, 40 to 50-pound Polynesian pig, which was managed as an agricultural commodity. Europeans arrived over 1,000 years later and brought with them the domestic hog, which was a much larger animal than the Polynesian pig. During the first 100 or more years of occupation, the hog became well established in the wild. In a 1930 Hawaiʻi Planters' Record, G. A. McEldowney reported that pigs were a bigger threat to watersheds than cattle or goats because they eat seeds and seedlings of trees, upturn soil, and cause erosion. Pigs depredate native plants, facilitate the spread of alien plants through seed dispersal and creation of sites favorable for colonization, serve as vectors for disease, and facilitate erosion.[12, 13, 14] *(See "Issue 2: Forest Health: Invasive Species, Insects, and Disease," for more information.)*

Impacts of Other Non-Native Animals

Fifty-five birds, 46 reptiles and amphibians, and 19 mammals are naturalized in Hawaiʻi, and have the potential to become serious pests in watersheds.[15] Rats, in particular, have significant effects on native vegetation and birds. Black rats (*Rattus rattus*) and Polynesian rats (*Rattus exulans*) are the dominant species throughout most of Hawaiʻi's forests. They consume the seeds, fruits, and flowers of numerous native plant species, including many rare ones. Rats also prey on native bird eggs and nestlings that are important pollinators and seed dispersers for native plants. Like ungulates, rats can affect water quality by serving as vectors for water-borne diseases such as leptospirosis and cryptosporidiosis.

Other non-native animals that pose problems in Hawaiʻi's watersheds include mongooses, feral cats, dogs, mice, chameleons, and non-native birds. Non-native forest birds have been observed in all vegetation types. They compete with native forest birds for food and other resources, provide vectors for avian diseases, and facilitate the spread of alien plants. Additionally, more than 3,300 alien arthropods are estimated to be naturalized in Hawaiʻi; this number grows by 20 to 40 per year. Alien arthropod species have been introduced intentionally and unintentionally over the past few centuries. Impacts of alien arthropods include direct consumption of rare plants, interference with plant reproduction, predation and parasitism of native animals, transmission of disease, alteration of soil formation processes, and hybridization with native forms.[16]

Plant Pathogens That Damage Ecosystems

Pathogens have limited the success of numerous native species and even caused extensive dieback, with serious consequences for watershed health. Most significantly, the fungus *Ceratocystis fimbriata,* which infects native *ʻōhiʻa* trees, threatens entire watersheds. This disease, aptly referred to as rapid ʻō*hiʻa* death or *ʻōhiʻa* wilt, was first detected in the Hilo and Puna districts on the Island of Hawaiʻi in 2012, and was in the Kona district by 2015.[17] It has the potential to spread and affect *ʻōhiʻa* on all Hawaiian Islands. The disease can spread fast across the landscape, it kills 50% of the trees it infects within a few weeks, and it can have greater than 90% mortality within 2–3 years.[18] By 2016, it had affected nearly 50,000 acres in the South Hilo, Puna, Kaʻū, and Kona districts of Hawaiʻi Island.[18] The fungus rapidly kills by taking over the tree's water transport system. Humans can spread the spores via their shoes, clothing, tools, vehicles, and equipment and transport it via mud stuck to wheels and vehicles. Other potential ways for the disease to spread include insects, underground via roots, on small wood or dust particles, and possibly on animals.[18] Invasive virulent diseases such as rapid *ʻōhiʻa* death, affecting keystone forest trees like *ʻōhiʻa,* can be catastrophic, not just for the affected species but for the entire watershed.

Another significant threat, *koa* wilt disease, caused by *Fusarium oxysporum*, threatens the health of *koa* (*Acacia koa*), one of the two dominant tree species in Hawaiʻi's native forests. This soil-borne disease causes dieback and decline of *koa* in native forests by compromising the tree's vascular system.[19]

Additionally, rust species have the potential to negatively affect the other dominant tree species in Hawaiʻi's native forests, ʻ*ōhiʻa lehua* (*Metrosideros polymorpha*). A recently introduced strain of *Puccinia psidii* was found to be pathogenic to ʻ*ōhiʻa*. Although this race of rust has demonstrated low virulence, scientists are concerned about introductions of future strains. Compromised health of Hawaiʻi's dominant native tree species, *koa* and ʻ*ōhi*ʻ*a*, would have devastating effects on Hawaiʻi's forested watersheds. *(See "Issue 2: Forest Health: Invasive Species, Insects, and Disease," for more information.)*

Human Activities That Exacerbate Other Impacts

Hikers and hunters can spread seeds, spores, or propagules of invasive plants and pathogens via their shoes, equipment, or vehicles. Additionally, illegal trails created by the use of all-terrain vehicles, motorcycles, and mountain bikes often contribute to soil erosion and sedimentation in streams and near-shore environments. Overharvesting of some culturally important plants also may be occurring. Lastly, fires, whether caused inadvertently or maliciously by humans, are a threat to all of Hawaiʻi's forests and their watersheds during drought periods.

Aquatic Invasive Species

Numerous alien aquatic species that exhibit the characteristics of being invasive threaten to cause ecological and economic harm. Aquacultural and aquarium species are introduced into streams via flooding, when effluents are discharged back into streams, through intentional introduction, and by overland travel. A number of aquarium fish directly compete with native stream fauna for food and other resources. In addition, disease and pathogens associated with cage-reared species could spread through streams and ditches. The loss of native stream fauna as a result of invasions by alien aquatic species would alter the biodiversity of the stream and degrade the native stream ecosystem. Invasive aquatic species such as apple snail (*Pomacea canaliculata*) could cause economic impacts on agricultural users of water, resulting in damage to crops such as taro; invasive mollusks could cause infrastructure damage, clogging irrigation and water distribution pipes; and aquatic weeds such as giant salvinia (*Salvinia molesta*) could clog waterways, irrigation ditches and pipes, and hydroelectric intakes and degrade water quality.[20]

Sedimentation of Water Resources

Most water quality problems in upper watersheds have human origins and are related to soil erosion. Although erosion is a natural process in forested areas, it can be amplified by non-native animals and by human disturbances (Figure 1.2). Sediment pollutants manifest as silt, suspended solids, turbidity, nutrients, and pathogens. Suspended sediment can stress native fish; damage the gills of some fish species, causing them to suffocate; increase water turbidity, which limits light penetration and impairs photosynthesis for aquatic plants; raise water temperatures; and lower dissolved oxygen concentrations, which can kill aquatic vegetation, fish, and bottom dwellers. Settled sediment can affect levels of nutrients, solids, and oxygen-demanding materials; eliminate essential habitat and bury food sources and

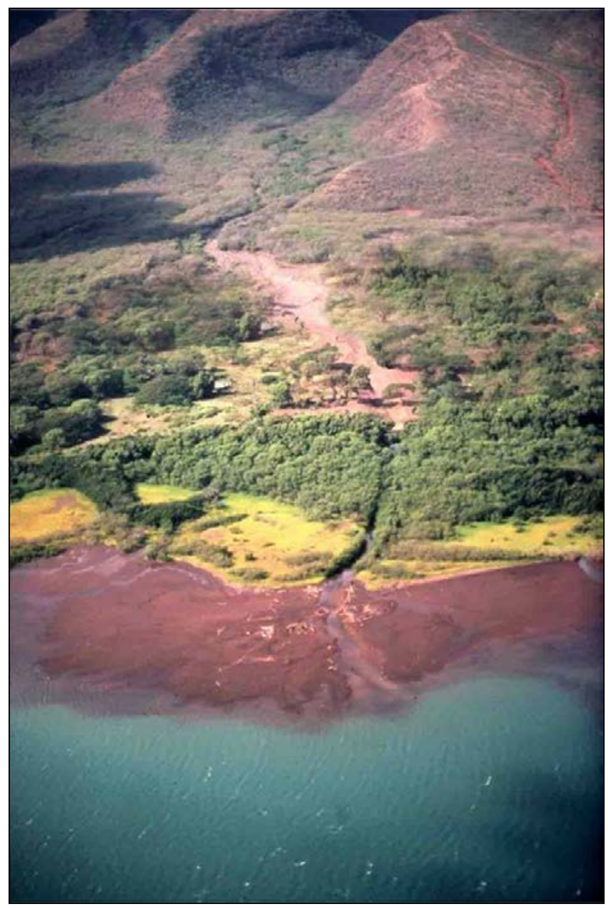


Figure 1.2. Brief but intense rainstorms are typical events in Hawai‘i; however, as shown in this photograph taken in Moloka‘i, sediment from denuded uplands can quickly reach the ocean during storms and smother nearshore habitats and coral reefs.

spawning sites for stream life; smother bottom-dwelling organisms; and reduce the capacity of stream channels and ditches to carry water and of reservoirs to hold water.

Human Disease Organisms

Leptospirosis and cryptosporidiosis are potentially fatal illnesses caused by water-borne microorganisms spread by pigs, dogs, mongooses, rats, and even frogs. Leptospirosis is a bacterium, transmitted from animals to humans where people contact the bacteria through water or mud that has been contaminated by animal urine or droppings. A total of 769 cases of human infection were reported in Hawai'i between 1990 and 2014.[21] Cryptosporidiosis is a diarrheal illness caused by a microscopic intestinal parasite, *Cryptosporidium*. People are typically exposed by eating food or drinking water contaminated with the feces of infected animals, including cattle, rodents, cats, dogs, and humans.

Effects of Wildfire on Watersheds

Because Hawai'i's flora have evolved with infrequent, naturally occurring episodes of fire, most native species are not fire-adapted and are unable to recover well after wildfires. Alien plants, particularly grasses, are often more fire-adapted than native species and will quickly exploit suitable habitat after a fire. Fire-adapted species are themselves flammable and foster an increase in the frequency and intensity of fires. Increased occurrence of fire leads to erosion, and the whole cycle thereby reduces the integrity and biodiversity of Hawai'i's watersheds. *(See "Issue 3: Wildfire," for more information.)*

Climate Change Impacts

Global and local climate change have the potential to affect Hawai'i's hydrology by altering rainfall patterns and cloud banks, thereby affecting all users, particularly agricultural water users, over a broad geographic area. Additionally, sea level rise, an inevitable outcome of climate change, will affect islands dramatically by killing vegetation that is not adapted to saltwater intrusion. Many cities and villages located near the ocean are already being affected by frequent storm surges and reduction in beach length and width.

Watershed functions would be compromised from the drying of the air, vegetation, and soil that would result from an elevation of the cloud bank. Rare ecosystems and species may be affected by the relatively quick changes in precipitation, temperature, and humidity that will result from a rapid and drastic change in regional or local climate patterns. Intense rainfall events can cause flooding and damage to forest streams, waterways, crops, human infrastructure, and health. *(See "Issue 5: Climate Change and Sea Level Rise," for more information.)*

Changing Availability and Reliability of Resources

Watershed management can be costly, especially when attempting to addressing threats in remote locations. To address the need for continuous and secured funding for the management of Hawai'i's watersheds, native ecosystems, and forest land, the state established the Natural Area Reserve Fund, which collected a percentage of conveyance tax revenue to address watershed management needs. These funds have served as one of the primary funding sources for DOFAW and its associated partnerships and programs for over 20 years. The Natural Area Reserve Fund has provided the state funding to manage public-private land conservation partnerships since 1993, including major support for managing Natural Area Reserves, the Forest Reserve System, the Watershed Partnerships program, the Natural Area Partnership Program, the Hawaii Invasive Species Council grant program, the Hawai'i Forest Stewardship Program, the Youth Conservation Corps, and other private forest lands assistance programs. The fund provided for management of essential forest and watershed resources and trained future land managers throughout the state.

However, during the 2015 state legislative session, the funding to support watershed management using the conveyance tax was terminated, and was replaced by biannual allocations from state general funds (i.e., the state shifted away from dedicated special funding for watershed management). Land management and protection programs require steady, reliable funding to be most efficient. It is yet to be seen whether the long-term support needed to fund watershed and forest reserve management can be maintained to meet the resource conservation needs, when these needs compete with other general fund programs such as public health, public safety, and education.

The goal of the Rains Follows the Forest Initiative and the "30 by 30 Watershed Forests Target" World Conservation Congress Legacy Commitment is to protect 30% (253,000 acres) of the highest-priority watershed forests by 2030, at a cost of up to $11 million per year.[1, 2] Meeting this goal will require identification of additional sources of funding and better coordination among all agencies and programs to leverage and maximize use of available funds.

Trends

Human activities, such as intentional introduction of plants for food and ornament, accidental introductions, and large-scale modification of the natural landscape for agriculture and development, have affected hydrologic functions. One legacy of Hawai'i's agricultural history is the development of miles of extensive ditches and culverts designed to divert water to reservoirs and irrigation systems that supplied the now-waning sugar and pineapple industries. Stream diversions, channelization, and impervious surfaces are more modern modifications created to support the ever increasing urban populations. All of these historical and current trends have lasting negative impacts on Hawai‘i’s water. *(See “Issue 2: Forest Health: Invasive Species, Insects, and Disease,” for more information.)*

Trends in Stream Flow

Proper management of the water resources of the state requires an understanding of surface water and the long- and short-term variability in stream flow characteristics that may occur. The U.S. Geological Survey maintains a network of stream gauging stations in Hawai‘i, including several stations with long-term stream flow records that can be used to evaluate long-term trends and variations in stream flow on the islands of Hawai‘i, Maui, Moloka‘i, O‘ahu, and Kaua‘i.[22]

From 1913 to 2002, in streams for which data are available, base flows generally decreased, and this trend is consistent with the long-term downward trend in annual rainfall over much of the state during that period (Figure 1.3).[22] Monthly mean base flows generally were above the long-term average from 1913 to the early 1940s and below average after the early 1940s to 2002. This pattern is consistent with the detected downward trends in base flow from 1913 to 2002. Long-term downward trends in base flows of streams may indicate a reduction in groundwater storage and recharge. Because groundwater provides about 99% of Hawai‘i’s domestic drinking water, a reduction in groundwater storage and recharge has serious implications for drinking water availability. In addition, reduction in base stream flows may reduce habitat availability for native stream fauna and water availability for irrigation purposes.

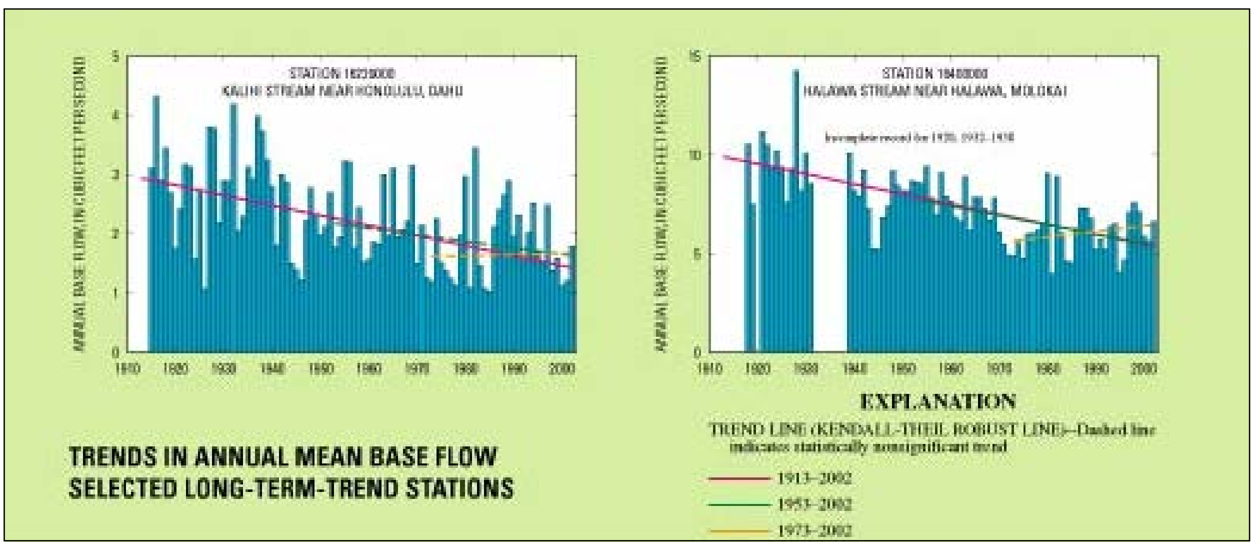


Figure 1.3. From 1913 to 2002, the trend has been a reduction in mean base flow and annual rainfall in Hawai‘i. Image courtesy of U.S. Geological Survey.

The downward trend in base stream flow, which was observed at seven stations, may be representative of many other unmonitored streams throughout the state. For more recent periods, such as 1953–2002 and 1973–2002, significant trends in base flow generally were not detected at the long-term-trend stations.[22] For the period of 1953–2002, a significant downward trend in base flow was detected at only one of 14 long-term-trend stations (16400000 on Molokaʻi), and for the period 1973–2002, a significant downward trend was detected at only one of 16 stations (16019000 on Kauaʻi). Detection of trends in base flow may therefore be highly dependent on the period being considered. The downward trends detected during 1913–2002 may reflect higher-than-average base flows prior to the 1940s, followed by a period during which base flows did not trend significantly upward or downward.

A statistically significant downward trend in annual total stream flow (base flow plus direct runoff) during 1913–2002 was detected at only one of seven long-term-trend stations (16229000 on Oʻahu). For the two more recent periods, significant trends in total stream flow generally were not detected at the long-term-trend stations.[22] For the period of 1953–2002, a significant downward trend in total stream flow was detected at only one of 14 long-term-trend stations (16211600 on Oʻahu), and for the period of 1973–2002, no significant trends in total stream flow were detected at 16 long-term-trend stations.[22]

Trends in Land Management and Collaborative Partnerships

More than 100 years ago, the territorial government of Hawaiʻi established the Forest Reserve System to protect important public and private watershed lands and began to restore degraded forests. Since the inception of the first watershed partnership in 1991, the number of watershed partnerships has grown to 11 partnerships on five islands, encompassing more than 2.2 million acres.[23]

A newer trend, particularly in highly urbanized watersheds, is the establishment of collaborations that take a whole-watershed approach or, embracing the 21st-century *ahupua'a*.

Watershed Partnerships

Watershed partnerships are voluntary alliances of both public and private landowners committed to the common value of protecting forested watersheds for water recharge, conservation, and other ecosystem services through collaborative management. Partners commit to work collaboratively to protect their lands despite differences in priorities, mandates, and constituencies. Watershed partnerships' goals are to develop and implement initiatives that support the long-term sustainability of the watershed. The five main objectives identified to implement these goals are as follows:

- Investigate long-term, sustainable funding options and determine solutions to support continued implementation of the landscape plans and associated project management plans developed under the watershed partnerships.
- Address capacity-building needs for the watershed partnerships.
- Support policies and laws that will benefit partnership goals and plans.

- Facilitate the annual Watershed Symposium or other similar events to maintain communication among partners and facilitate information exchange.
- Expand outreach and education initiatives to develop support for the work done by watershed partnerships, particularly among the public and decision makers.

The watershed partnerships have a proven track record of on-the-ground management that has led to results-oriented protection and restoration of forested watersheds through fencing and ungulate removal, invasive species control, native outplantings, and outreach and education involving schools and communities (Figure 1.4). Much of this success can be attributed to having committed partners, dedicated staff and leadership, landscape plans that prioritize threats and actions, effective organizational structures to ensure that dollars go directly to projects, and passionate volunteer and community support. In 2015, combined partnership accomplishments included:[23]

- 300,000 acres managed to control damage caused by feral ungulates and destructive invasive species;
- Planted 83,000 native and endangered plants for forest restoration;
- Engaged 5,500 volunteers in projects, including community members, teachers, and school groups;
- 40 miles of protective forest fence completed.

Today, there are 11 watershed partnerships on five islands: Kauaʻi,[24] Oʻahu,[25] Molokaʻi,[26] Maui,[27, 28, 29] and Hawaiʻi.[30, 31] Together, these partnerships involve over 71 public and private landowners and partners and 24 public agencies that cover more than 2.2 million acres of land in the state. Additionally, DOFAW works with the private landowners and managers in the watershed partnerships to develop forest stewardship management plans to help guide actions at their property level while addressing threats identified in the corresponding watershed partnership landscape plan. To learn more about the watershed partnerships and their many accomplishments, visit the HAWP website at http://www.hawp.org.



Figure 1.4. Watershed partnership staff in the field building fences, monitoring and removing invasive plants.

Additionally, DOFAW works with the individual and small private landowners and managers to promote and implement beneficial watershed management practices throughout the state. A variety of individual grant programs are available for private landowners to obtain state and federal support for activities such as invasive species control, reforestation, outplanting of rare species, and weed control (*see "Appendix C: Forestry-Related Assistance Programs"*). Small landowners can also get assistance for their watershed efforts through projects such as low-cost sale or free handout of native plants, under community watershed or Urban and Community Forestry projects, or free materials and technical support for control of weeds and invasive species in community invasive species control efforts. Expanding these small landowner outreach efforts will help with watershed protection and management.

Watershed Collaborations

Watershed collaborations cross boundaries, such as the forested Conservation District lands and agricultural lands that often abut suburban residential communities and highly urbanized areas. This section highlights only a few of these collaborations.

Nonpoint source pollution, associated with many water quality issues, is often preventable. The Center for Watershed Protection emphasizes that the key to maintaining and improving the quality of our valuable water resources is to minimize the collective impacts of urbanization and other land use changes at the local watershed scale, thus emphasizing the importance of watershed and community partnerships at the local and regional level.[32]

One example of a grassroots, community-based collaboration in Hawai‘i working on local water quality issues is the project at Maunalua Bay initiated by Mālama Maunalua (see http://malamamaunalua.org/). This initiative is dedicated to creating a more culturally and ecologically healthy Maunalua region in southeast O‘ahu. Mālama Maunalua works in collaboration with the Polynesian Voyaging Society, Mālama Hawai‘i, The Nature Conservancy of Hawai‘i, Hui Nalu Canoe Club, DLNR, community groups, and many others. Key issues being addressed include sediment, nutrients, and polluted runoff from modified streams and impervious surfaces. Trees and forests are considered part of the solution for improving these water quality issues.[33] Trees can decrease the amount of stormwater runoff and associated pollutants that reach the ocean and promote the infiltration of rainwater into the soil.

Other public-private watershed collaborations include the West Maui Watershed Restoration Action Strategy, spearheaded by the West Maui Soil and Water Conservation District (http://www.hacdhawaii.org/districts/westmaui.html), and the Ala Wai Watershed Project on O‘ahu (http://www.alawaiwatershed.com/). The Ala Wai Watershed Project is a multi-purpose project being undertaken by USACE, DLNR, and the City and County of Honolulu. The goal of the project is to improve the overall quality of the Ala Wai watershed, from the crest of the Ko‘olau mountains to the nearshore waters, while minimizing flood risks.

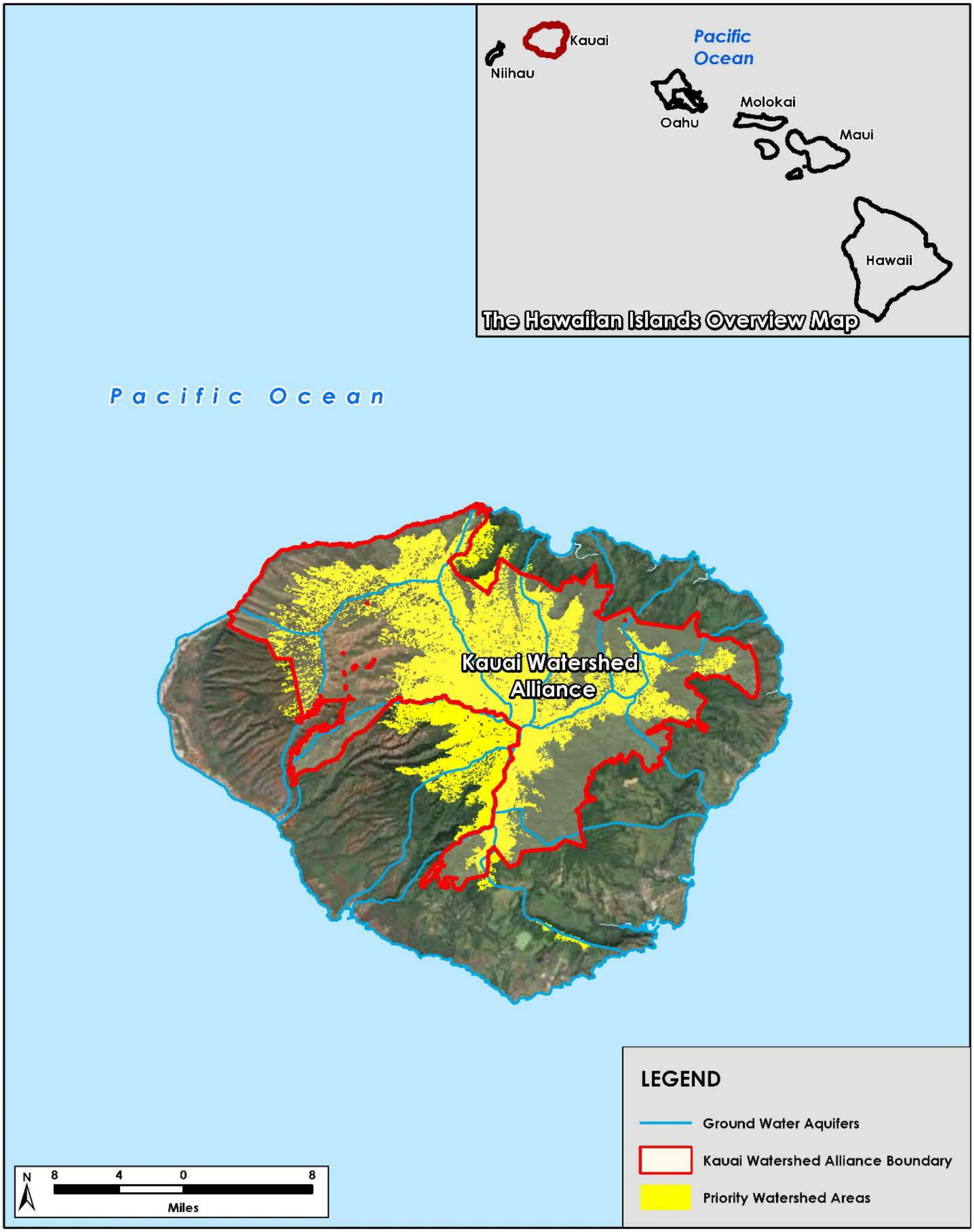
Another collaboration produced a “Tropical Urban and Community Forestry Summit,” which was held November 4–5, 2009. The purpose of the summit was to clarify urban forestry conditions, threats, trends, visions, and strategies. The collaboration included DOFAW’s Kaulunani Urban and Community Forestry Program, the U.S. Forest Service (FS), the Friends of Hawai‘i’s Urban Forest, and The Outdoor Circle. *(See “Issue 4: Urban and Community Forestry,” for more information.)*

Priority Issues and Areas for Water Quality and Quantity

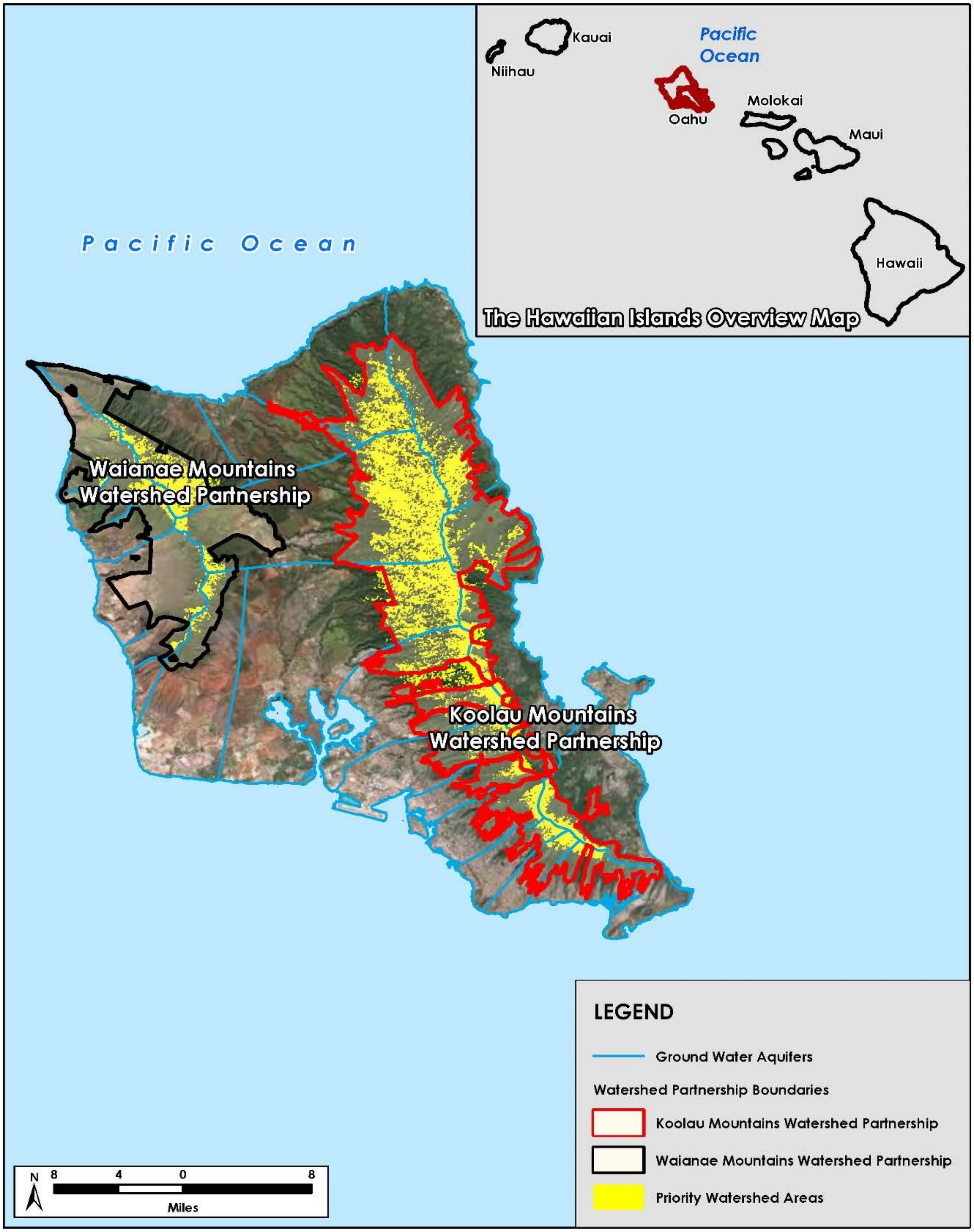
This Forest Action Plan explicitly supports and aims to contribute to all existing approved plans and programs of our federal, state, county, and private partnerships that include management of forest resources to improve and maintain water quality and quantity. Each program has a common goal to produce abundant and pure water for public use, but different programs may have slightly different focus and identify different priority areas to direct their management efforts. Under its Rain Follows the Forest Initiative of 2011,[1] DLNR identified its high-priority areas for surface water production and groundwater recharge to consist of all lands that have native-dominated wet and mesic ecosystems. Approximately 20% of land area in Hawai‘i is identified as priority watershed (843,000 acres).

In 2011, only about 10% of these priority watersheds were protected (90,000 acres). Under the Rain Follows the Forest Initiative, watershed protection efforts accelerated and by the end of 2015, approximately 127,000 acres (15% of priority watersheds) were under a high level of protection. In 2016, as part of the *Aloha+ Challenge*, and World Conservation Congress Legacy Commitment, the governor and State administration embraced an even more ambitious watershed protection goal of “30 by 30”, and committed to protect 30% of our highest priority watershed forests (253,000 acres) by the year 2030.[2] See Maps 1.1 to 1.4 for priority watershed areas.

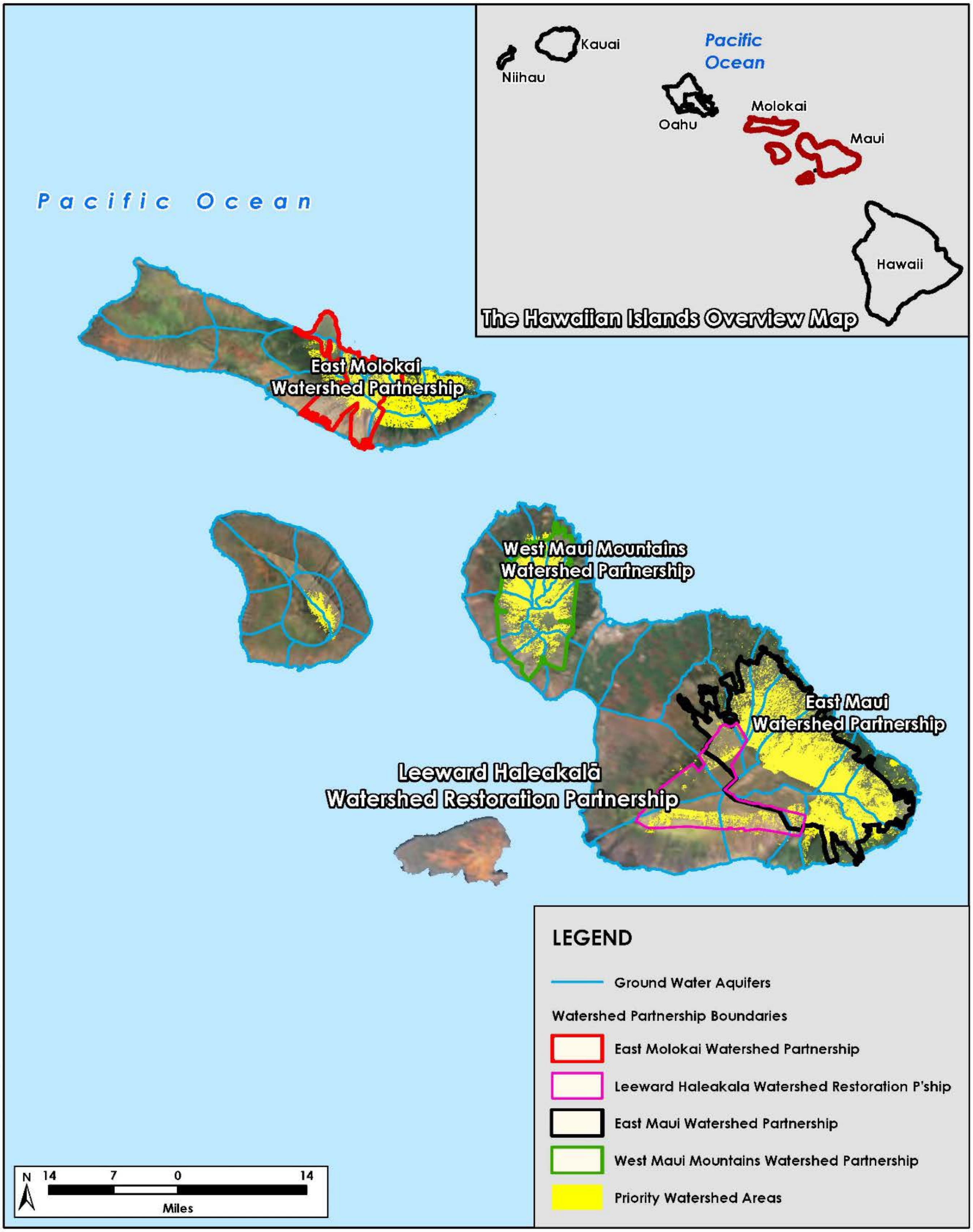
There are other agencies and programs that identify priority areas for watershed management. The Honolulu BWS, although an active member of the Ko‘olau and Waianae Mountains Watershed Partnership, also prioritizes watershed management based on its water supply perspective (Figure 1.5) and incorporates considerations for groundwater recharge and groundwater production needs.[34] BWS’s supply-focused priorities can be incorporated into the partnership’s larger prioritizations, and also serve as a stand-alone prioritization for any solo BWS watershed protection or restoration work. Although these priorities can vary from the native wet and mesic ecosystem approach taken by DLNR, they support the common goal to produce adequate water for public consumption.



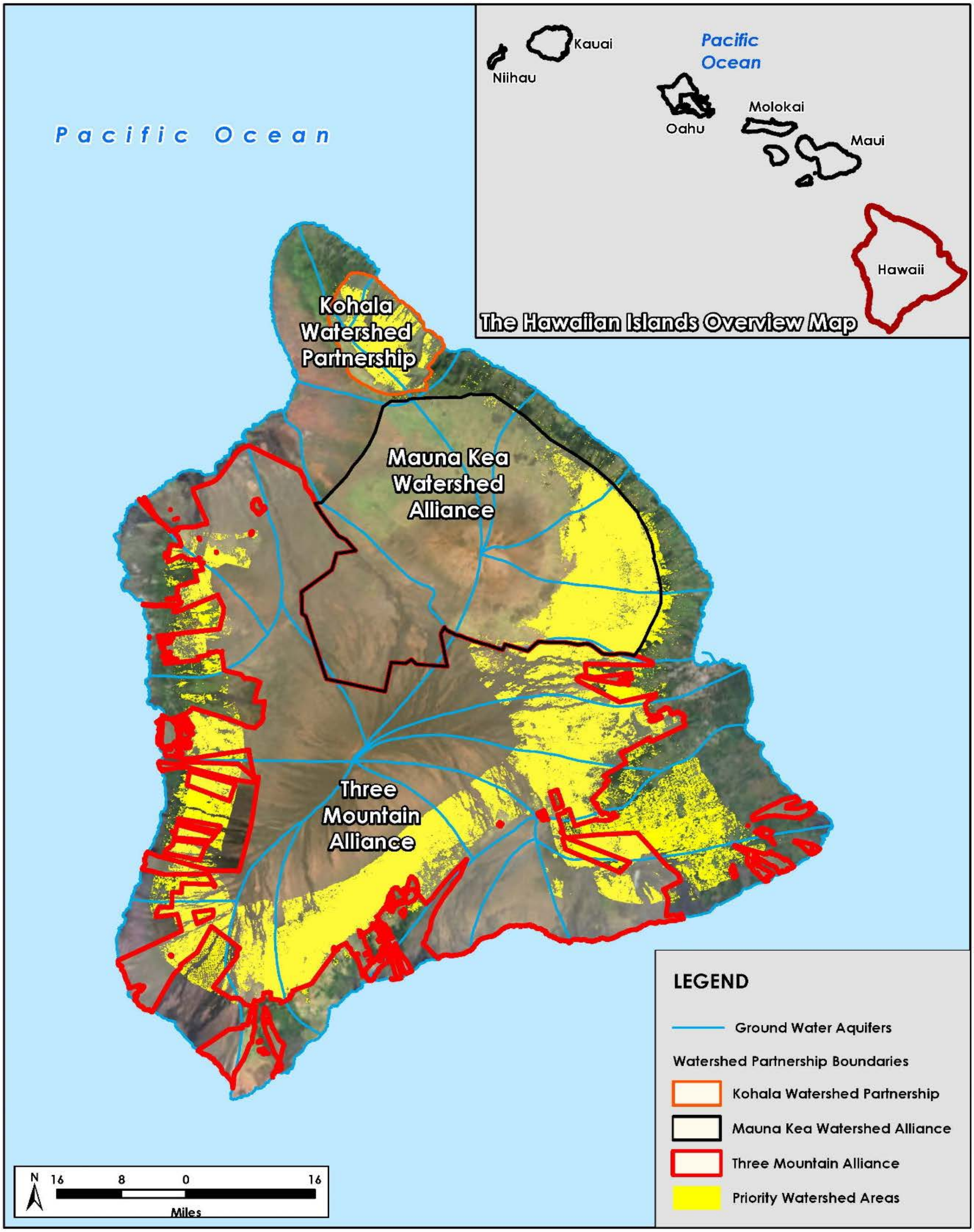
Map 1.1. Priority watershed areas and lands in Watershed Partnership County of Kaua'i



Map 1.2. Priority watershed areas and lands in Watershed Partnership City and County of Honolulu.



Map 1.3. Priority watershed areas and lands in Watershed Partnership County of Maui.



Map 1.4. Priority watershed areas and lands in Watershed Partnership County of Hawai'i.

The areas identified by the BWS as its priority watersheds for management are the Kaupuni and Mākaha watersheds in the Wai‘anae mountain range, and the Waikele, Waiawa, Waimalu, Kalauao, Hālawa, Moanalua, Nu‘uanu, Makiki, Mānoa-Pālolo, and Punalu‘u watersheds in the Ko‘olau mountain range.[34]

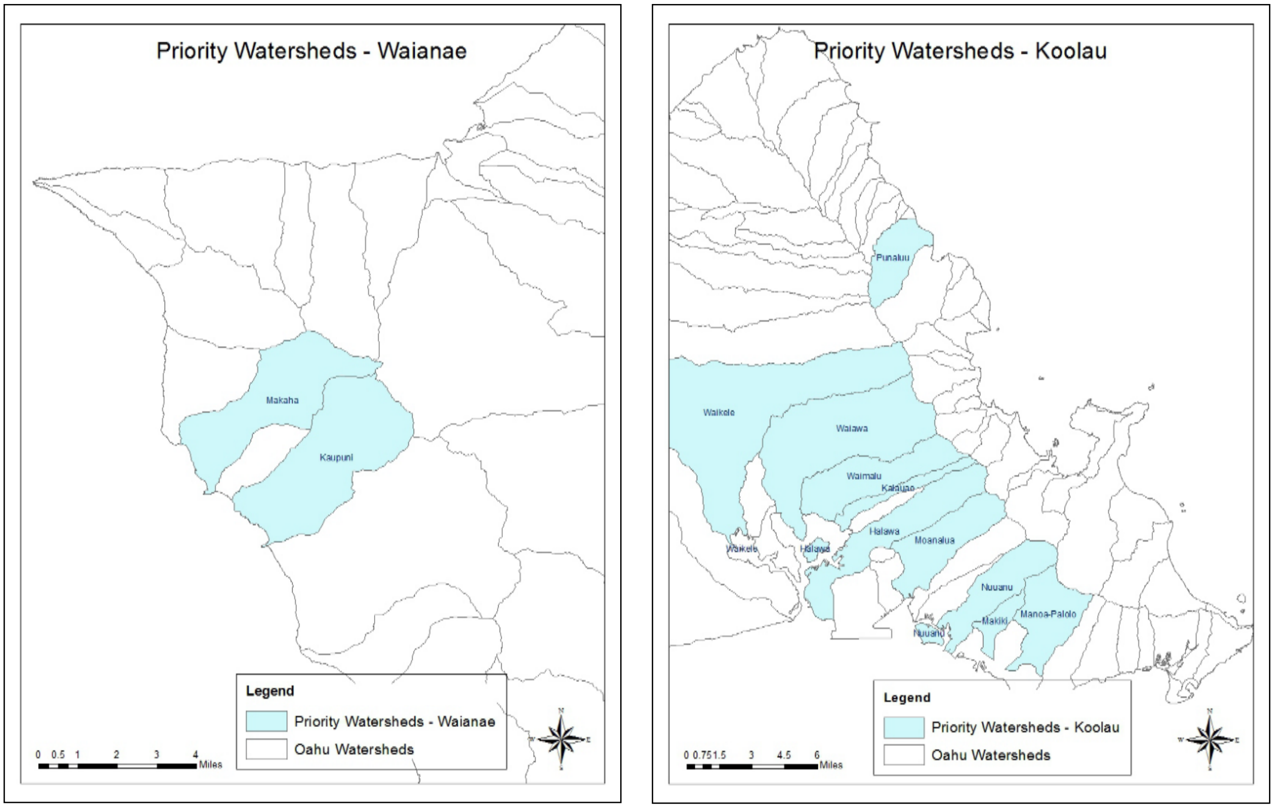


Figure 1.5. Board of Water Supply priority watersheds based on water supply–focused priorities.[34]

To ensure that the state’s watersheds are providing a clean and unpolluted source of water, DLNR is working closely with the Office of Planning and other local, state, and federal partners on improving water quality at a whole-watershed, or *ahupua‘a,* level. One example is the ongoing collaboration between the Hawai‘i CZM program and the Hawai‘i Department of Health (DOH) to implement the Coastal Nonpoint Pollution Control Program in conformance with Section 6217 of the federal Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) and the Polluted Runoff Control Program in conformance with the Clean Water Act, Section 319.[35] These programs provide much-needed funding for watershed planning, protection, and management. Although focused on water quality, these programs promote forest management as a tool, and watershed partnerships are seen as a key component in efforts to improve water quality from ridge to reef (see http://health.hawaii.gov/cwb/files/2013/05/2015-Hawaii-NPS-Management-Plan.pdf).

The Coastal Nonpoint Pollution Control Program is intended to be comprehensive and to address methods to manage potential or ongoing water quality impacts from urban areas, agricultural areas, forestry activities, onsite wastewater disposal systems, marinas, wetlands protection and restoration, and hydromodification (shoreline erosion, dams, and stream channelization). Early on, the CZM program and DOH recognized the benefits of promoting the broader concept of watershed planning with a targeted application of management measures to combat nonpoint source pollution. The watershed approach looks at the entire watershed to identify potential sources of pollutants and combat them. To assist with this approach, CZM and DOH developed the *Hawai'i Watershed Guidance* report to help managers of Hawai'i's watersheds develop and implement watershed plans.[36] The guidance lays out the steps in watershed management, the minimum elements of a watershed plan, and the management measures needed to demonstrate results. The guidance uses the Coastal Nonpoint Pollution Control Program's approach of addressing water quality impacts from a broad range of areas and activities as tools for more effective watershed planning and implementation of the State's Polluted Runoff Control Program.

One of the water quality–related functions of DOH is to identify state marine and inland waters that do not meet state water quality standards. In its most recent (2012) report,[37] DOH identified 88 impaired freshwater stream segments and 225 impaired marine segments. The poor water quality of these segments was mostly due to turbidity. The *Hawai'i Watershed Guidance* identifies nine priority groups of watersheds where there are opportunities to achieve water quality improvements.[36]

- Nāwiliwili Bay watersheds—includes Pū'ali, Hulē'ai, and Nāwiliwili stream watersheds
- Hanalei Bay watersheds—includes Hanalei, Waikoko, Waipā, and Wai'oli watersheds
- Ala Wai watersheds—includes Mānoa-Pālolo, Makiki, Ala Wai watersheds
- Ko'olau Poko watersheds—includes Windward O'ahu watersheds from Kualoa to Makapu'u
- Kapakahi Stream watershed
- South Moloka'i watersheds—includes watersheds from Kāluape'elua to 'Ōhi'a
- Pelekane Bay watershed
- Hilo Bay watersheds—includes Wailuku, Honoli'i, Pauka'a, Mā'ili, Pukihae, Wainaku, and Wailoa watersheds
- West Maui—includes watersheds from Launiupoko to Honolua

Data Gaps and Opportunities

To adequately address ongoing threats to our watersheds, the following actions are needed to close data gaps and build on current initiatives and successes:

- Increase research and monitoring of new emerging watershed and forest threats, such as Rapid *ʻŌhiʻa* Death, to determine origin and impacts, and to develop approaches and management tools for controlling and reducing impacts on watersheds where found and to prevent spread to uninfected areas.
- Refine ungulate survey methods and population management techniques to address wildlife threats and improve watershed health. Conduct additional, comprehensive surveys of forest land affected by ungulates, evaluating ungulate populations, public uses, and corresponding forest health conditions.
- Increase monitoring and survey of invasive species populations using aerial surveying methods, including high-resolution and multispectral imagery, supported by ground survey techniques. Develop and use new technology such as aerial drones to improve coverage and efficiency.
- Support long-term hydrologic monitoring programs to understand and document changes in watershed productivity that result from improved watershed management activities.
- Refine models of predicted effects of climate change at a spatial scale appropriate for Hawaiʻi.
- Support research on the effects of climate change on watersheds and water resources in Hawaiʻi.
- Continue to improve the modeling and monitoring of effects of different land use practices and plant species on local water budgets.
- Analyze potential conflicts or synergies between forest lands managed for carbon sequestration and water storage, production, quality, and quantity.
- Develop and use new decision-making tools to help guide and prioritize management activities to identify the most cost-effective targets and approaches for control and restoration work in watersheds.
- Develop economic data and practical models for assessing the costs and benefits of "green engineering" mitigation of stormwater runoff effects in urban areas.
- Identify specific areas, regions, or watersheds to target for concentrated efforts and collaborate on setting priority areas for watershed management with key federal, state, and county agency partners, landowners, and stakeholders.
- Improve collaboration among county water departments, the CZM Program, DOH, EPA, FS, the U.S. Fish and Wildlife Service (USFWS), DAR, and NRCS, which have overlapping priorities, to jointly set future priorities, to strategically advance projects for competitive grant opportunities at the local and national watershed-scale conservation programs, and to maximize the amount of watershed acreage being protected and the conservation benefits realized.
- Investigate funding opportunities under new local and national landscape- and watershed-scale natural resource conservation programs, such as USDA's Regional Conservation Partnership Program, Two Chiefs' Joint Landscape Restoration Partnership, Landscape Conservation Program, other Farm Bill conservation programs,

USFWS’s Endangered Species Recovery Programs, National Fish and Wildlife Foundation grants, and other granting opportunities to increase acreage under active watershed management for multiple benefits, including water quality and production.

- Improve methods for targeting and communicating with communities and the general public about the importance of watershed management, the threats to the Hawai‘i’s forests, and the community’s role and contribution to improving management of watersheds locally and across the state.
- Improve monitoring, data collection, and information sharing between the watershed partnerships, various private and public land management programs, and the ISCs to consolidate and collect comparable data regarding watershed and forest health, location of invasive species, management actions being taken, and impacts of land management activities on water quality and quantity.

Summary

The importance of water quality and quantity to the state of Hawai‘i cannot be overstated. Water is vital to human health; cultural practices; leisure and recreation such as swimming, boating, snorkeling, diving, and surfing; the visitor industry; ecosystem and species health and diversity; and fishing and other food-gathering activities. Important threats to water quality and quantity include human lack of appreciation or knowledge of hydrologic functions, invasive species, land development and associated nonpoint source pollution, the effects of feral ungulates and other pests and introduced species (including aquatic species), plant pathogens that can decimate entire ecosystems, human disease organisms, human activities that exacerbate other issues, sedimentation, wildfire, the effects of climate change, and lack of reliable funding for watershed and forest management. Watershed-level management requires collaboration and cooperation across landscapes and organizations, and steady and adequate funding. The adoption of the *ahupua’a* approach; coordination and collaboration across agencies and programs; and the work of the HAWP and the individual watershed partnerships, ISCs, county water departments, DLNR’s DOFAW, DAR, OCCL, and Commission on Water Resources Management, the CZM program, the DOH Clean Water Branch, and EPA provide only some of the examples of progress that is being made in managing our water resources in Hawai‘i. However, if we are to successfully meet new and ongoing challenges of inadequate funding, invasive species, the spread of diseases such as Rapid *‘Ōhi‘a* Death, conversion of forested watersheds and prime agricultural lands to uses that negatively affect water, and climate change, then much more needs to be done. As Nainoa Thompson of the Polynesian Voyaging Society reminds us, “Each time we lose another Hawaiian plant or bird or forest, we lose a living part of our ancient culture.”

Strategies for Issue 1: Water Quality and Quantity

Protecting forested watersheds for improved water quality and quantity creates many additional benefits, including carbon sequestration, protection of endangered species, and preservation of native Hawaiian cultural values. Each long-term strategy, by virtue of protecting these forests, will all yield multiple national objectives.

The state acknowledges and strives to incorporate all existing landscape, management, organizational, and regional plans pertaining to water.

Water Quality and Quantity: Invasive Species Control

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Control established and incipient invasive species by conducting weed surveys and creating and implementing prioritized weed management plans for priority watersheds.	Watershed partnerships, Conservation District, DOH impaired watersheds, CZM's *Hawai'i Watershed Guidance* priority watersheds, Honolulu County Board of Water Supply Priority Watersheds.	Reduce soil erosion, protect native biodiversity and coral reefs, involve school and community volunteers.	Watershed Partnerships, ISCs, NARS, FRS, HISC, FS Forest Health and Special Technology Development Program, FSP, CREP, NAPP, USFWS, FSCG, community groups.	Private landowners, DLNR, USFWS, NRCS, DOH, U.S. Army, FS, watershed partnerships, DHHL, OHA, counties, NPS, TNC, county water departments, visitors to Hawai'i.	Special Technology Development Program, Americorps Internships, FS, NRCS, USGS, U.S. Army, USFWS, UH, CGAPS, HCA, YCC, DAR, IPIF.	Acres surveyed/treated for invasive species that threaten watersheds; number of forest and/or weed management plans completed or updated; improved hydrologic functions island wide.	1.1 1.2 2.1 3.1 3.4 3.5	1.2 2.2
2. Control impacts of feral ungulates through fencing, hunting by the public, agency staff control, trapping, and other appropriate methods.	Same as above.	Same as above plus improve health of coral reefs, reduce mosquitoes and associated human and avian diseases.	Same as above.	Same as above.	Same as above.	Number of acres fenced; miles of fence line inspected and maintained; improved forest health and ecosystem structure and diversity.	1.2 2.2 3.1 3.4 3.5 3.6	

Strategies for Issue 1: Water Quality and Quantity

Water Quality and Quantity: Partner, Community, and Public Outreach and Education								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Increase public involvement in watershed management through volunteer programs for children and adults. Develop broad messaging and associated information that integrate science with Hawai'i's unique cultural traditions.	Statewide.	Increase understanding of watershed threats and management, engage and dialogue with community groups, increase leverage of resources, improve policies and incentives promoting water quality enhancement.	Watershed partnerships, NARS, FRS, HISC, FS Forest Health and Special Technology Development Program, FSP, FLP, CREP, LLCP, NAPP, USFWS, FSCG, HCA, community groups.	Same as above.	Americorps Internships, HISC, HI Counties, CGAPS, YCC, DAR, OHA, FS.	Number of outreach events and presentations; number of participants in outreach and education events; number of volunteers opportunities provided to communities, number of participates in watershed events; increased partnerships.	3.6	1.2 1.3 1.4 1.5 2.2 2.3 3.1 3.2 3.3 5.1
2. Build public support, create sustainable funding to replace NARF, and develop new policies and laws supporting water quality and quantity.	Statewide.	Improve water production and water quality, improve wildlife habitat, and reduce extinctions.	PICCC, HCA, Hawaii Green Growth, CGAPS, HAWP, HISC.	Same as above and regional island neighbors.	TNC, HCA, Watershed Partnerships, FS, Land Trusts, OHA, HAWP, HISC, CGAPS.	Increased state funding and programs supporting water; water related bills proposed to HI state legislature, increased matching funds from federal and other sources.	1.1 1.2 2.2 3.1 3.5 3.6 3.7	1.2 1.4 5.1 6.4
3. Coordinate with agencies and organizations with water and watershed management authority to set priority landscapes and projects and to maximize the area managed, the resource threats addressed, program development, and conservation benefits.	Statewide.	Support multi-agency and program collaboration, increase funding and work in priority watersheds, improve water production and water quality.	County water departments, watershed partnerships, CZM, DOH, EPA, DAR, NARS, FRS, HISC, FS Forest Health, FSP, FLP, CREP, LLCP, NAPPs, USFWS, FSCG, private landowners, schools, community groups.	Private landowners, watershed partnerships, county water departments, HAWP, DLNR, USFWS, NRCS, DOH, FS, DHHL, OHA, counties, NPS, TNC, visitors to Hawai'i.	HAWP, FS, NRCS, watershed partnerships, U.S. Army, USFWS, CGAPS, HISC, HCA, DOH, CZM, IPIF.	Number of watershed competitive grants identified, amount of new funding received, amount of acreage brought under management; improved hydrologic functions island wide.	1.1 1.2 2.2 3.1 3.4 3.5 3.6 3.7	1.2 2.2

Strategies for Issue 1: Water Quality and Quantity

4. Raise the capacity of land management agencies to manage watersheds and leverage resources to accomplish landscape-scale management. Share watershed management expertise within the watershed partnerships and other partner groups, and with the general public.	Statewide.	Support multi-state and international collaboration.	WPs, DAR, HAWP, FSP, EQIP, CREP, FSCG, FRS, NARS, UCF, HCA, USFWS.	Private landowners, watershed partnerships, DHHL, OHA, counties, NPS, TNC, county water departments, schools, community groups, env. ed. orgs.	HCA, TNC, IPIF, NOAA, UH.	Number of watershed/forest symposia, conferences, meetings, and other information sharing events with stakeholders; total annual funding for watershed management; partnerships leveraging available resources; number of opportunities to interact with communities and the public on watershed management; new policies or laws enacted.	1.2 2.2 3.1 3.3 3.4 3.5 3.6	3.1 3.2 3.3 5.1

Water Quality and Quantity: Enhance Watershed Function

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Protect and improve the quality and quantity of surface water available for economic, ecological, and cultural purposes.	Major surface water areas statewide; watersheds above coral reef ecosystems; priority watersheds.	Improve quantity of marine food stocks, reduce soil erosion and stream and near-shore sedimentation, lower saltwater intrusion.	DAR, FRS, NARS, HDOA, USDA, HAWP, FSCG, UCF, HCA, FSP, CREP, FLP, LLCP, EQIP, USFWS, NOAA, USACE.	Same as above.	Same as above.	Increased stream flow, enhanced habitat for aquatic resources, improved agricultural management to address water quality and soil erosion concerns, tree planting in degraded watersheds, forest lands in priority watershed protected from conversion, improved water quality, increased aquifer recharge.	1.2 2.2 3.1 3.3 3.4 3.5 3.6	1.2 1.5 2.2

Strategies for Issue 1: Water Quality and Quantity

2. Improve water quality in estuaries, bays, and near-shore waters.	Same as above plus coastal bays, estuaries, and streams statewide.	Improve quantity of marine food stocks, reduce soil erosion and stream and near-shore sedimentation.	DAR, HAWP, FSP, EQIP, CREP, FSCG, NARF, UCF, HCA, USFWS.	Same as above.	HCA, TNC, IPIF, NOAA, UH, DOH, Community groups.	Increased water quality assessments; reduced negative chemicals in waterways and bays; enhanced habitat for aquatic resources, improved agricultural management to address water quality and soil erosion concerns, tree planting in degraded watersheds, forest lands in priority watershed protected from conversion.	1.2 2.2 3.1, 3.3, 3.4, 3.5, 3.6	1.2 1.5 2.2

Water Quality and Quantity: Address Key Forest Health Concerns

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai‘i Environmental Literacy Plan Goals
1. Work closely with other programs to address additional key watershed threats such as fire, predators, diseases, and inappropriate human use.	Statewide.	Improve and increase native carbon sequestration.	HAWP, DOFAW Fire, DOFAW Forestry and Forest Health, FSP, FSCG, NRCS, USFWS, U.S. Army, OHA.	Same as above.	CGAPS, HISC, HCA, HAWP, FSCG, UH, FS, IPIF, USGS, Private landowners, Land Trusts.	Number of projects completed related to fire, disease and human activity; collaboration with partners.	1.2 2.2 3.1 3.3 3.4 3.5 3.6	1.2 1.4 2.2 2.3 3.1 3.2 3.3 5.1
2. Increase monitoring and research to detect and contain new diseases and insects affecting watersheds and native forest species. Develop new tools to manage diseases and insect pests.	Statewide.	Reduce native forest species dieback, maintain water production, protect coral reefs, conserve native biodiversity.	HAWP, FS, USGS, DOFAW Forestry and Forest Health, USFWS, FSP, CREP, EQIP, watershed partnerships, NARS, FRS, HISC.	Private landowners, DLNR, DOFAW, FRS, NARS, USFWS, NRCS, DOH, U.S. Army, FS, watershed partnerships, DHHL, OHA, counties, NPS, TNC, county water departments.	IPIF, USGS, USFWS, UH, TNC, NARS CGAPS, HISC, HAWP, USGS, FS.	Number of new cases of disease or insect infestation that can be identified and controlled before it spreads to other locations.	1.2 2.2 3.1 3.3 3.4 3.5 3.6	1.2 1.4 2.2 2.3 3.1 3.2 3.3 5.1

Strategies for Issue 1: Water Quality and Quantity

3. Restore native species and forested areas in priority watershed forests and eroded areas.	Priority watersheds, streams, watersheds above coral reef ecosystems.	Increase native carbon sequestration, increase native biodiversity.	Watershed partnerships, FSP, CREP, FRS, NARS, USDA, NRCS, EQIP, USFWS, FS.	Same as above.	Private landowners, FS, USFWS, FSCG, Land Trusts.	Number of plants planted; number of plants surviving after 5 years; number of native forest riparian buffers installed; number of tree planting projects.	1.1, 1.2 2.2 3.1, 3.4, 3.5	1.2 1.4 2.2, 2.3 3.1, 3.2, 3.3

Key:
CGAPS = Coordinating Group on Alien Pest Species
CREP = Conservation Reserve Enhancement Program
CZM = Coastal Zone Management
DAR = Division of Aquatic Resources
DHHL = Department of Hawaiian Homelands
DLNR = Department of Land and Natural Resources
DOFAW = Division of Forestry and Wildlife
DOH = State Department of Health
env. ed. orgs. = environmental education organizations
EPA = U.S. Environmental Protection Agency
EQIP = Environmental Quality Incentive Program (a program of the NRCS)
FLP = Forest Legacy Program
FRS = Forest Reserve System
FS = U.S. Forest Service
FSCG = U.S. Forest Service Competitive Grants
FSP = Forest Stewardship Program
HAWP = Hawai'i Association of Watershed Partnerships
HCA = Hawai'i Conservation Alliance
HDOA = Hawai'i Department of Agriculture
HISC = Hawai'i Invasive Species Council
IPIF = Institute of Pacific Islands Forestry
ISC = Invasive Species Committee
LLCP = Legacy Land Conservation Program
NAPP = Natural Area Partnership Program
NARF = Natural Area Reserve Fund
NARS = Natural Area Reserve System
NOAA = National Oceanic and Atmospheric Administration
NPS = National Park Service
NRCS = Natural Resources Conservation Service
OHA = Office of Hawaiian Affairs
PICCC = Pacific Islands Climate Change Cooperative
TNC = The Nature Conservancy
UCF = Urban and Community Forestry (Kaulunani)
UH = University of Hawai'i
USACE = U.S. Army Corps of Engineers
USDA = U.S. Department of Agriculture
USFWS = U.S. Fish and Wildlife Service
USGS = U.S. Geological Survey
WP = Watershed Partnerships
YCC = Youth Conservation Corps

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Issue 2: Forest Health: Invasive Species, Insects, and Disease

Overview

The Hawaiian Islands represent the most isolated archipelago in the world, with a multitude of climates and varied topography conducive to forest growth. These islands provided a remarkable opportunity for establishment, population growth, and evolution of the first relatively few arrivals of plants, insects, and vertebrates. One particularly successful plant species among these, the ancestor of endemic *Metrosideros polymorpha* (in the myrtle family), known in Hawai‘i as *‘ōhi‘a lehua*, arrived on Kaua‘i nearly 4 million years ago and evolved to form the matrix of forests found throughout roughly 80–85% of the archipelago.[1] *Koa* (*Acacia koa)* (in the legume family) likely arrived more recently, but co-dominates in 10–15% of the forest.[2] Among Hawai‘i's other native species, many are endemic to small areas such as a mountain range or a valley, a factor contributing to Hawai‘i's exceptionally high biodiversity and corresponding number of endangered species.[3] Hawai‘i, like oceanic islands in general, is especially vulnerable to the establishment of invaders and subsequent impacts of invasions.[4, 5] Although habitat destruction by humans has been a direct factor in Hawai‘i's ecological losses in the past, human-facilitated biological invaders are currently the primary agents of continuing degradation.

Polynesian settlers were the first humans to land on Hawai‘i's shores, and with their arrival they brought the plants and animals they needed to survive the long voyage and settle a new land. The settlers quickly learned how to use the forest resources of Hawai‘i for food, clothing, medicine, and shelter. Several of the Polynesian introduced plants, such as *kukui* (*Aleurites moluccana*), naturalized in forests, while the Polynesian rat (*Rattus exulans*) had an impact on the original pre-human ecosystems of Hawai‘i. By the time the first Europeans arrived in 1778, the native Hawaiians had developed land use practices that were highly productive yet sustainable. This, however, changed when wide-scale ecosystem degradation was caused by the non-native plants, livestock, insects, game species, and diseases introduced by Europeans. As a result, over the past two centuries, entire ecosystems have been replaced by invasive species in Hawai‘i.

Managing invasive species, along with reducing human impacts and protecting watersheds, is a key element of forest health in Hawai‘i today. To protect forest resources, both area-based and species-based collaboration programs have been implemented. The area-based programs follow a model of identifying landowners who manage a common area, often linked by watersheds or other geographic features. By working across borders, the landowners can achieve effective management, providing landscape-scale benefits for habitats and watersheds and perpetuating cultural traditions. Area-based invasive species management is an integral component of native forest restoration (*see "Issue 1: Water Quality and Quantity," for more information*).

Species-based programs recognize that introduced species often arrive at ports and become established first in urban areas. Once species are established, early detection and rapid response programs search for, evaluate, and remove new invasive species that have not yet invaded native forest areas. The highest chance of success for eradication is when the numbers of a new invader are low. Eradication also provides the greatest long-term benefit by removing the risk that the newly establishing species will cause harm.

The long history of colonization and human use in Hawaiʻi has introduced a large number of species that degrade forest resources. These invasive species are very widespread and include pigs (*Sus scrofa*), albizia (*Falcataria moluccana*), rats (*Rattus* spp.), over 40 ant species, slugs, and many more. The only way to preserve the function of important watershed areas and native species habitat is to find new tools to target invasive species across large areas. Research into toxicants, biological controls, and landscape-scale management techniques is critical to slowing the harm caused by invasive species that are already widespread.

The harm caused by invasive species in Hawaiʻi is so great that multiple federal, state, county, nonprofit, and private agencies have developed separate programs to address the issue. The Hawaiʻi State Legislature and Governor established the Hawaii Invasive Species Council (HISC) to provide enhanced statewide coordination. This body operates under the authority of state law and ensures that state agency actions related to invasive species are complementary to each other. The strategic plan is available at: http://dlnr.hawaii.gov/hisc/.

The Coordinating Group on Alien Pest Species (CGAPS), which pre-dates HISC, is a voluntary partnership of federal and state agencies and nongovernmental organizations (NGOs) whose goal is to protect Hawaiʻi from invasive species that adversely affect the economy, environment, agriculture, and public health. Two significant reports in the 1990s (NRDC/TNCH 1992; OTA 1993) found that Hawaiʻi had the nation's worst invasive species problem due to gaps in prevention, detection, and control programs.[6, 7] These reports concluded that many of these gaps could be addressed through increased inter- and intra-agency communication and cooperation, and by increasing public awareness and participation. Since its formation in 1995, CGAPS has met quarterly and has published strategic plans identifying priority invasive species needs (http://www.cgaps.org/action-plan/). CGAPS has a small paid staff that coordinates the partnership and collaborative projects and conducts outreach on invasive species issues and solutions.

Field capacity to tackle invasive species as part of species-based projects is effectively provided by the Invasive Species Committees (ISCs) that have been established in each of Hawaiʻi's counties: the Kauaʻi Invasive Species Committee (KISC), the Oʻahu Invasive Species Committee (OISC), the Maui Invasive Species Committee (MISC), the Molokaʻi Invasive Species

Committee (MoMISC), and the Big Island (Hawai‘i Island) Invasive Species Committee (BIISC).[8] The ISCs are organized under the University of Hawai‘i's Pacific Cooperative Studies Unit (PCSU) and have two essential components that work together: a voluntary committee of local agencies and landowners who are working on invasive species issues, and a field crew that is dedicated to invasive species detection and control. Map 2.1 shows where the ISCs have surveyed and controlled invasive species.

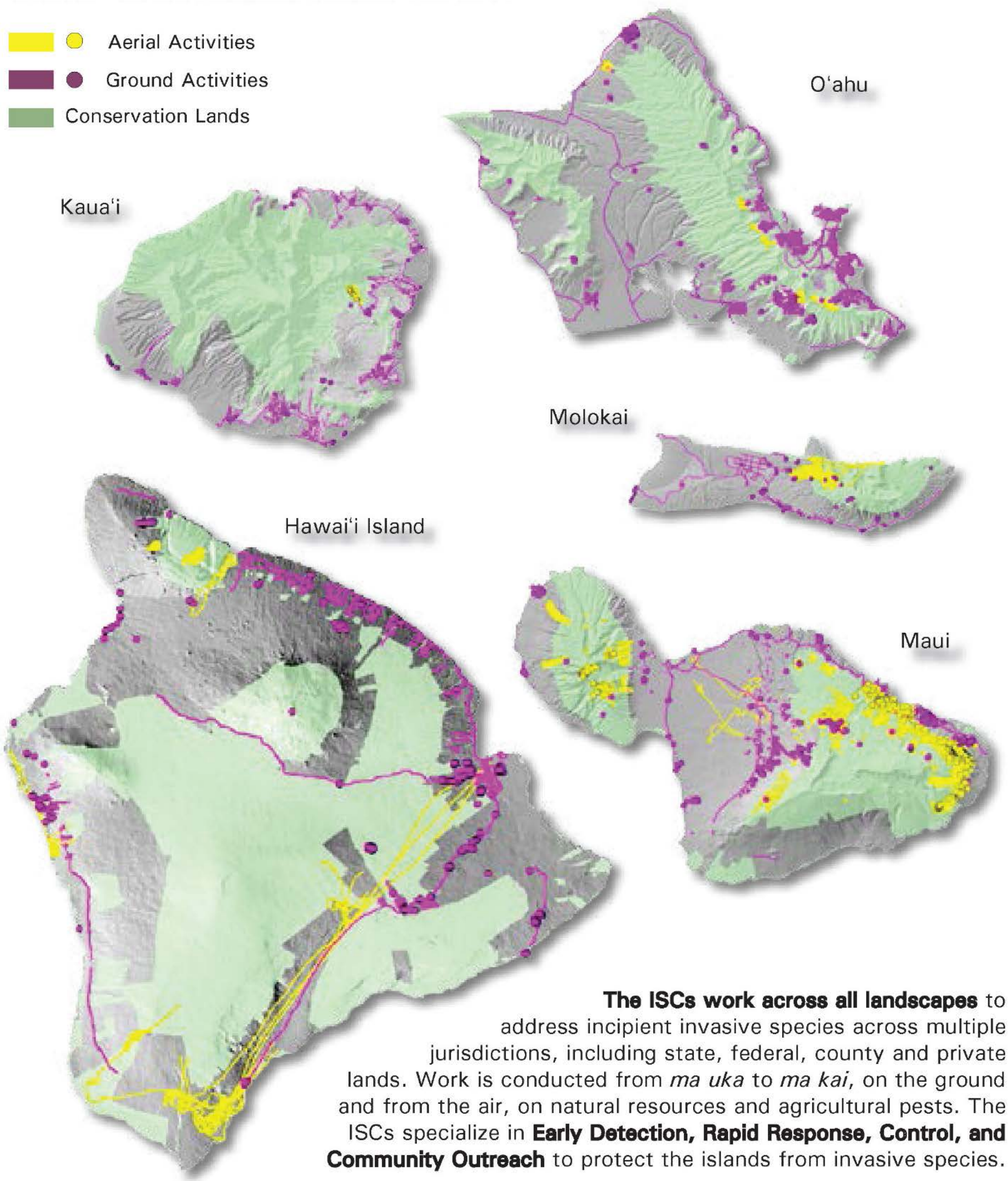
Landscape-scale projects in Hawai‘i are carried out by the watershed partnerships, which exercise area-based management to protect and restore native forest communities. Watershed partnerships are voluntary alliances of public and private landowners funded largely by the Hawai‘i Department of Land and Natural Resources (DLNR) to collaboratively protect forested watersheds for water recharge, biodiversity, and other ecosystem services. Much of the work carried out by watershed partnerships involves the control of invasive species, especially feral ungulates and invasive plants in high-priority conservation areas such as the upland native-dominated forests (*for more information, see "Issue 1: Water Quality and Quantity"*).

Threats

Invasive Plants and Animals

The two main threats to watershed health in Hawai‘i, and the focus of most on-the-ground management, are feral ungulates and invasive plants. Animals such as feral pigs, goats, sheep, deer, and cattle trample, browse, and destroy vegetation that evolved without any measures to protect itself from these animals. Feral ungulates also tear up the ground with their hooves, leaving the ground bare and exposed, resulting in increased erosion and allowing seeds of fast-growing non-native species to germinate and thrive. These animals also serve as important seed vectors for invasive plants (*also see "Issue 6: Conservation of Native Biodiversity"*).

More than 8,000 plant species have been introduced to the islands, with a couple hundred of them invasive to various degrees. Perhaps the most direct impact of invasive plants in Hawai‘i's forests is the loss of habitat for native plants and animals. Native Hawaiian forests are relatively open compared to continental tropical forests, and many native tree species need high light levels for germination and survival.[9] Many invasive trees are able to germinate and establish in low-light conditions and shade out native Hawaiian forest species. Consequently, native animals, like birds and insects that are dependent on the native plants, are also displaced.



Map 2.1. Invasive Species Committees activities during 2014. The ISCs work to prevent incipient species from moving into conservation lands (green shaded areas). This work complements that of the watershed partnerships and DOFAW, which control established species on conservation lands.

Figure 2.1. A monotypic stand of *Miconia calvescens* in Tahiti illustrates what can happen if Miconia is left unchecked. Erosion is attributed to Miconia's shallow root system. Photo courtesy of Ryan Smith.

Invasive plants often have negative impacts on the hydrologic processes of forested watersheds. Many non-native trees invading our forests have shallow roots that reduce the ability of the forests to withstand erosion, rockfall, and landslides on steep hillsides (Figure 2.1). Some alien invasive species such as Miconia (*Miconia calvescens*) (Figure 2.2) have been shown to be significantly less effective than native trees in allowing rain to slowly infiltrate watersheds, and instead they create runoff.[10] There is also evidence that strawberry guava has higher evapotranspiration rates than *ʻōhiʻa*-dominated forest, but the extent of this relationship has not been fully documented.[10] Researchers have found that strawberry guava reduces the proportion of rainfall that becomes available for groundwater recharge when compared with native-dominated forests.[11]

Hawaiʻi has no native reptiles or amphibians, and only one native land mammal (the Hawaiian hoary bat). Fifty-five non-native birds, 40 terrestrial reptiles, 6 amphibians, and 19 mammals are naturalized in Hawaiʻi, and some of these have become serious pests in our watersheds. Rats, in particular, have a significant effect on native vegetation and bird species. Black rats (*Rattus rattus*) and Polynesian rats (*Rattus exulans*) are found in abundance throughout most of Hawaiʻi's forests. Rats consume the seeds, fruits, and flowers of numerous native plant species, including many rare ones; they also prey on native bird eggs and nestlings.[12, 13] Like ungulates, rats can affect water quality by serving as vectors for water-borne diseases such as Leptospirosis and Cryptosporidiosis. Other non-native vertebrates that pose problems in Hawaiʻi's watersheds include mongooses, feral cats, dogs, mice, and birds. Non-native forest birds have been observed in all vegetation types. They compete with native forest birds for food and other resources, act as vectors for avian diseases, and disperse the seeds of many invasive plant species such as Miconia. Invasive vertebrate issues are managed through partnerships with state agencies with jurisdiction over

Figure 2.2. Introduced to the islands as an ornamental plant, Miconia is one of Hawaiʻi's worst invasive plant threats. Photo courtesy of OISC.

harmful and injurious wildlife and federal agencies such as the U.S. Fish and Wildlife Service and the U.S. Department of Agriculture's (USDA's) Wildlife Services.

Plant Diseases and Insects

Figure 2.3. An *'ōhi'a* forest on the Big Island is affected by the wilt diseases caused by *Certocystis fimbriata*. Photo courtesy of Pictometry International.

Introduced insect pests and plant diseases are a continual threat to Hawai'i's resources and occur in all areas of the state, including forests, urban areas, and agricultural areas. Non-native pest introductions can devastate plant species that have no history of exposure or resistance to the pest or similar taxa, as is frequently the case in Hawai'i.

Of special concern are pests that could cause widespread mortality to wide-ranging dominant native forest species such as *koa* and *'ōhi'a*. A newly identified fungal pathogen, *Ceratocystis fimbriata*, also referred to as *'ōhi'a* wilt or Rapid *'Ōhi'a* Death (ROD), is threatening to wipe out *'ōhi'a* trees, Hawai'i's most widespread and ecologically important tree species, which defines forest succession and ecosystem function and provides critical habitat to rare, threatened, and endangered birds and insects.[14] After the appearance of symptoms (crowns turning yellow then brown), the tree dies within a few weeks. As of 2014, 6,000 acres from Kalapana to Hilo on the Island of Hawai'i had been infected, with stands showing greater than 50% mortality (Figure 2.3). The disease is easily transmitted, but details on how it spreads and how to control it are still being investigated. This disease is limited to Hawai'i Island and has not yet been reported on other islands, but it threatens *'ōhi'a* trees statewide.[15] Large-scale dieback of such predominant forest species would be devastating to Hawai'i's remaining native ecosystems.

Another pathogen, a rust species, also has the potential to negatively affect *'ōhi'a* forests. In 2005, a strain of *Puccinia psidii* was found to be pathogenic to *'ōhi'a*, as well as to many other species in the Myrtaceae family occurring in Hawai'i. Although the disease currently present in Hawai'i has demonstrated low virulence in *'ōhi'a*, scientists are concerned about introductions of future strains.[16] The same disease has proven to be quite virulent in rose apple (*Sygyzium jambos*), an introduced fruit tree popular for its rose-flavored fruit, and also in *Eugenia koolauensis*, an endangered native Hawaiian plant with only a few populations remaining.[17] *'Ōhi'a* seedlings are more susceptible than mature trees (Figure 2.4), and impacts on regeneration are being monitored in collaboration with the U.S. Forest Service (FS).

ʻŌhiʻa and many of the commercially important eucalyptus species belong to the Myrtaceae family. There is a documented risk that the pests of Myrtaceae will spread through pathways such as establishment of commercial eucalyptus plantations and the import of nursery pests. For example, *Coniothyrium zuluense*, a serious fungal leaf pathogen of eucalyptus, believed to be derived from a pathogen of native Myrtaceae in South Africa, has already arrived in Hawaiʻi.[18] Whether this pathogen can infect *ʻōhiʻa* is unknown, but its arrival further illustrates the need for careful management of the myrtle family pathway, not just to detect *P. psidii*, but to manage numerous forest pests.

Figure 2.4. An *ʻōhiʻa* seedling is infested by *Puccinia psidii*. In nurseries where conditions are conducive to outbreaks, the disease must be managed with fungicides.

Fusarium oxysporum is a pathogen that causes *koa* wilt disease and threatens the health of *koa* forests in Hawaiʻi. This soil-borne disease causes dieback and decline of *koa* by compromising the tree's vascular system.[19] Figure 2.5 shows the stain that this pathogen produces in *koa*. The disease has been especially virulent in lowland plantations of *koa* on former agricultural lands and greatly hinders the establishment of commercial plantations. The full extent of the impact of *koa* wilt disease in natural forests is still unknown.

Figure 2.5. This stain on *koa* wood is attributed to *Fusarium oxysporum* in a plantation.

DLNR's Division of Forestry and Wildlife (DOFAW) has worked closely with the Hawaiʻi Agriculture Research Center (HARC) in developing disease resistance in *koa*, using seed collected from its natural range in the islands. After screening collected seed with virulent isolates of *F. oxysporum*, HARC outplants families with high survivorship. Several small plantations of resistant *koa* have been planted on DOFAW-managed lands and the lands of partnering private forest landowners. These plantations will provide seed for future plantings in the state. Where outplanting of *koa* is used as a tool for reforestation, using disease-resistant planting stock could be important to project success. In areas where a *koa* seedbank already exists, scarification instead of outplanting is the preferred method of regeneration. Other challenges to *koa* forest management are described in a *koa* action plan that is under development.

Invasive insects have wrought substantial damage to certain forest species in Hawaiʻi. Particularly notable examples include the fern weevil (*Syagrius fulvitarsus*), established about 1900 and especially damaging to species of the tree fern Sadleria; the black twig borer (*Xylosandrus compactus*), established in the 1970s and particularly damaging to *Acacia koa*[20] and numerous rare endemic dry forest trees, such as *mehamehame* (*Flueggea neowawrea*); the two-spotted leafhopper (*Sophonia rufofascia*), established in 1988; and the *Erythrina* gall wasp (*Quadrastichus erythrinae*), established in 2005.[21]

A species of thrips (*Klambothrips myopori*) first detected on the Hawaiʻi Island in March 2009 has the potential to severely damage *naio* (*Myoporum sandwicense*), an important tree in Hawaiʻi forests[21] as well as in urban landscaped areas (Figure 2.6). Thrips feeding causes gall-like symptoms and kills foliar tissue. Severe infestations can lead to branch die-back and ultimately to tree mortality. A monitoring program started by DOFAW in 2010 found that the infestation levels in leaves as well as the dieback levels increased considerably during the 3-year monitoring period and were higher at mid-elevation sites.[22] The infestation is still limited to Hawaiʻi Island, and early detection/rapid response plans have been developed for the other main islands (http://dlnr.hawaii.gov/hisc/species-management-plans/).

Figure 2.6. An introduced thrips insect damaging native *naio* (*Myoporum sandwicensis*) was first detected in 2009 on Hawaiʻi Island.

Coconut rhinoceros beetle (CRB) (*Oryctes rhinoceros*), a major pest of coconut palms, was first detected in Honolulu in December 2013. CRB is mainly a pest of coconuts and oil palms, but may also attack other palm species. The adults of this large scarab beetle damage palms by boring into the center of the crown, where they injure young, growing tissue and feed on the sap (Figure 2.7). As they bore into the crown, they cut through developing leaves, causing damage to the fronds. This pest currently is limited to the island of Oʻahu; and an incident command system has been established by the Hawaiʻi Department of Agriculture (HDOA) to coordinate efforts by various partner agencies to respond to this pest emergency.[23]

Figure 2.7. Coconut rhinoceros beetles create holes in palm frond stems. Photo courtesy of Ernie Nelson, Greenscapes, Inc.

In 2012, a lobate lac scale (*Paratachardina pseudolobata*) was detected on O'ahu defoliating a ficus tree (*Ficus benjamina*). The scale has been reported to have over 30 hosts, including several native plant species such as the native hibiscus and *koa*. So far, the scale is limited to O'ahu, and DOFAW, in collaboration with the University of Hawai'i, is monitoring forest species for scale-caused injury to determine appropriate management actions.

Climatic ranges for most of these insects are not well studied, but typically they are a problem throughout the environmental range of the host, such as with the *Erythrina* gall wasp, which has infested all known populations of *wiliwili* to varying degrees, and has virtually eliminated other species in the genus *Erythrina* that were popular trees in urban and agricultural areas. Figure 2.8 demonstrates the effect that this tiny wasp has on *Erythrina* species. The native *wiliwili* have recovered significantly since the release of a biological control in 2011. The gall wasp continues to limit seed set in the species, however, and release of a second agent is planned for the near future. Black twig borer, with a much wider host range, is limited by elevation (found under 3,000 feet) but is widely distributed in ecosystems at lower elevations.

Figure 2.8. Leaves can be severely damaged by the *Erythrina* gall wasp. Photo courtesy of Ron Heu.

The absence of social insects in Hawai'i throughout its evolutionary history has had enormous implications for Hawai'i's flora and fauna.[24] Over time, unfortunately, accidental introductions of social insects have greatly altered Hawai'i's ecosystems. Invasive yellow jackets (*Vespula pennsylvanica*) have been found to decimate native invertebrate populations in forest areas. Invasive species such as fire ants (*Solenopsis geminate*) and yellow crazy ants (*Anoplolepis gracilipes*) have been documented to severely injure seabird chicks and affect their ability to fledge. Today, Hawai'i is home to at least 45 known species of ants. Without ants present for protection, piercing and sucking insects (such as scales and aphids) were unable to successfully colonize the Hawaiian Islands and were therefore absent. These insect pests are now established in tandem with the introduced ants, which are pests in forest and urban areas of Hawaiʻi.

Figure 2.9. Little fire ants (*Wasmania auropunctata*) are a serious pest for Hawaiʻi's environment, its agriculture, and our way of life.

Of significant concern in Hawaiʻi is the little fire ant (LFA) (*Wasmania auropunctata*) (Figure 2.9). LFAs are serious pests that deliver a painful sting to humans, causing welts that can last for weeks. In infested agricultural fields and farms they can damage crops and sting workers and animals. Heavy infestations can negatively affect commercial, recreational, or residential property. First discovered in 1999, the LFA was limited to Hawaiʻi Island, but in 2013 this species was detected on Kauaʻi, Oʻahu, and Maui. Eradication is being attempted on three islands, but on Hawaiʻi, where there are numerous infestations, eradication is impossible owing to limited agency resources. LFAs are easily transported in potted plants, on plant material, and in vehicles. Public outreach and support is critical in mitigating the spread of the LFA in Hawaiʻi.[25, 26] A bioeconomic study of the LFA in Hawaiʻi estimated that the benefits from increased management of the LFA were $5 billion in savings, including $540 million in reduced damages and reflecting 2.1 billion fewer sting incidents over 35 years.[27]

Trends

Invasive Species

The numbers of non-native species established in Hawaiʻi is increasing. While new species continue to be introduced accidentally, new pathways of introduction (such as Internet mail order for some taxa) contribute to the addition of new species each year in the islands. Island-wide botanical surveys for new plants continue to record new introductions along roadsides and in cultivation. The focus of invasive species management has shifted to prevention and early detection; however, consistent funding and a comprehensive biosecurity plan for Hawaiʻi are needed to further mitigate the arrival of new invasive species. Through the ISCs, there is more capacity to respond to new invasive plants, and at least a dozen species have been eradicated on individual islands, preventing harm to the environment and economy of the state.[8]

Insects and Disease

Introduction of insects and diseases is a continuing problem, in part because Hawaiʻi is so heavily dependent on imports. With the accelerated movement of people and goods in the

Pacific, Hawaiʻi is particularly vulnerable to new insects and diseases that are difficult to detect visually. Approximately 20 insect species establish in Hawaiʻi each year, about half from foreign countries and half from the U.S. mainland. Some of these organisms are new to science and are described only after they begin to cause damage. *Myoporum* thrips and the *Ceratocystis* pathogen are just two examples. The loss of 30% of HDOA inspectors in 2009 reduced state inspection capacity. Additionally, loss of HDOA monitoring and biocontrol positions in 2009 seriously compromised detection and assessment of new pests (*see "Issue 9: U.S. Tropical Island State and Territorial Issues," for additional information*).

Climate Change

Global and local climate change has the potential to affect Hawaiʻi's suite of established invasive species by extending their ranges to higher elevations. Warming temperatures at higher elevations, where most remaining native forests exist, could make these forests more vulnerable to pest damage by increasing the climatic range of certain pests that are still limited to lower elevations. One well-documented example of this threat of warming is the potential range expansion of mosquito species to higher elevations, resulting in increased exposure of remnant forest bird populations to mosquito-transmitted infectious diseases.[28] Increased drought could also increase susceptibility to existing pests (*see "Issue 5: Climate Change and Sea Level Rise," for additional information*).

The effects of climate change and invasive species are often synergistic and have devastating consequences for forest health and communities. For example, climate change is expected to increase the frequency of storm events such as hurricane Iselle, which hit the eastern side of Hawaiʻi Island in August 2014. The vast majority (~90%) of trees that fell during this storm were invasive albizia (*Paraserianthes falcataria*). This fast-growing, shallow-rooted tree species is widespread in the eastern side of the Hawaiʻi Island. The trees, towering over homes and along roadsides, were easily toppled in the high hurricane winds. The downed trees took down power lines, isolated communities by blocking roads, further complicated and prolonged the cleanup efforts, and significantly increased the economic costs of responding to a natural disaster.[29]

Both vertical range shifts and increased disturbance from violent weather events may open opportunities for invasive species to establish in new areas (*see "Issue 5: Climate Change and Sea Level Rise," for further details*).

Management Approaches

Biosecurity Plan

The draft Hawaiʻi Interagency Biosecurity Plan is scheduled for completion in December 2016. This plan is a 10-year road map for implementing the infrastructure and capacity needed to support biosecurity program at multiple agencies, including HDOA, DLNR, Hawaiʻi Department of Health, University of Hawaiʻi, and the Counties. The goal of the plan is to ensure that existing and future biosecurity programs at multiple agencies are well supported, aligned to protect Hawaiʻi from the impacts of invasive species, and effectively implemented by the respective organizations in a synergistic and coordinated manner. The plan includes specific tasks to enhance postborder management of invasive species and protect forest health; these include:

- Hiring four forest health specialists and one forest health pathologist to conduct monitoring, detection, and control of high-risk pests and pathogens in forest habitats (e.g. Rapid ʻŌhiʻa Death and lobate lac scale).
- Hiring 45 invasive species technicians plus operational support and purchase vehicles to be used to detect, monitor, remove, and control invasive species in DOFAW's protected areas.
- Increase DLNR's funding by $400,000 each year to address threats from established invasive species.
- Implement one or more mechanisms (e.g. interisland nursery certification program) to minimize the movement of plant pathogens and pests via interisland transport of agricultural products.
- Propose for enactment the necessary legislative amendments and promulgate new administrative rules to prevent the introduction of invasive species to natural areas, sensitive ecosystems, and protected areas and the spread of these species in these areas via commercial activities such as ecotourism, agrotourism, and construction activities.

Prevention

It is well established that prevention is the most cost-effective tool for invasive species management. The agencies responsible for Hawaiʻi's border inspection services are HDOA, USDA's Animal and Plant Health Inspection Service (USDA APHIS), and the Department of Homeland Security's U.S. Customs and Border Protection (DHS CBP). Working closely with these agencies through forums like HISC and CGAPS, DOFAW attempts to prevent new species from being introduced to the state and between islands. This effort addresses invasive plants, insects, and diseases, as well as any other organisms that could harm Hawaiʻi's environment. Risk assessments for pathways and specific pests are an important tool for prevention.

Hawaiʻi-Pacific Weed Risk Assessment

The Hawaiʻi-Pacific Weed Risk Assessment (HP-WRA) is a diagnostic tool to help predict a plant's likelihood of becoming a weed. The HP-WRA was developed in Australia and New Zealand and modified for use in Hawaiʻi and other Pacific Islands by Professor Curt Daehler of the University of Hawaiʻi. The HP-WRA screens plant species and assigns a score based on propensity to become weedy. A high-scoring plant poses a high risk of becoming an invasive pest. The assessment is based on 49 questions that address several plant characteristics, such as number of seeds produced and habitat preferences, to determine if a species is likely to become invasive. As of November 2015, more than 1,680 plant species have been screened using the HP-WRA. Request for screening plants using the HP-WRA can be submitted to the state's Weed Risk Assessment Specialist via the website https://sites.google.com/site/weedriskassessment/home. Although the HP-WRA was developed as a tool to prevent new invasions, it is also used by DOFAW and others to evaluate the threat of newly established plants. The HP-WRA also has potential to be used by HDOA and the nursery industry to help screen and select species that are appropriate to import and use in the industry and as a tool to identify species appropriate to put on the state's restricted plant list when updated.

Early Detection

Several limited-term projects have focused on identifying the locations and extents of populations of plants known to have been planted in Hawai‘i and considered to pose a threat to native ecosystems (based on the HP-WRA scores). These early-detection surveys covered specific areas at high risk for introduction of vascular plants, creating a framework of agencies and data collection protocols to ensure that these high-risk areas are monitored on a periodic basis and are tied to an effective rapid response capability.

Early-detection projects for new invasive plant species that may have been introduced via arboreta, nurseries, or residential plantings have continued on O‘ahu, Hawai‘i Island, Kaua‘i, Lāna‘i, Maui, and Moloka‘i. Map 2.1 shows areas surveyed and/or treated by the ISCs on five of the Main Hawaiian Islands in 2014. Sustained funding is needed to continue these surveys across the islands.

Support also is needed to evaluate and prioritize rapid response efforts after targets are identified through these early-detection surveys. Detecting plant species when they are limited to a few individuals or cover less than 10 acres greatly increases the likelihood of a successful eradication effort, as supported by studies of invasive trees in the Galapagos.

Standardizing the risk evaluation process has significantly improved prioritization of new invasive species targets for control. Initially, the "Eradicate this weed or not?" decision tree created by the New Zealand Department of Conservation was used on O‘ahu and in a modified form on Maui. This decision tree has been modified to apply the HP-WRA screening system, along with other factors relating to ecology, distribution, and known control techniques, to evaluate the risk that species will become serious forest pests. This standardized process ensures that the limited resources available are used to control the species that pose the greatest risk and have the best potential for island-wide eradication.

Rapid Response

Given its geography as an archipelago, rapid response efforts in Hawaiʻi can be relatively effective compared to other states. If a new invasive species is detected on one island, other islands can be kept free from this new pest species through strict intra-state quarantine practices and constant monitoring followed by effective control. Rapid response to pursue island-specific eradication or containment is the most cost-effective for the long-term statewide protection of native ecosystems. Although several of the high-priority plant species are fairly widespread, rapid responses to new targets will be prioritized by the level of the threat they pose to native forest ecosystems and the feasibility of eradication.

Insects and Disease

Insect and disease pests damage all forest ecosystems in the state. Non-native insects and diseases are a primary threat in Hawaiʻi. Currently, efforts by DOFAW have focused on working with partner agencies such as FS, the University of Hawaiʻi, and HDOA to (1) understand and manage the spread of *ʻōhiʻa* wilt disease that is limited to Hawaiʻi Island, but has the potential to spread statewide and devastate our native *ʻōhiʻa* trees and the watershed; (2) eradicate or contain CRB on Oʻahu and prevent its spread to neighboring islands; (3) monitor potential native host plants of the lobate lac scale in forests to plan future management actions; and (4) limit LFA establishment to the Island of Hawaiʻi.

In addition to focusing on managing the recent invasion of the above-mentioned insects and diseases, DOFAW's forest health management efforts have continued to support control of invasive pests such as the *Erythrina* gall wasp (using biological control), black twig borer (developing and refining lures for local control), myrtle rust (advocating for regulations and capacity to prevent the arrival and establishment of new strains), and *naio* thrips (investigating natural resistance to *Myoporum* thrips in populations of *naio* from around the state). Preventing new pests from entering Hawaiʻi by strengthening early detection and quarantine is key to protecting Hawaiʻi's forests.

Of significant importance are the insects and diseases affecting our *koa* forests. In addition to being a critical component of Hawaiʻi's watersheds, *koa* also has special cultural and economic importance in the state (see *"Issue 8: Forest Products and Carbon Sequestration"*). DOFAW, in collaboration with HARC, has been successful in isolating and developing genetic resistance in *koa* to *F. oxysporum*. Activities include continuing to screen for resistant *koa* families, retesting a subset of seedlots to examine repeatability of results, planting additional *koa* seed orchards capable of producing resistant seed, and refining methods for vegetative propagation of disease-resistant koa families.[22]

The *koa* moth (*Scotorythra paludicola*) is endemic to Hawai'i, and its caterpillars, which feed only on *koa* leaves, are capable of defoliating mature koa trees. In 2013, an island-wide outbreak of *koa* moth on Hawai'i Island defoliated approximately 70,000 acres of koa forest—the most expansive outbreak ever recorded.[22] Although most trees recovered, damage can still be seen 2 years following the outbreak.

Abiotic stressors such as vog (volcanic fumes) and drought also affect forests and may interact with pest damage stress in Hawai'i.

Biological Control

As a part of an integrated pest management strategy, biological control is often the most effective and permanent approach, and makes best use of limited funds to control pest species, especially when a pest is widely established. Long-term suppression of ecosystem-altering pests or pests that threaten key native species is often unachievable with any other tool. HDOA, FS, the University of Hawai'i, and USDA's Agricultural Research Service all maintain some capacity for biological control research and collaborate with scientists in other states and countries to efficiently pool resources. Their efforts are coordinated through a statewide biological control working group.

Galling levels on the endemic *wiliwili* trees by the invasive *Erythrina* gall wasp have been significantly reduced by the biocontrol agent *Eurytoma erythrinae*. *Wiliwili* trees statewide are recovering—flowering, which had ceased at the height of the gall wasp infestation, has resumed. In some areas, managers are beginning to outplant *wiliwili* in restoration sites again. However, the infestation rate in flowers remains high, adversely affecting seed production. DOFAW, in collaboration with HDOA, is working on releasing another biocontrol agent, *Aprostocetus nitens*, to further control the *Erythrina* gall wasp populations to allow for successful seed production and recruitment of *wiliwili* in Hawai'i's dry forests.

After 15 years of testing and a contentious environmental assessment process, a Brazilian scale insect, *Tectococcus ovatus*, was released at several locations to combat the widespread impacts of strawberry guava (*Psidium cattleianum*), the most damaging forest tree species in Hawai'i. The gall forming insects do not kill the tree, but are expected to slow the tree's growth and spread, making it less competitive with native plants.[30] Projects are currently investigating how to accelerate its establishment and spread.

Current statewide capacity to develop biological controls is severely limited. Facilities are outdated, cramped, and inadequate for comprehensive testing of multiple species. The HDOA biocontrol facility is no longer certified for work on diseases, owing to lack of maintenance. The program is understaffed as well. In order to adequately address invasive species issues in Hawai'i, a substantial increase in resources for biological control is required. This needs to be accompanied by public engagement and outreach efforts so that the public has a better understanding of biological control as a necessary tool in invasive species management.

Restoration

Restoration is an integral part of invasive species management. Without revegetating treated areas with desirable plants, invasive plants are likely to return. Native forest restoration in Hawai‘i normally follows a two-pronged strategy of fencing out harmful ungulate species and suppressing invasive plants. Outplanting native plants or conducting scarification, which can release the seedbank in areas previously covered by *koa* forests, can also be used to suppress invasive plants. Creating forest canopy can suppress invasive grasses, which promote fire and prevent native species from re-establishing. Restoration efforts need to be site-specific based on climate, historical use, and other physical factors. Invasive species management needs to take into consideration how treatment will affect future plant and animal communities.

Part of restoration also involves the genetic preservation of species threatened by a pest or disease. For example, a statewide effort was made to collect *wiliwili* seed from as many populations as possible when the gall wasp was introduced and it became apparent that the species could become endangered. As the gall wasp population has been suppressed by the introduced biological control agent, restoration efforts will use this seedbank for re-establishing *wiliwili* in forests. Similarly, collections of *koa* that are screened for *koa* wilt resistance can be used to establish *koa* forests where they have been long extirpated by animal grazing.

Innovative Management Techniques

Monitoring of forest health conditions occurs throughout the state on land of all ownership types (private and public). These programs use ground surveys, transect monitoring, helicopter surveys, road surveys, photo points, and remote sensing for gathering data. The watershed partnerships have extensive data on invasive plant management for their internal use, and efforts have been made to standardize and communicate species-specific information statewide, in the same manner as is used for the data from the ISCs.

Progress has been made in developing remote sensing tools for monitoring the presence of invasive plants and in identifying plant mortality and damage caused by insects and disease in Hawai‘i’s forests. Many of the most habitat-modifying invasive plants live in the understory, making them difficult to detect during regular aerial surveys. Combining hyperspectral imaging and Light Detection and Ranging (LiDAR) technology has significantly contributed to mapping and monitoring vegetation, particularly the spread on invasive plants in Hawai‘i’s watersheds, by being able to detect not just the canopy but also elements of the understory vegetation. Forward Looking Infrared (FLIR) technology has made it possible to find the location of habitat-damaging feral ungulates that may be hiding in dense undergrowth and otherwise go undetected by monitoring and control efforts.

Efforts are underway to use FS's Digital Aerial Sketch Mapping platform for mapping ROD and perhaps other forest damage. Experimental helicopter-based survey flights will determine whether this method (used widely in Western states from fixed-wing aircraft for mapping mortality and damage) will be a cost-effective mapping tool for Hawaiʻi.

Herbicide ballistic technology has made it possible to control invasive plants such as Miconia in areas that cannot be accessed by foot, by delivering small amounts of herbicide into plant tissue from a distance. The herbicide is delivered via a projectile fired from a device similar to a paintball gun. Also, the use of Unmanned Aerial Vehicles (UAVs) is being explored for invasive species management. For example, early detection of weeds, typically a ground-based effort, can become challenging in terrains that are hard to traverse by foot. BIISC is investigating the efficacy of using UAVs for the early detection of its target weeds, like gorse (*Ulex europaeus*), on Mauna Loa. The complex regulatory framework for UAVs is currently a challenge for natural resource organizations.

Outreach and Education

An educated and informed public is essential for effective invasive species management. Public awareness surveys show that public knowledge of invasive species in Hawaiʻi has improved in past years, and the percentage of people who view invasive species as a serious problem is rising. Ongoing efforts to convey to the public the threat and costs of invasive species such as snakes, red imported fire ants, invasive seaweeds, and miconia appear to be working. HISC sponsors Hawaiʻi Invasive Species Awareness Week every February and features public events with the governor and legislators, awards for industry and citizen efforts, and invasive species volunteer opportunities.

Plant Pono, a project spearheaded by CGAPS, connects the HP-WRA (described in more detail above) to the general public by making weed risk assessments for popular ornamentals available on the Internet in an easy-to-read format (*Pono* translates as *correct* or *righteous*). Landscape professionals and the general public can also use the website to submit requests for weed risk assessments for species not listed on the website.

Although there is a high level of public awareness of the concept of invasive species in general and of certain species[8] (see http://www.cgaps.org/public-awareness-studies/ for a full report on recent surveys), much more is needed to engage and inform the public. Additional efforts are still needed to increase public understanding of the important role of biological control in the long-term management of invasive species (Table 2.1). Increased awareness by nurseries, especially of pests shipped inter-island, can be achieved through collaborations with HDOA and CGAPS. DOFAW also recognizes the need to target more outreach to hunters, many of whom view the state's attempts to control or remove ungulates from priority watershed areas as an encroachment on their culture and livelihoods.

Table 2.1. Results of a public survey to assess support for biological control as a tool to help control a widespread invasive species in Hawai'i. Table obtained from Qmark Research 2012.[31]

2012	
Strongly support (4)	32%
Somewhat support (3)	46%
Net Support	**78%**
Somewhat oppose (2)	9%
Strongly oppose (1)	7%
Net Oppose	**16%**
Don't know	5%
Mean	**3.10**

Priority Issues and Areas for Forest Health

Management of invasive species in Hawai'i involves working in diverse areas. Many species are initially detected in urban areas around harbors and ports, along roadways, at commercial nurseries, and in people's yards. If they are not eradicated or contained, they can quickly spread to adjacent forested watersheds naturally or with the help of humans. Therefore, priority landscapes for invasive species include high-risk areas such as ports, harbors, and new developments in urban areas, as well as high-value areas such as predominantly native forests identified to have important hydrological or biodiversity values (*see "Issue 6: Conservation of Native Biodiversity"*). This does not preclude working in any area that becomes infested with a high-priority species, using a species-based strategy as described in the "Overview" section above.

Priority issues include insect pests and diseases that adversely affect important forest species such as *koa* and *'ōhi'a* (such as ROD); invasive plants that are able to invade intact watersheds and alter the hydrology and biological community (such as Miconia and strawberry guava); ungulate species that degrade watershed forests (such as pigs); and species that can negatively affect our economy and way of life in Hawai'i (such as CRBs and LFAs).

Data Gaps and Opportunities

Forest Monitoring Technologies

Monitoring forest health in Hawai‘i presents many challenges. Hawai‘i’s rugged terrain limits ground access to control invasive species and increases the difficulty of remote monitoring, owing to vertical slopes and shadow effects. Technologies such as LiDAR, FLIR, and UAVs are being explored for the detection, mapping, and monitoring of invasive species. Research and development of existing and new technologies must be supported if they are to become practical tools for the management of invasive species. More projects demonstrating cost-effectiveness are needed.

Genetic Resistance Projects

Protecting Hawai‘i’s native forest species from the ever-mounting list of pests will likely require sophisticated genetic breeding programs. The *koa* wilt project led by HARC has demonstrated initial success in developing disease-resistant *koa* for commercial and forest restoration projects. The project has benefitted from mainland-based technical expertise from partner agencies such as FS. Other issues for which resistance breeding might be the best long-term management option include ROD and *Myoporum* thrips. More capacity is needed locally to take on such projects.

Early Detection in Urban Forests

The diverse and well-established urban forests in Hawai‘i are an extraordinary resource for local communities (*see "Issue 4: Urban and Community Forestry"*). However, these forests link ports of entry of invasive species with the native forests and could provide a bridge for the spread of introduced pests and pathogens into native forests. Establishing closer links between DOFAW, HDOA staff, and urban forest professionals would lead to the detection of these pests and diseases and to the analysis of their impact. It would also promote the development of appropriate control measures and inform arborists and other landscape professionals on how to recognize and contend with these pests and pathogens.

Plant Import Regulations

There is also a need for information to support the addition of candidate species to HDOA’s restricted and prohibited plant lists, the expansion of which could help protect forests from damaging pests. Most insects and plant pathogens arrive on imported plants—the more diverse the imported flora, the higher the risk. Information on what plants are entering the state is very limited. DOFAW is supporting a project being conducted by CGAPS to identify invasive plants that are in trade and likely to enter the state. This list could be used by HDOA to conduct necessary risk assessments and add to the state's restricted plant list. This information also could be used to place high-risk species on USDA APHIS's "Not Authorized Pending Pest Risk Assessment" (NAPPRA) list, thereby restricting their import into the U.S.

Increased Outreach

Invasive species outreach is conducted by DOFAW, the ISCs, and CGAPS largely with soft funding. HISC lost its statewide Communications Coordinator position in 2013 and has not replaced it. Dedicated funding and more effort is needed for public outreach on the invasive species issue, which in return is likely to increase public support for funding invasive species management in Hawai‘i.

Summary

Human-facilitated biological invasion and its impacts are the primary agents of continuing degradation of forest health in the Hawaiian Islands. The main threats to forest health are from feral ungulates, invasive plants, and invasive insects and diseases. Feral ungulates browse, trample, and destroy vegetation. They also disturb soil, which subsequently increases soil erosion and facilitates the further establishment of invasive plants. The direct impact of invasive plants on Hawai‘i's forests includes the loss of habitat for native plants and animals and the negative impacts on the hydrological processes in watersheds. Invasive insects and diseases are a continual threat to Hawai‘i, and their impacts extend beyond forests into agricultural and urban areas. Rapid ‘Ōhi‘a Death, a wilt disease caused by the fungus *Ceratocystis fimbriata*, has decimated thousands of acres of ‘Ōhi‘a forests in the last few years, and coconut rhinoceros beetle continues to be a threat to the widely planted coconut and other palm trees in urban O‘ahu.

With the accelerated movement of people and goods in the Pacific, Hawai‘i in particular is vulnerable to insect pests and diseases that are difficult to detect visually. Species continue to be introduced accidentally, and new pathways of introduction, such as via Internet mail order, exacerbate the problem. Climate change further complicates this trend. Increases in temperatures at higher elevations, where most native forests exist, could make the forests more vulnerable to damage by invasive species. An increase in storm frequency attributable to climate change also increases forest disturbance, facilitating the spread and establishment of invasive species.

Over the years, invasive species management has shifted toward prevention and early detection. Given Hawai‘i's geography as an archipelago, rapid response is effective because a new invasive species detected on one island can be eradicated or contained before it can spread to other islands. A significant step toward statewide efforts to manage invasive species is the development of the 10-year Hawai‘i Interagency Biosecurity Plan. The goal of the plan is to ensure that existing and future biosecurity programs at multiple agencies are well supported, aligned to protect Hawai‘i from the impacts of invasive species, and effectively implemented by the respective organizations in a synergistic and coordinated manner.

DOFAW’s forest health management efforts have continued to support control of established high-impact invasive species. Taking an integrated pest management approach, DOFAW has worked with HDOA and FS to successfully release biocontrol agents for the control of widespread pests, such as the Erythrina gall wasp and the invasive strawberry guava. Restoration continues to be a key component of invasive species management for DOFAW because without revegetating treated areas with native plants, invasive plants are likely to return.

Priority areas for invasive species management continue to be predominantly native forests but also include urban areas around ports and harbors, where many new invasive species are detected. Priority issues for forest health include insect pests and diseases that adversely affect important forest species like ‘Ōhi‘a and *koa*.

Further opportunities to improve forest health management include using technologies such as LiDAR and UAVs for forest monitoring, tightening plant import regulations, and using enhanced statewide outreach regarding invasive species issues.

Strategies for Issue 2: Forest Health: Invasive Species, Insects, and Disease

Management of invasive species in Hawai'i involves working in diverse landscapes from mauka to makai. Many species are initially detected in urban areas, around harbors and ports, along roadways, and in people's yards, but there are many more that go undetected. Where early detection and total eradication are not possible, invasive species can quickly spread to adjacent areas and eventually impact entire watersheds' hydrologic and other ecological functions. Much of Hawai'i's low-elevation forest is fractured into patches dominated by incipient non-native populations, whereas upland forested areas are more intact and include more native species. Maintenance and protection of these priority native forests and suppression of encroaching lowland non-native species are equally important.

Forest Health: Suppression of Invasive Species

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Prevent harm from new invasive species by improving biosecurity policies (e.g., stricter plant import regulations). Engage the public on the current policies and how to be a part of a biosecurity solution.	Ports and harbors, urban areas, targeted upland areas, wildland-urban interface.	Improve protection of T&E species, improve hydrologic functions, protect coral reefs.	HISC, HDOA, USDA, APHIS, CPB, CGAPS, Forest Health, Invasive Species Committees, UCF, DOD, FSCG (LSR), conservation education in schools, community groups.	Private landowners, industry groups, NPS, TNC, HI counties, DOD, HAWP, USFWS.	Cargo fees, conveyance tax, state general funds, HDOA, CGAPS, HISC, FHP, LICH, TNC, SPC, SPREP, HCA, USDA, APHIS CAPS, USGS-BRD, Private Foundations.	Interceptions of forest weeds and pests by quarantine officials; risk assessments; strengthened quarantine rules and expansion of lists of restricted commodities; development of an inter-agency biosecurity plan.	1.2 2.2 3.1 3.4 3.5	1.2 1.5.b, d
2. Establish early detection networks and support statewide eradication and containment of incipient species (rapid response).	Ports and harbors, urban areas, wildland-urban interface, degraded ecosystems; watershed partnership lands; private landowners.	Same as above.	Same as above plus FSP, CREP.	Same as above.	Same as above.	Species eradicated; acres; new state or island species detections; surveyed/treated for incipient invasive species; reports of priority targets by the public; species-based early detection/rapid response plans.	1.2 2.2 3.1 3.4 3.5	1.2.a, c, f 1.5 3.1 3.2 3.3
3. Restore areas where invasive plants, insects, and disease have harmed forests. Engage communities and students in restoration efforts.	Intact native forests, threatened ecosystems and watersheds, conservation district lands, watershed partnership lands, degraded/ fallow agricultural lands.	Same as above.	WPP, NARS, Wildlife, FRS, FHP, FSP, CREP, schools, community groups, env. ed. orgs.	Public, private landowners, TNC, DOD, HAWP, USFWS.	State general funds, FHP, FSCG (LSR) USFWS, stewardship, schools, community groups, env. ed. orgs.	Acres of forest restored; miles of fence installed and maintained.	1.2 2.2 3.1 3.4 3.5	1.2 1.3 1.4 1.5 6.2

Strategies for Issue 2: Forest Health: Invasive Species, Insects, and Disease

4. Develop new tools to increase effectiveness of invasive plant, insect, and disease management, including biological control and pest resistance. Engage public on biocontrol to develop informed community members.	Intact native forests, threatened ecosystems and watersheds, conservation district lands, watershed partnership, commercial plantations, degraded/ fallow agricultural lands.	Share new knowledge with the rest of the Pacific and Caribbean, T&E species protection.	Invasive species program (Wildlife), HISC, Forest Health, FSP, CREP, Special Tech. Development Program, FSCG (LSR), NRCS.	UH, USFWS, USDA APHIS Wildlife Services, NWRC, HDOA, TNC, HARC, WPP, USGS-BRD.	HISC, STDP, IPIF, PSWRS, HDOA staff and facility, UH scientists, CGAPS.	Increased capacity to suppress invasive species, insects and disease; number of biocontrol agents released; improved best management practices.	1.2 2.2 3.1 3.4 3.5	1.2 1.4 1.5
5. Monitor invasive plants and damage or mortality caused by forest pests for trends to inform management activities.	Statewide.	Address native and non-native forests, urban forests.	HISC, HDOA, USDA, APHIS, CPB, CGAPS, Forest Health, Invasive Species Committees, UCF, DOD, FSCG (LSR), WPP.	Public at large, agricultural and horticultural industries, urban forest users and workers, land management agencies.	State general funds, UH, HISC, CGAPS, Forest Health Monitoring.	Acres monitored; appropriate funding levels for the profundity of problems we have.	1.2 2.2 3.1 3.4 3.5	1.2.a, c, f 1.5 3.1 3.2 3.3
6. Develop site-specific climate models that can better inform invasive species management strategies to adapt to climate change.	Intact native forests, threatened ecosystems and watersheds, conservation district lands, watershed partnership lands, commercial plantations, degraded/ fallow agricultural lands.	Improve protection of T&E species, improve hydrologic functions, protect coral reefs.	HISC, PICCC, USGS, CGAPS.	Public, private landowners, TNC, DOD, HAWP, USFWS.	Cargo fees, conveyance tax, state general funds, HDOA, CGAPS, HISC, FHP, LICH, TNC, SPC, SPREP, HCA, USDA, APHIS CAPS, USGS-BRD, private foundations.	Increased number of site-specific climate models that can inform strategies to mitigate the spread of invasive species.	1.1 2.2 3.7	1.2 1.5.b, d

Forest Health: Outreach and Education

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Increase public support and involvement in invasive species prevention and control. Engage the public and community groups in invasive species control.	Statewide.	Increase funding.	Conservation Education, HISC, Invasive Species Program (Wildlife), FSCG (LSR), Forest Health, WPP, UCF, FSP, WPP, HCA, schools, community groups, env. ed. orgs.	Public at large, agricultural and horticultural industries, urban forest users and workers, land management agencies.	HISC, state special funds, CGAPS, LICH, AAA, DOFAW staff, schools, community groups, env. ed. orgs.	More effective invasive species control messages to the public.	1.2 2.2 3.1 3.4 3.5 3.6	1.2 1.3 1.4 1.5 3.1 3.2 3.3 5.1 6.2

Strategies for Issue 2: Forest Health: Invasive Species, Insects, and Disease

2. Utilize schools and community groups to map and identify invasive species.	Statewide.	Address native and non-native forests, urban forests.	Same as above.	Same as above.	Forest Health Monitoring, schools, community groups, env. ed. orgs.	Acres monitored by school and community groups.	1.2 2.2 3.1 3.4 3.5 3.6	1.2 1.3 1.4 1.5 3.1 3.2 3.3 6.2
3. Work with other programs ensuring integrative approaches to management of invasive species.	Statewide.		Forest Health, UCF, FSP, CREP, UH, Wildfire Conservation Education, FSCG, schools, community groups, env. ed. orgs.	UCF, FSP Council, HAWP, HISC.	DOFAW and U.S. Forest Service personnel, CGAPS, schools, community groups, env. ed. orgs.	Improvement in sharing resources; multi-agency invasive species management plans.	1.2 2.2 3.1 3.4 3.5 3.6	1.2 1.4 1.5 6.2

Key:
AAA = Aloha Arborists Association
APHIS = Animal and Plant Health Inspection Service
CAPS = Conservation Activity Plans
CGAPS = Coordinating Group on Alien Pest Species
CPB = Customs and Border Protection
CREP = Conservation Reserve Enhancement Program
DOD = Department of Defense
DOFAW = Division of Forestry and Wildlife env. ed. orgs. = environmental education organizations
FHP = Fish Habitat Partnership
FSCG = Forest Service Competitive Grants
FSP = Forest Stewardship Program
HARC = Hawai'i Agriculture Research Center
HAWP = Hawai'i Association of Watershed Partnerships
HCA = Hawai'i Conservation Alliance
HDOA = Hawai'i Department of Agriculture
HI = Hawai'i
HISC = Hawai'i Invasive Species Council
IPIF = Institute of Pacific Islands Forestry
LICH = Landscape Industry Council of Hawai'i
LSR = Landscape Scale Restoration
NARS = Natural Area Reserves System
NPS = National Park Service
NRCS = Natural Resources Conservation Service
NWRC = National Wildlife Research Center
PICCC = Pacific Islands Climate Change Cooperative
PSWRS = Pacific Southwest Research Station
SPC = Secretariat of the Pacific Community
SPREP = Secretariat of the Pacific Regional Environment Programme
STDP = Special Technology Development Program
T&E = threatened and endangered
TNC = The Nature Conservancy
UCF = Urban and Community Forestry Program
UH = University of Hawai'i
USDA = U.S. Department of Agriculture
USFWS = U.S. Fish and Wildlife Service
USGS-BRD = U.S. Geological Survey, Biological Resources Division
WPP = Watershed Partnerships Program

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Issue 3: Wildfire

Overview

Prior to the arrival of humans, the source of wildfire ignition was limited to volcanic activity and rare lightning strikes. Native ecosystems in Hawaiʻi are not adapted to wildfire. "Except in active volcanic areas, fire is not a part of the natural life cycle of native Hawaiian ecosystems, and only a few native species are able to regenerate after fire."[1] Wildfire occur throughout the year in Hawaiʻi and today, humans are the main cause of these wildfires. Wildfires in Hawaiʻi place communities at risk, destroy irreplaceable cultural resources, cost taxpayers money, negatively affect drinking water supplies and human health, increase soil erosion, adversely affect nearshore and marine resources, destroy native species and native ecosystems, and further threaten Hawaiʻi's rare, threatened, and endangered species. Moreover, disruptions from wildfires, including road, trail, camping, and hunting area closures; evacuations; power outages; and water consumption restrictions; can significantly affect the lives of Hawaiʻi's residents and visitors.

Brief History of Fire Management in Hawaiʻi

The first reported disastrous wildfire in Hawaiʻi was in 1901 on the Hāmākua coast of the Island of Hawaiʻi. Over 30,000 acres of agricultural and forested lands burned during this fire, over a period of 3 months. This event directly led to the establishment of Hawaiʻi's Forest Reserve System and the integration of wildfire management into government forest management policy. Historically, the Division of Forestry and Wildlife (DOFAW) relied on a system of district fire wardens to help suppress wildfires in rural settings. Many plantation and ranch personnel across the islands served as fire wardens, creating an effective network of partners who responded to wildland fires with manpower and equipment, extinguishing the blazes in a timely fashion. However, these partnerships began to diminish in the 1980s with the decline of ranching and plantation agriculture.

As the number of fire wardens decreased and the state's population increased, particularly in rural areas, there was a gradual increase in the number of fire stations and the capabilities of local fire departments. In spite of these increased capabilities, DOFAW was often called upon to assist with fire suppression efforts beyond its legal jurisdiction. This led to a depletion of DOFAW's limited fire suppression funding and highlighted the need to clarify the relationship between the dedicated fire services and DOFAW. In order to continue to meet its fire protection mandate and honor its partnership with local fire agencies, cooperative mechanisms in the form of Memoranda of Agreement (MOAs) or Understanding (MOUs) and Mutual Aid Agreements (MAAs) became increasingly important. DOFAW has established MAAs, MOAs, or MOUs with all four county fire departments as well as with federal land management agencies, such as the

National Park Service, U.S. Fish and Wildlife Service (USFWS), and U.S. military. With the number of wildfires increasing and funding levels diminishing, these formal agreements are crucial to providing rapid multi-agency response to wildfires and ensuring coordinated efforts in successfully suppressing wildfires.

Division of Forestry and Wildlife Fire Management Program

The state's Fire Management Program is part of the Watershed Protection and Management Section of DOFAW. The principal function of the Watershed Protection and Management Section is to ensure viable water yields by institutionalizing statewide protection and enhancement of Hawaiʻi's forested watersheds, commensurate with their social, economic, and environmental values. The mission of the Fire Management Program is to provide fire protection of the state Forest Reserve System, public hunting areas, wildlife and plant sanctuaries, and Natural Area Reserves. Continuing partnerships with local fire agencies and technical and financial assistance received from the Region 5 of the U.S. Forest Service (FS) are important components of DOFAW's Fire Management Program.[2]

DOFAW's Fire Management Program continues to be at the forefront of wildfire and all other risk-management training throughout the state, despite the fact that DOFAW personnel are primarily natural resource managers and not full-time wildland firefighters. Almost all DOFAW personnel who participate in firefighting have received basic training in Incident Command System (ICS), and approximately 50% are specifically trained in command and general staff positions within ICS. DOFAW's Fire Management Program also provides training to other fire response agencies statewide, including county fire departments, the National Park Service, and The Nature Conservancy, and also private organizations such as the Lānaʻi Company.

In the event of a wildfire, DOFAW personnel are mobilized, often with the assistance of county and federal partners. In the event of a large fire, DOFAW staff can be called from neighboring islands to assist in suppression efforts.

Benefits

In fire-adapted ecosystems, fire plays a vital role in forest successional patterns and other ecological functions; however, in Hawaiʻi and on many other Pacific islands, fire is not a significant part of, nor does it result in positive benefits for, the native ecosystems. The use of fire in Hawaiʻi may benefit non-native species such as forage grasses and ungulates that have value for recreational, agricultural, or cultural uses.

Threats and Harmful Effects of Wildfire in Hawaiʻi

Threats to Communities and the Wildland-Urban Interface (WUI)

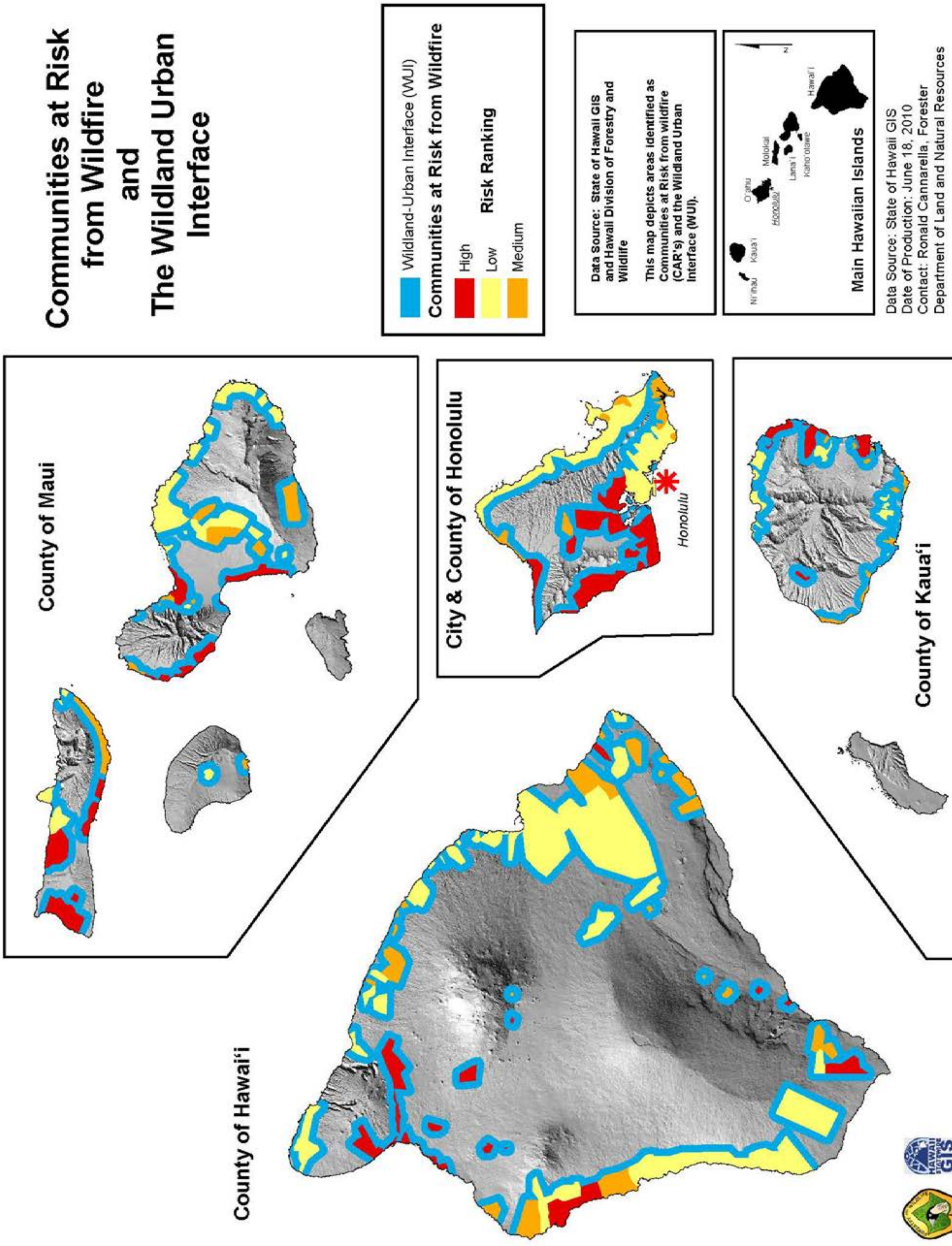
In 2005, DOFAW began identifying Communities at Risk from wildfire (CARs) in the WUI on a statewide basis. Criteria used to identify CARs include current vegetation type, climatic regimes, and fire history. The threat of wildfire in the WUI is of great concern in Hawaiʻi. Table 3.1 lists the wildfire threats associated with the various Forest Service national themes or objectives (see section on Background) and Map 3.1 depicts the CARs identified by DOFAW and its partners.

The WUI for Hawaiʻi is currently identified as areas within a 1-mile buffer around any CARs designated as Low Risk to High Risk. The number of CARs has increased over time because where there was previously little or no wildfire risk, there is increased commercial and residential development and more people living in close proximity to wildland areas. Also, some CARs that had a lower risk designation in the past are now at higher risk.

Table 3.1. Wildfire Threats and USDA Forest Service National Themes.

Wildfire Threats	National Themes
Wildfires threaten homes and lives.	2.1, 3.3
Wildfires destroy native plants, ecosystems, and forests and deprive native animals of their habitat.	1.1, 1.2, 2.2
Wildfires cause soil erosion that pollutes and negatively affects the ocean and reefs.	3.1, 3.5
Wildfires increase the spread of invasive plants that are highly flammable and adapted to fire.	2.1, 2.2
Wildfires adversely affect the health of Hawaiʻi's watersheds.	3.1

The wildland areas in the WUI comprise vast tracts of land that were once used and maintained for agricultural purposes, but are now fallow and dominated by highly fire-prone invasive grasses. In addition to being a threat to the communities, wildfires in the WUI are carried rapidly by these invasive grasses into forested areas, putting threatened and endangered plant and animal species at risk (*see "Threats to Native Biodiversity," below*). Additionally, the Hawaiʻi Wildfire Management Organization (HWMO) has completed hazard assessments for every community in the state. These assessments are another tool that provides communities, decision makers, fire responders, and natural resource managers with a more thorough understanding of wildfire hazards.[3]



Map 3.1. Communities at Risk from Wildfire and the Wildland-Urban Interface.

Threats to Native Biodiversity

The State of Hawaiʻi is the most geographically isolated island chain on earth, home to plants and animals found nowhere else in the world. Approximately 90% of Hawaiʻi's 10,000 native species are endemic, with some species being endemic to just one island or to a narrow mountain range, which makes them more vulnerable to extinctions after large-scale fires.[4] For example, the endangered *palila* (*Loxioides bailleui*) is dependent on the *mamane* forest on Mauna Kea for food and shelter. Prolonged drought conditions on Mauna Kea have already contributed to the decline of *palila,* and a large fire under drought conditions could sweep through the core habitat and core population of *palila,* leading to the extinction of this species.[5]

According to local biologists, many native plant and animal species are only one wildfire away from extinction.[1] The wildfire in Nānākuli, in May 2005, burned more than a third of the Nānākuli Forest Reserve on Oʻahu and destroyed seven out of the eight individuals of the endangered Hawaiian gardenia (*Gardenia brighamii*) known to occur on Oʻahu. For plant species with such narrow ranges, even if seed stock were still available, the necessary habitat may not be available after a wildfire. *Mao hau hele* (*Hibiscus brackenridgei*), with fewer than 60 individuals in the wild, is another plant species believed to be directly threatened by wildfires in Hawaiʻi.

Impacts on Watersheds, Groundwater, and Coral Reef Ecosystems

In Hawaiʻi water is the most precious resource, and healthy forests are essential for maintaining water quality and quantity. By destroying forests, wildfires directly degrade our watersheds. Almost all of Hawaiʻi's public water systems are supplied by artesian wells, which rely on groundwater aquifers. Wildfires destroy vegetation in watersheds and diminish their capacity to absorb rainfall and fog drip, which replenish the groundwater aquifers.

Watersheds on all islands are subject to frequent tropical downpours, brief but intense events that can quickly cause erosion and landslides. When such heavy rainfall follows a wildfire event, it affects not just the *mauka* burned areas, but *makai* resources as well. Soil erosion and landslides lead to increased sediment deposits in streams, wetlands, and the nearshore zone. This sedimentation impedes the capacity of these systems to function properly. It also damages coral reef ecosystems that are vital economic, cultural, and subsistence resources for local residents. For example, between 1988 and 1998, the island of Molokaʻi experienced three wildfires that damaged more than 10,000 acres on the island. All three wildfires took place on mountain slopes where runoff is channeled directly to the longest continuous reef in the United States. In addition to deteriorating the health of the reef, the soil erosion and sedimentation caused stress on local food supplies, which affected residents who rely on nearshore fishing for sustenance.

Another recent example that illustrates the *mauka* to *makai* impact of fires is the wildfire that occurred in August 2015 in Kawaihae. Over 4,500 acres burned in this wildfire. Heavy rainfall following this wildfire washed large amounts of ash, soil, and flood debris, such as stumps and branches of burned vegetation, into the Kawaihae harbor (Figure 3.1) and Mau‘umae beach, obstructing fishing and smothering coral reefs.[3]

Figure 3.1. Ash and soil deposition in Kawaihae harbor after heavy rains that followed a wildfire in August 2015. Photo courtesy of Hawai‘i Wildfire Management Organization.

Spread of Invasive Fire-Adapted Species

Wildfires in Hawai‘i significantly contribute to the spread of fire-adapted invasive species. As discussed above under "*Wildfire and Fuel Loading Cycle*," invasive fire-prone grasses readily invade forests. The dry, dense biomass of these grasses increase fuel loads, ignite easily, and carry fire quickly over large areas, particularly in windy conditions, thereby increasing the frequency and intensity of fires in forests. With each subsequent fire, invasive fire-adapted species proliferate, displacing native vegetation. Post-fire reduction in soil moisture also makes it more difficult for native plants (in subsurface seed banks) to germinate and recolonize these arid areas. This wildfire/invasive plant cycle perpetuates the spread of opportunistic, fire-adapted invasive species.

Trends

Human-Caused Ignitions

An overwhelming majority of wildfires in Hawai‘i are caused by arson or human error. Human error–type causes include errant fireworks, ignited trash, cooking accidents, vehicle sparks, and agricultural fires that get out of control in the WUI. The WUI is the zone where structures and other human development meet and intermingle with undeveloped wildland or vegetative fuels. Thus, human error, combined with the spread of invasive fire-adapted grasses, shrubs, and trees, has led to an increase in wildfires across the islands.

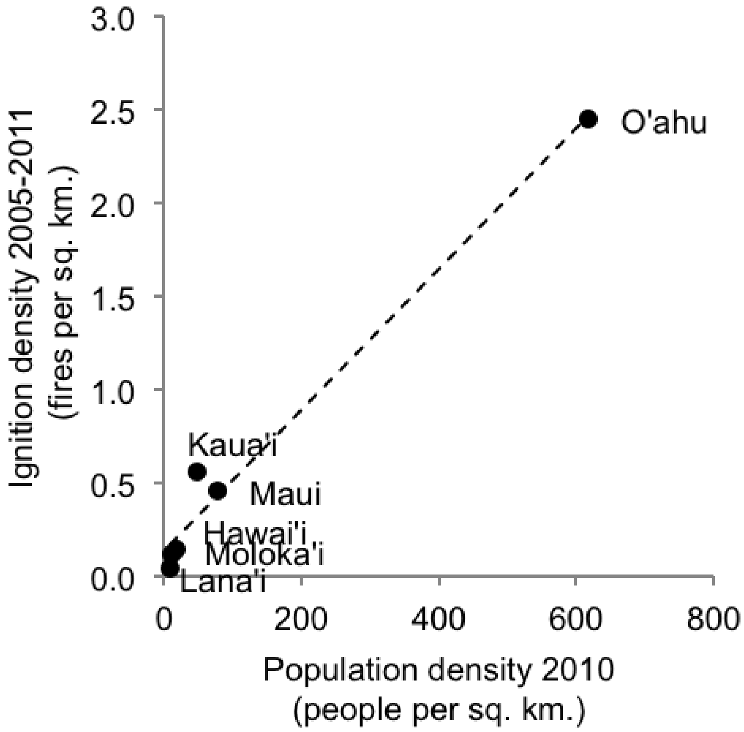


Figure 3.2. There is a strong correlation (Pearson's *P* = 0.99) between population density per island (from 2010 U.S. Census) and the total ignitions per square kilometer during 2005–2011 (*n* = 7,054). The overall pattern remains intact when O'ahu is removed from the analysis, although the correlation is slightly weaker (Pearson's *P* = 0.86). Figure obtained from Trauernicht et al. 2015.[6]

There is a strong positive correlation between frequency of ignition and human population across the islands[6] (Figure 3.2). The leeward portions of the Main Hawaiian Islands and mountain ranges, which typically receive less rain than other parts of the islands, are particularly susceptible to wildfires and have experienced an increase in the number and severity of wildfires. Human-caused wildfires that become uncontrolled in the WUI, especially in residential areas near native ecosystems and forested watersheds, are the primary fire-related concern of natural resource managers. In 2014, a human-caused wildfire that started near Makakilo on Oʻahu threatened homes and moved toward valuable conservation areas.

Wildfire and Fuel Loading Cycle

Developed areas have high ignition rates, but most areas burned are located in the dry non-native grasslands and shrublands that compose 24% of Hawaiʻi's total land cover and currently are the state's most extensive vegetation type.[6] These dry grassland areas mostly comprise fire-prone species such as guinea grass (*Megathyrsus maximus*), buffel grass (*Cenchrus ciliaris*), fountain grass (*Pennisetum setaceum),* and molasses grass (*Melinis minutiflora*). Monotypic stands of grasses create fine continuous fuel loads that ignite easily and carry fire rapidly, putting not just human safety, but the state's watersheds and native ecosystems, at risk (Figure 3.3). These grasses readily invade forests, thereby increasing the fuel loads and the risk of fire in systems that were relatively more fire resistant. After each fire event in the forest, the fire-adapted grasses grow more vigorously, thereby further displacing native plants not adapted to fire and converting forested areas to grasslands dominated by invasive grasses.[7] Removal of grazing ungulate species can also contribute to higher fuel loads.

Figure 3.3. Wildfires like this one on Maui are occurring with increasing frequency, in large part because of the introduction of non-native fire-adapted grass species that convert the land from forest. They threaten human lives and property, affect watershed function, destroy habitat for native species, and contribute to non-point source pollution. Photo courtesy of Pacific Disaster Center.

Fountain grass is perhaps the best example of this cycle. Introduced to Hawai‘i as an ornamental plant nearly a century ago, fountain grass is rapidly spreading throughout the islands. During a wildfire, most of the aboveground portion of the grass is burned, including a highly flammable seed head. The seeds are dispersed by windy conditions that occur during wildfires. Fountain grass roots, which can easily withstand fire, quickly regenerate during Hawai‘i's rainy winter season. The ash from the fire nourishes the fountain grass rhizomes and provides nutrients for the newly sprouting seeds. Thus, the range of fountain grass spreads into native habitats, preventing native species regeneration and converting the forest to grasslands.

Climate Change and Wildfire

In Hawai‘i, wildfire has also been correlated to drought conditions; wildfire history data show an increase in ignition and the areas burned during the warmer drier months of summer.[8] Climate change models of rainfall for the Hawaiian Islands through the remainder of this century predict, on average, a decrease in rainfall and reduced availability of freshwater resources.[8] The models predict that most areas will have a decrease in wet-season rainfall, with the exception of the trade wind–dominated wet regions along and above the eastern slopes of the mountains, which are expected to see a slight increase or remain stable in rainfall amounts. The leeward, climatically dry areas of the islands and mountain ranges are predicted to have drier than normal conditions during the wet and dry season. Based on these patterns, climate change is predicted to exacerbate drought conditions in Hawaiʻi, thereby increasing the risk of wildfire.

Land Use and Population Growth

Land use and population growth trends continue to be a concern for fire protection agencies. In Hawaiʻi, wildfire risk reduction approaches focus largely on voluntary mitigation measures for existing communities. Yet, land use planners and policymakers who determine where and how growth occurs play an important role in safeguarding Hawaiʻi's emerging communities from wildfires. Planning and regulatory tools, including land use laws, subdivision design regulations, home ignition zone ordinances, and building codes, can be used to provide better wildfire protection for new residential development. Growth is occurring in some of the driest parts of Oʻahu, and development is being allowed to sprawl beyond the primary urban center.[9] This trend is not limited to Oʻahu. By 2030, over a third of the state's population will be on the neighbor islands.[10] Risk reduction for new communities can be achieved by forming a wildfire planning policy that aligns land use and planning decisions with safe growth.

Present Conditions

Hawaiʻi comprises approximately 4.1 million acres of land.[11] As designated by the State of Hawaiʻi Land Use Commission, land is zoned as agriculture, conservation, rural, and urban.

DOFAW's Fire Protection Plan

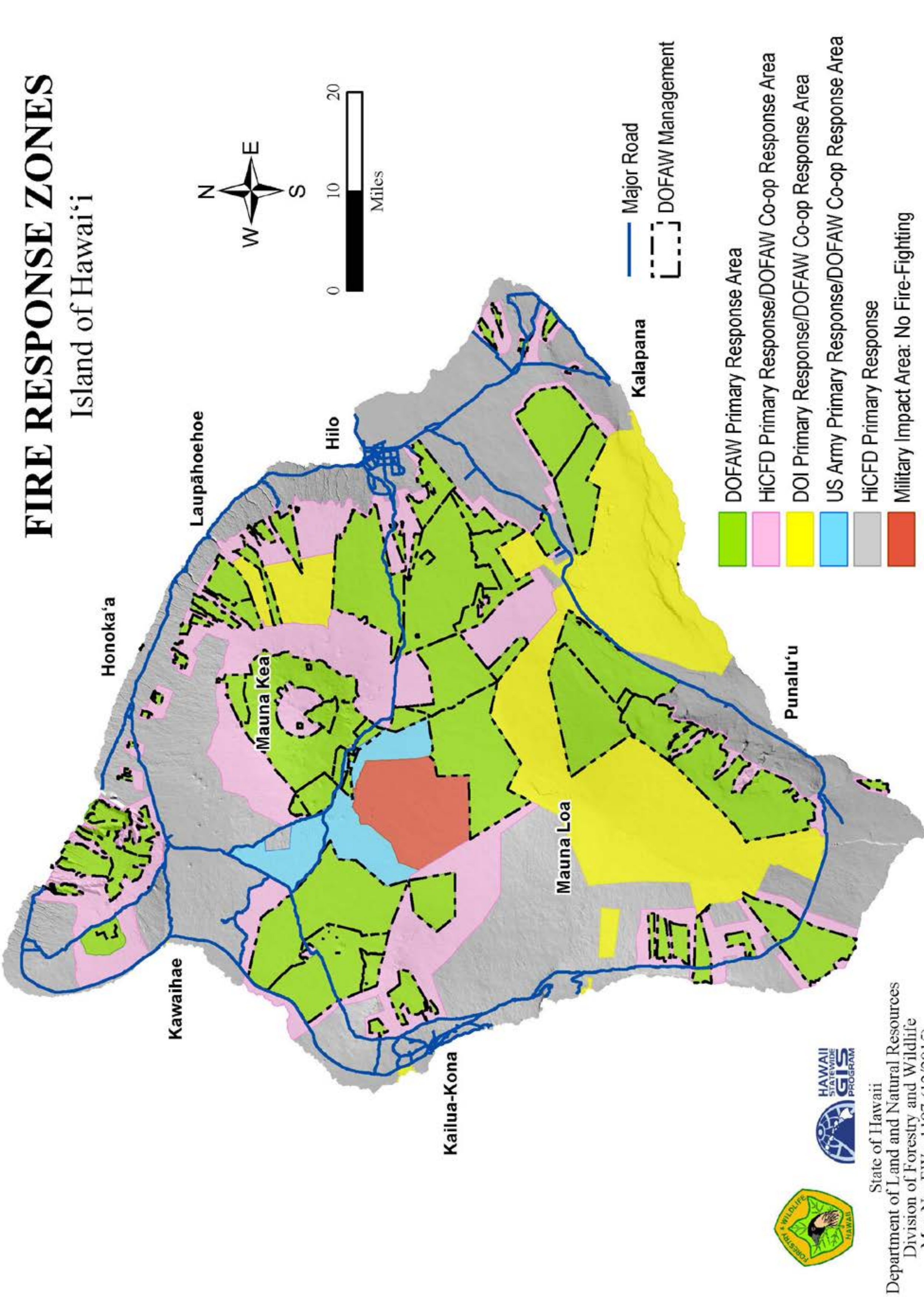
DOFAW has developed a 5-year (2014–2018) Fire Protection Plan[2] that addresses the uniqueness of the fire situation in Hawaiʻi and outlines initiatives for DOFAW to undertake to help reduce the negative impacts of wildfires on native ecosystems, forests, and watersheds, as well as the threatened rare habitats near them. This plan addresses specific objectives and action items for the following overarching goals:

1. Prevention
    a. Reduce the threat from wildfires to native ecosystems, forests, watersheds, and threatened and endangered species as well as communities within WUI areas through established fire prevention programs.
2. Pre-suppression
    a. Conduct basic firefighting and specialized emergency management training statewide; collaborate with other fire agencies in Hawaiʻi and the U.S. mainland in the development and use of joint training, educational, and leadership opportunities.

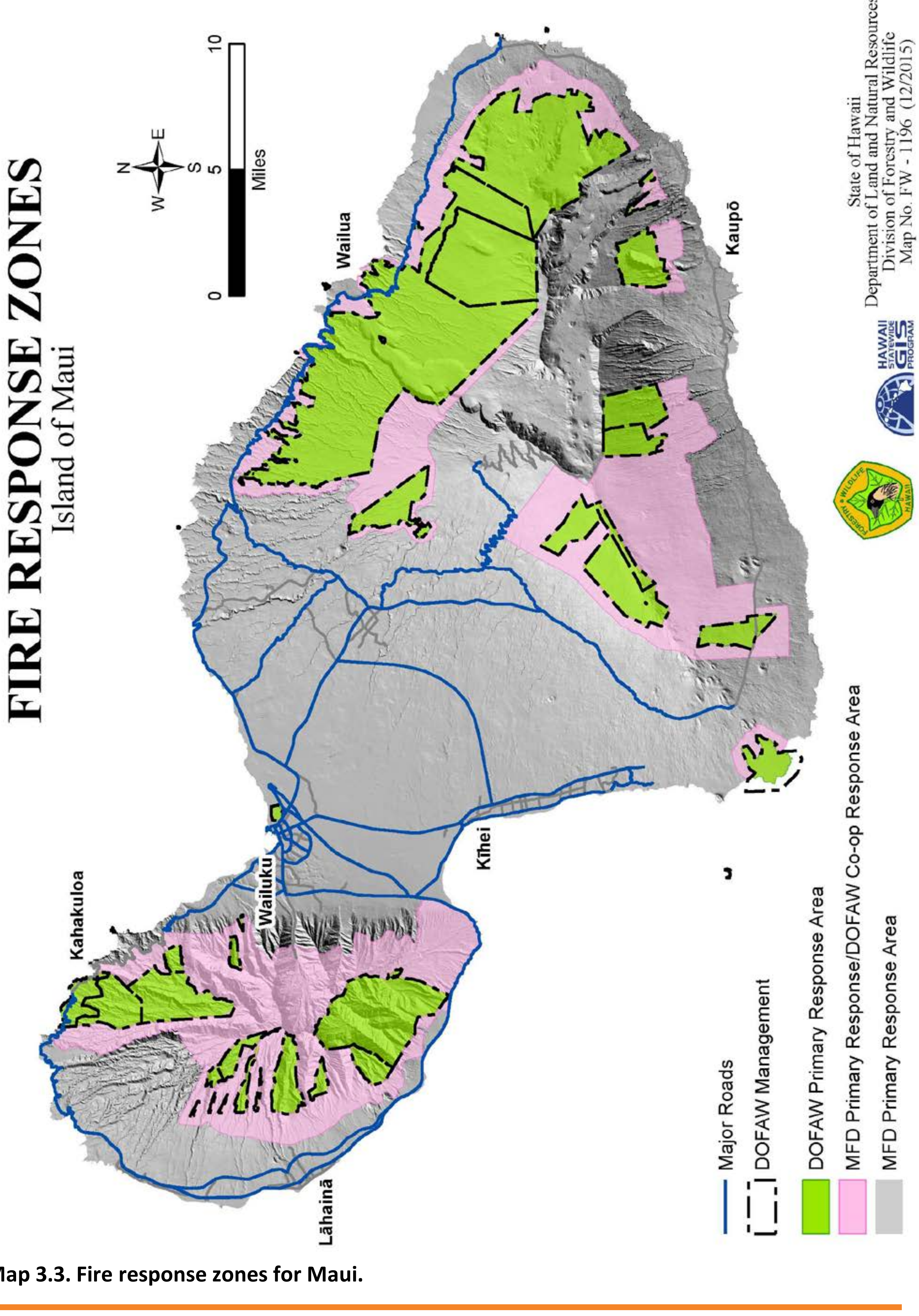
   b. Adequately equip state and county firefighting agencies that provide wildland fire protection for non-federal wildlands and rural communities and areas.
   c. Mitigate the impacts of wildfires on natural and built environments through fuel assessment, modeling, reduction, and management.
   d. Improve the fire data management system through updated technology in order to obtain necessary data to support fire management projects.
3. Suppression
   a. Improve fire response capabilities by securing adequate and expeditious funding to conduct suppression activities.
4. Post-Fire
   a. Reduce risk to the public's health, safety, and welfare as well as to natural resources from post-fire effects by developing a statewide strategy for the stabilization, rehabilitation, and recovery of burned areas.
5. Other
   a. Form a comprehensive approach to provide fire protection for the state through the establishment of dedicated fire crews at each DOFAW branch level to concentrate on all aspects of fire management, including fire prevention, pre-suppression, suppression, and post-fire emergency response and long-term rehabilitation and recovery activities.

Fire Response Zones

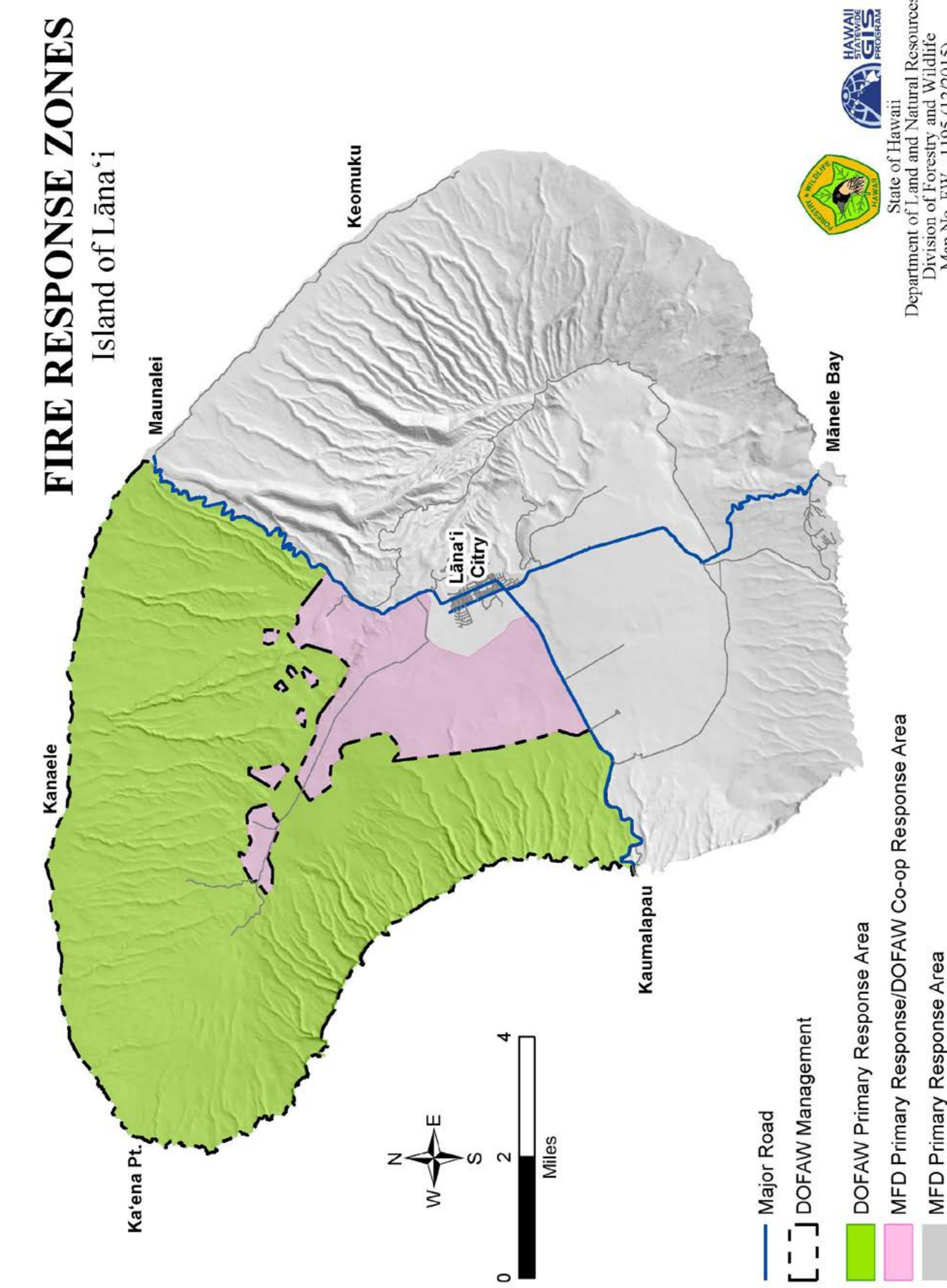
DOFAW has established formal agreements with all county and federal land management agencies for responding to wildland fires. Through this process, DOFAW's response to fire varies based on whether the fire is on lands within DOFAW's jurisdiction, whether it is adjacent to DOFAW's jurisdiction, or whether it is beyond DOFAW's jurisdiction.[2] Maps 3.2 to 3.7 depict these fire response zones. DOFAW's jurisdiction (green areas on the map) include all lands within its control. Fires in these areas require an immediate response by DOFAW personnel. In adjacent lands (shown in pink), DOFAW can respond mutually with the initial responding agency (county or federal fire department) according to the terms of agreements with those agencies. Availability of resources and whether or not the fire is threatening DOFAW's jurisdictional areas are taken into consideration when responding to fires in the pink area. Fires in areas beyond DOFAW's jurisdiction where no formal agreement exists (white areas) require additional layer of decision making. This is because wildfires in these areas do not affect DOFAW's programs or projects. DOFAW would respond only in extraordinary circumstances and only if certain conditions occur, such as extreme threats to public safety, local resources being already fully committed, and extreme fire behavior. In such an event, the request for DOFAW's assistance must go through the appropriate channels before DOFAW can respond, if state resources are available.



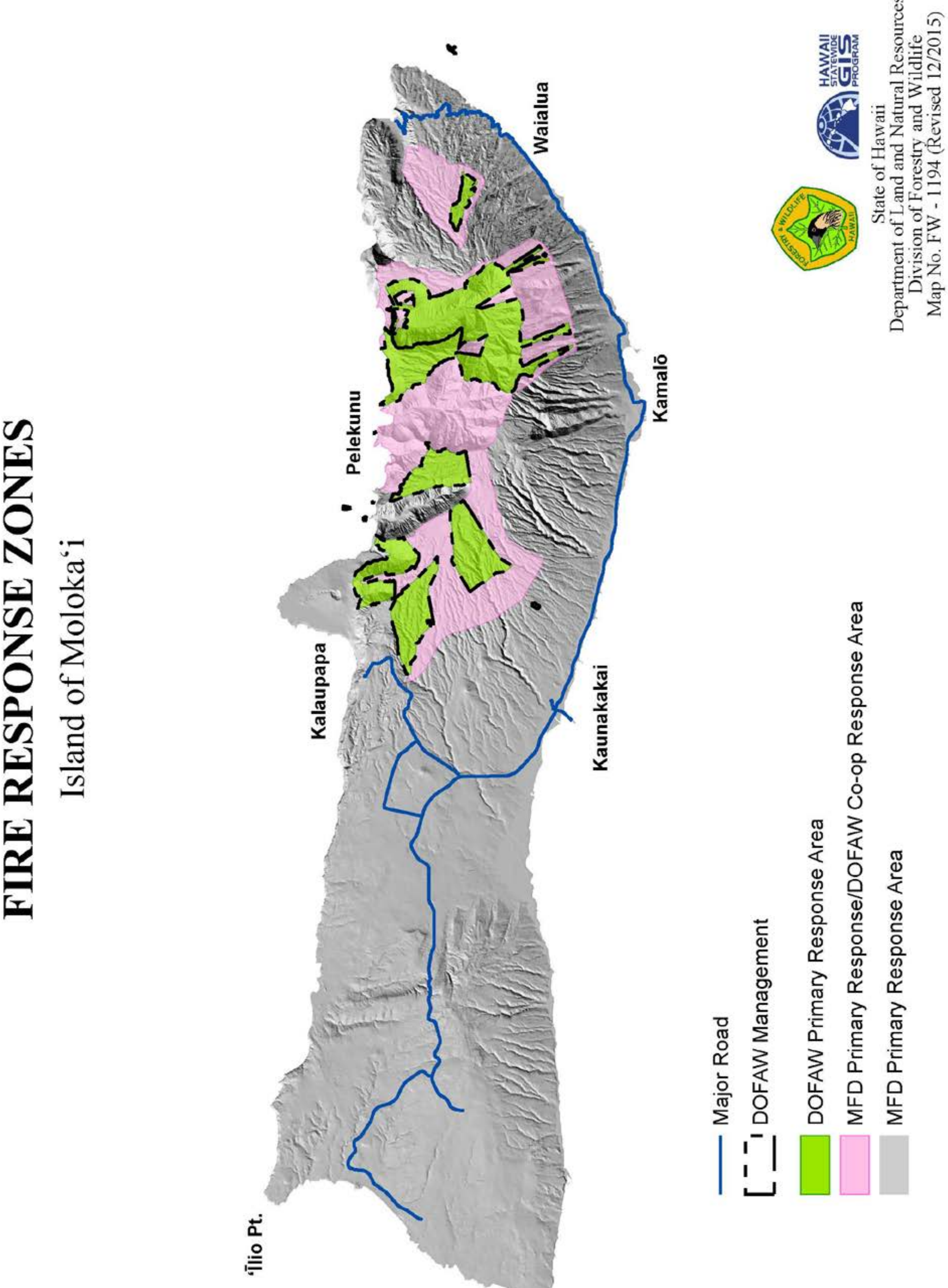
Map 3.2. Fire response zones for the Island of Hawai'i.



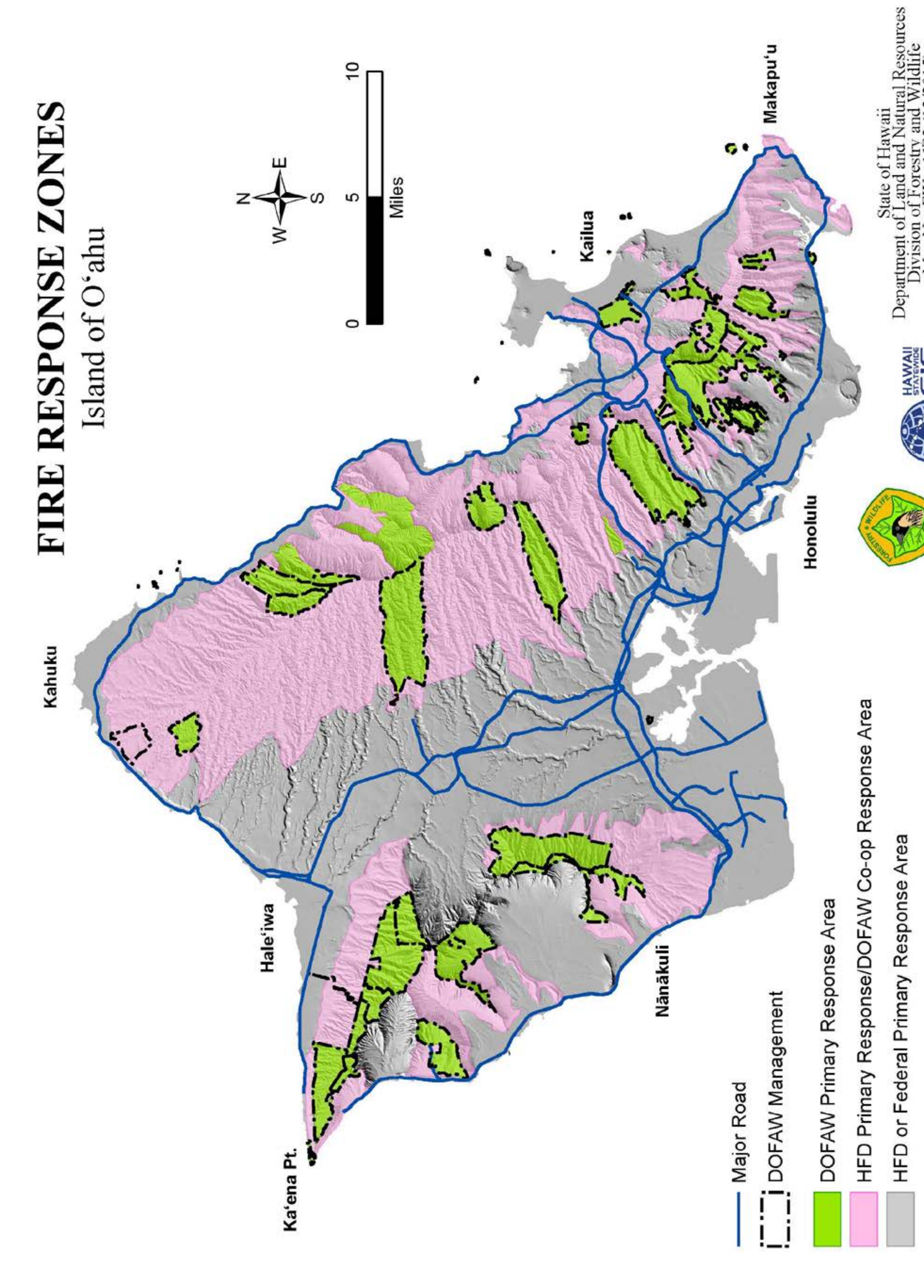
Map 3.3. Fire response zones for Maui.



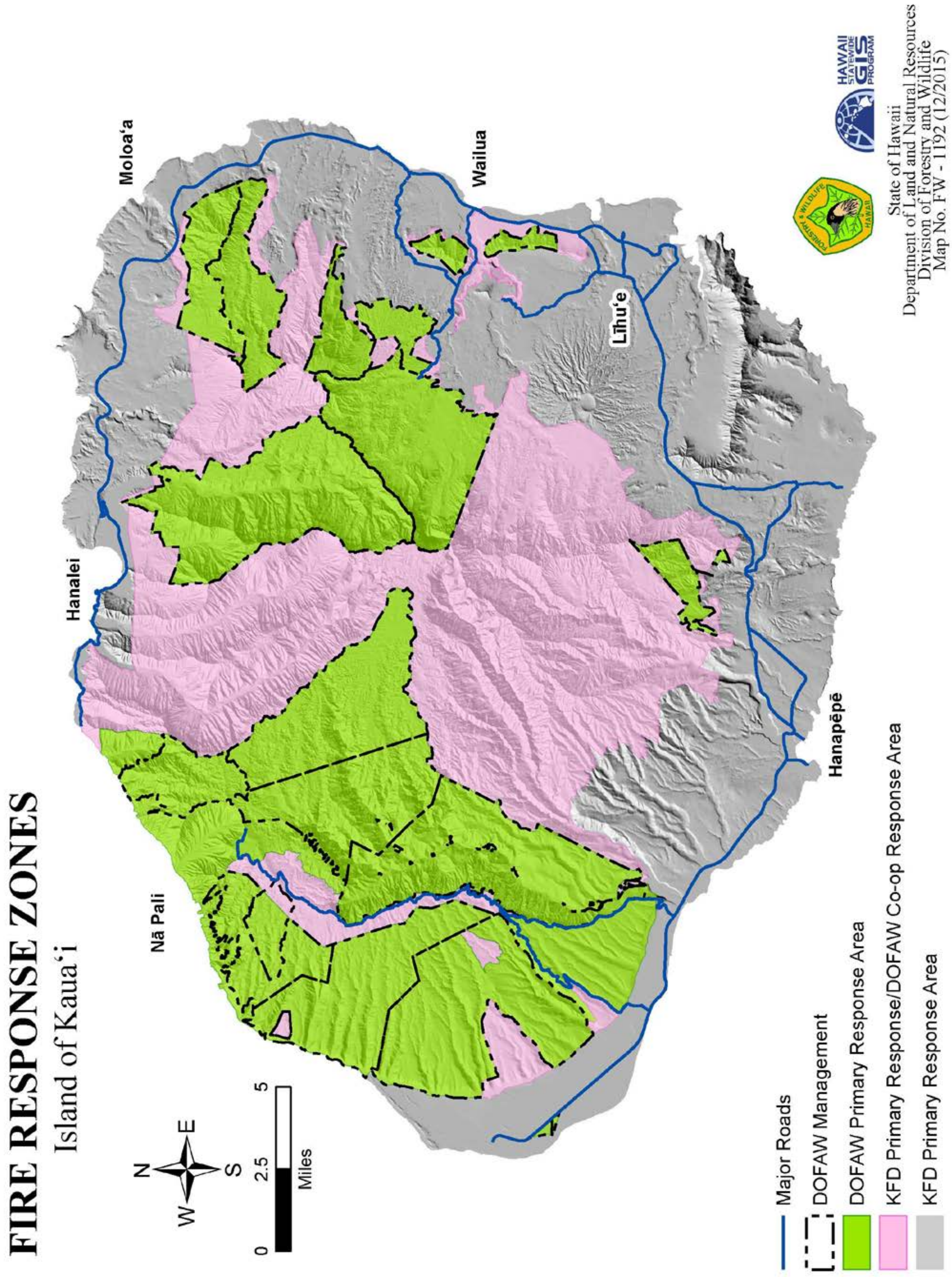
Map 3.4. Fire response zones for Lānaʻi.



Map 3.5. Fire response zones for Molokaʻi.



Map 3.6. Fire response zones for O'ahu.



Map 3.7. Fire response zones for Kauaʻi.

Funding

State and federal budget constraints on fire pre-suppression and suppression activities negatively affect the response time needed to contain fires and can drain resources from other mandated DOFAW programs. Sources of funding include state general and capital improvement project (CIP) funds, FS's State Fire Assistance (SFA) and Volunteer Fire Assistance (VFA) grant programs, and FS's WUI programs.

DOFAW depends heavily on the Federal Excess Personal Property program for fire equipment. However, much of this borrowed equipment has become outdated and expensive to repair. The state legislature recently budgeted funds for the 2016–2017 biennium for updating some of DOFAW's outdated firefighting equipment, but additional resources are needed.

DOFAW also relies on technical and financial assistance from Region 5 of FS through the SFA and VFA programs. SFA funds provide for all-risk management training, including ICS; creation and maintenance of fuel breaks; education and prevention efforts; radio equipment; Remote Automated Weather Station maintenance; and supplies such as personal protective equipment. FS Region 5 also provides important technical assistance by allowing DOFAW teams to shadow ICS teams on mainland fires.

The VFA program is a key component in engaging the county fire departments to provide continued fire protection to rural communities. Funds from this program currently supplement efforts in the County of Hawai‘i, the only county with a volunteer program, to equip, train, and organize its personnel to meet agency objectives in rural community fire protection.

FS's WUI program provides funds for fuels reduction, planning, and educational projects that target the WUI. This is a well-funded, competitive program that requires Hawai‘i to compete with other Western states. Improved coordination and project identification are needed to be more successful in competing for WUI dollars for Hawai‘i.

The Land Fire Protection Law, Chapter 185, of the Hawai‘i Revised Statutes (HRS) mandates the Department of Land and Natural Resources (DLNR) to "take measures for the prevention, control, and extinguishment of wildland fires within forest reserves, public hunting areas, wildlife and plant sanctuaries, and natural area reserves."[12] This area totals 1,689,825 acres. DLNR is also statutorily required to cooperate with established county and federal government fire agencies for suppression of wildfires on lands not within DOFAW jurisdiction, which, when combined with its management areas, total 3,360,000 acres statewide. A Firefighter's Contingency Fund is established pursuant to the Land Fire Protection Law, Chapter 185, HRS, for fire suppression, although the legislature has not budgeted anything for the fund in recent years and suppression costs are taken off of the top of DOFAW's budget. Over the past 50 years, the number of wildfires larger than 100 acres has increased in Hawai‘i.[13] Furthermore, the percentage of land area burned per year in Hawai‘i exceeds the national average, and in some years surpasses the other Western states.[13] The increase in the number and size of wildfires makes the Firefighter’s Contingency Fund a funding priority for DOFAW.

Federal Emergency Management Agency (FEMA) Fire Management Assistance Grants (FMAGs) can provide financial support when very specific conditions are met. Increased collaboration with counties in tracking costs, better coordination with State Civil Defense, and internal education on the application process are needed to better take advantage of FMAG funds.

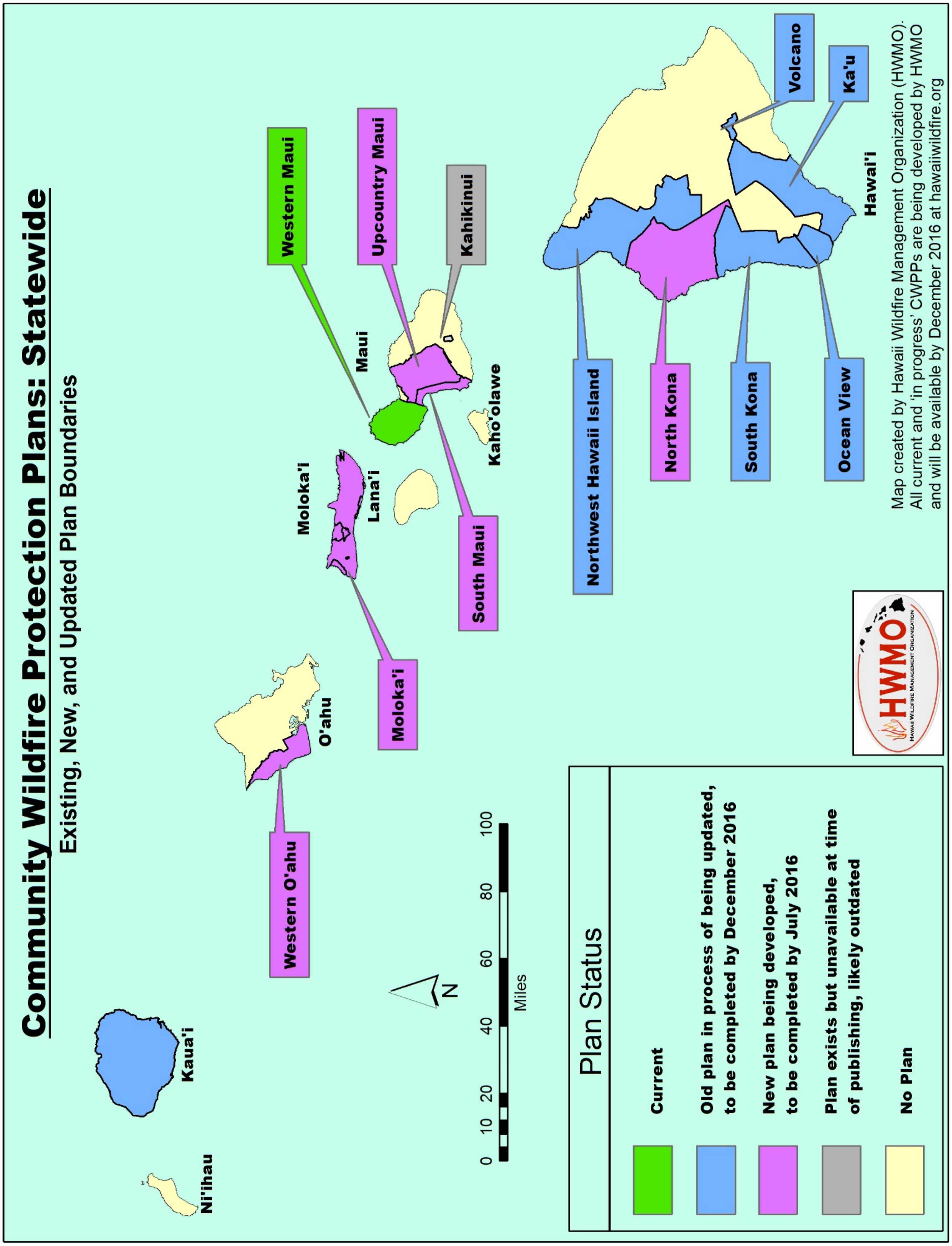
In co-op response areas where DOFAW has established agreements, compensation of costs is sometimes available. However, when the fire occurs on the extensive holdings of Department of Hawaiian Homelands, the Department of Agriculture, or Office of Hawaiian Affairs, DOFAW and/or the county fire agency must absorb all costs. Providing mechanisms for these agencies to pay costs related to fire response on their lands would help alleviate resource shortages at DOFAW.

Community Wildfire Protection Plans

Wildfires in the WUI pose a tremendous risk to life, property, and infrastructure. Communities are encouraged to develop Community Wildfire Protection Plans (CWPPs) by the Healthy Forest Restoration Act of 2003. The development of CWPPs involves collaboration among communities and government agencies, resulting in the assessment of local wildfire hazards, identification of a community’s wildfire risk, and prioritization of fuel mitigation projects. Having CWPPs allows communities to be eligible for certain federal funding.

Currently, CWPPs exist for eight areas on three islands: Western Maui, Kahikinui Maui, Kaua‘i (the entire island), Northwest Hawai‘i Island (north and south Kohala), South Kona, Volcano, Ka‘u, and Ocean View (*see Map 3.8.*). Some of these CWPPs are outdated or have lost momentum within the community. To address this, CWPPs for the following areas are being updated by HWMO: Northwest Hawai‘i Island, South Kona, Ocean View, Volcano, Ka‘u, and Kaua‘i. Additionally, new CWPPs are being developed (anticipated completion mid- to late 2016) for the following areas: Upcountry Maui, South Maui, Moloka‘i, West O‘ahu, and North Kona.

CWPP stakeholders vary by island and community; however, each CWPP calls for participation from the county fire department, county civil defense agencies, and DOFAW. Other agencies that participate in the CWPP process include the National Park Service, Federal Fire Department, U.S. Army Garrison- Hawai‘i, Natural Resources Conservation Service, USFWS, and the Department of Hawaiian Homelands. Although the communities in Hawai‘i with CWPPs differ dramatically, they have similar concerns and recommended actions, some of which are described below.



Map 3.8. Areas with Community Wildfire Protection Plans.

Recommended actions from the CWPP process include:

- Improvement of roads within residential areas. Creation and/or improvement of secondary emergency access roads in residential areas where necessary.
- Creation and maintenance of a buffer zone/fuel break around residential zone and/or subdivision.
- Increased use of current reservoirs and/or installation of pre-staged static water tanks.
- Creation of dedicated landing zones for helicopters for fire suppression purposes.
- Implementation of pre-incident planning meetings between natural resource managers and fire officials to raise awareness of sensitive ecological areas.
- Fuel load reduction along highways, especially in summer months. Reduction of excessive fuel loads around individual properties.
- Community newsletter articles to increase fire-prevention awareness among homeowners. Coordination and implementation of at least one fire prevention awareness event per year.
- Identification of evacuation route roads within subdivisions. Installation of metal reflection signs showing evacuation routes within the residential areas.
- Development of a Community Emergency Operation Plan. Development to include identification of ham radio operator points of contact, training in ham radios, and purchase of equipment.
- Community Emergency Response Training for community members.
- Creation of community compost pile for local residents, and development of a green-waste dumping education program.
- Implementation of community chipping days to encourage fuel load mitigation and green waste recycling.
- Increased use of fire-resistant building materials in new residential development.
- Implementation of Firewise Communities guidelines in the planning process of new residential developments (i.e., create fuel breaks and plan for multiple means of ingress/egress).
- Increased radio communications between federal, state, and county fire response agencies.
- Updated system for estimating costs of fire damage in watersheds and other natural areas.

Communities and DOFAW partners may apply for grants through the WUI program for the development of CWPPs and for activities prioritized by the plans.

Hawaiʻi Firewise Communities Program

The national Firewise Communities program, http://www.firewise.org, serves as a valuable resource for information about reducing the threat of wildfires to communities. DOFAW engages homeowners who live in WUI areas via the Hawaiʻi Firewise Communities program, which has been active statewide since 2002. This program was born out of the national program, which is designed to encourage homeowners, community leaders, and others to take actions to protect people, property, and natural resources from the risk of wildfires before a wildfire starts. This approach emphasizes community responsibility for planning a safe community, as well as effective emergency response and individual responsibility for safer home design, construction, landscaping, and maintenance. Several communities have applied for and received National Fire Plan funding for fuel reduction projects; however, only Kohala By The Sea, a community on the leeward side of Hawaiʻi Island, is recognized as a National Firewise Community. This community received National Fire Plan grants, achieving national recognition status for 10 consecutive years. Hawaiʻi's 5-year Fire Protection Plan calls for an increased number of nationally recognized Firewise Communities through increased effort to promote the Hawaiʻi Firewise Communities program.

Priority Landscape Areas for Wildfire

Priority Landscape areas for wildfire consist of any land that has one or both of the following characteristics:

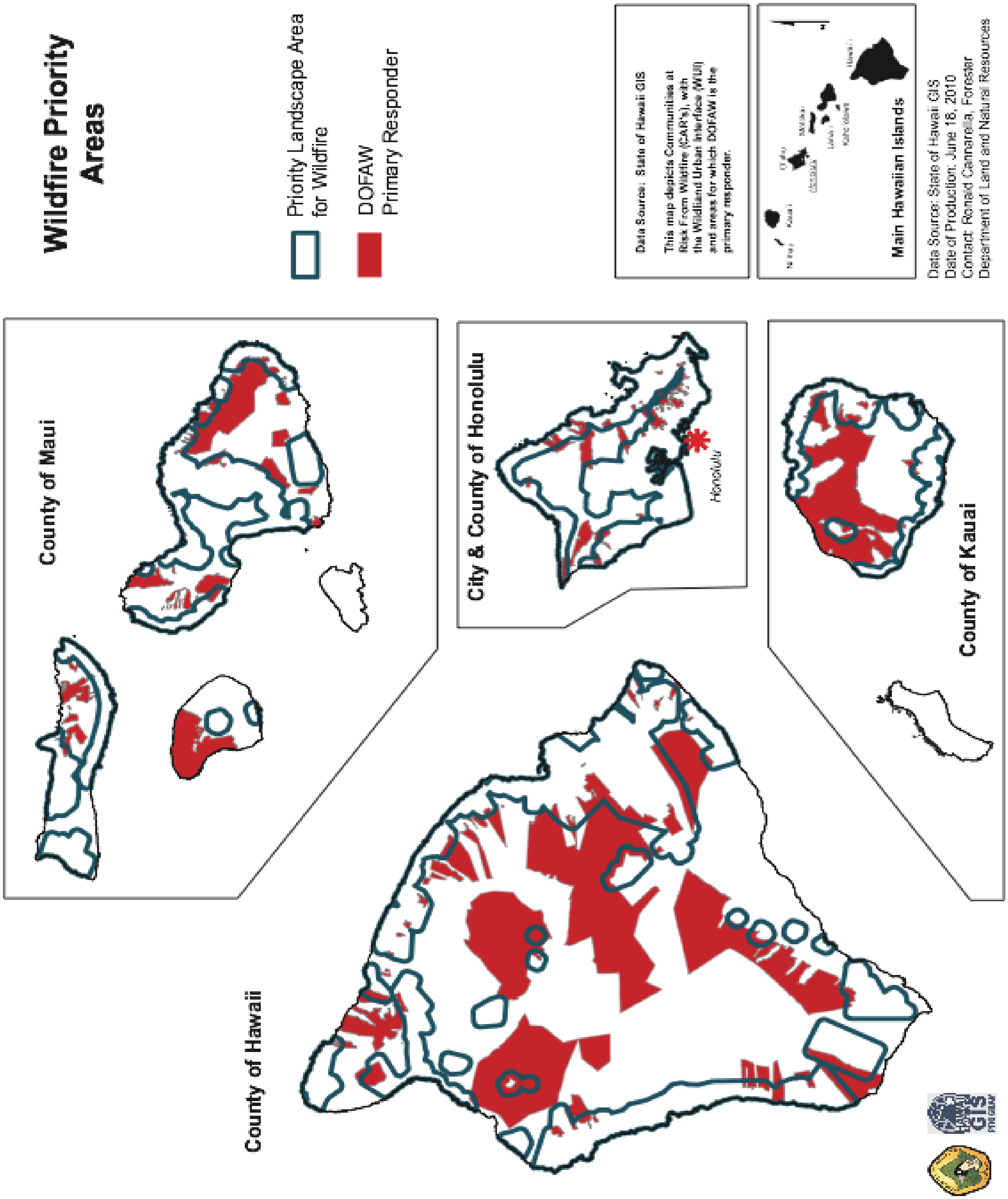
- Is a CAR in the WUI
- Is located where DOFAW is the primary responder

Please refer to Map 3.9 for the map of DOFAW's priority landscape areas for wildfire.

Data Gaps and Opportunities

To adequately address the wildfire issues in Hawaiʻi, implement the long-term strategies, pursue opportunities, and close the data gaps identified below, as well as in DOFAW's Fire Protection Plan,[2] it is imperative that DOFAW secure funds and strengthen collaborative partnerships across areas of expertise and jurisdictional boundaries.

- Work with the Hawaiʻi Legislature toward funding the Firefighter's Contingency Fund.
- Establish hand crews at DOFAW branches to focus on fire management.
- Improve coordination of fire history data and record keeping by developing a geospatial database for all DOFAW fire responses.



Map 3.9. Priority Landscape Areas for Wildfire.

- Use FS technical assistance by sending DOFAW ICS teams to the mainland to experience large forest fire responses.
- Develop maps on the distribution of fuel loads in Hawaiʻi, identify the resources they threaten, and develop risk assessments.
- Explore redefining WUI boundaries in Hawaiʻi and acquire WUI funds for priority projects.
- Maintain and improve radio system infrastructure and collaborate closely with other response entities to ensure effective communication on fire responses.
- Work with DOFAW landowner assistance programs to address wildfire risk. Address wildland fire landowner management plans and training.
- Improve modeling for the potential impacts of climate change on fire-adapted invasive species.
- Several fire behavior models based on fuel types on the mainland do not apply to Hawaiʻi—develop and improve fire behavior models specific to fuel types in Hawaiʻi.
- Develop a dedicated post-fire rehabilitation program within DOFAW. Elements of such a program could include a seedbank, plant nursery, and staff dedicated to post-fire restoration efforts.
- Through focused outreach and coordinated messaging, convey concise and reliable information to the public, as well as decision makers who influence funding and policy.
- Support the implementation and enforcement of state and county fire codes, specifically WUI codes.
- Ensure that local and statewide climate change and drought plans, policy, and initiatives address wildfire.
- Engage land use planners and policy makers who determine where and how development occurs in order to address land use and population growth trends with respect to wildfire risk.
- Hawaiʻi's wildfire risk reduction approaches are largely voluntary measures—explore regulatory tools to better protect communities and natural resources from wildfires.

Summary

Native ecosystems in Hawaiʻi are not adapted to wildfire. Other than in volcanic areas, fire is not part of the natural life cycle of native Hawaiian ecosystems, and few native species are able to regenerate after a fire.

The vast majority of wildfires are caused by arson or human error. Fires ignited in the developed areas quickly spread to the WUI, which is the zone where human development intermingles with undeveloped wildland dominated by invasive, fire-prone grasses such as guinea grass, fountain grass, and molasses grass. Monotypic grass stands in the WUI provide fine fuels, ignite easily, and carry fire rapidly, putting not just human safety but also adjacent watersheds and native ecosystems at risk. These grasses readily invade the forests, increasing fuel loads and the risk of fire in systems that previously were more fire resistant. Each fire in the forest encourages invasive, fire-adapted grasses to grow more vigorously, further displacing native plants not adapted to fire and converting forested land to grasslands. Human development sprawling beyond the urban core into the wilderness, particularly in the drier parts of the islands, is also a factor in increased risk of wildfires. Rise in temperatures and drought conditions in parts of the islands attributable to climate change are expected to exacerbate the risk of wildfires.

Wildfires threaten homes and lives; destroy native plants, ecosystems, and forests, depriving native animals of their habitat; cause soil erosion that pollutes and negatively affects the ocean and reefs; increases the spread of invasive plants that are highly flammable and adapted to fire; and adversely affects watersheds. DOFAW has identified CARs at risk from wildfires statewide based on vegetation type, climate regime, and fire history. The HWMO has completed hazard assessments for all CARs, and these assessments provide communities, decision makers, fire responders, and natural resource managers with a more thorough understanding of wildfire hazards. The Healthy Forest Restoration Act of 2003 also encourages communities to prepare CWPPs. The Hawai‘i Wildfire Management Organization, in collaboration with DOFAW, is updating old and preparing new CWPPs for communities statewide. DOFAW also engages communities through the Firewise Communities Program, a nationally funded program to take actions to protect property and natural resources from the risk of wildfires.

The mission of DOFAW’s Fire Management Program is to provide fire protection for the state Forest Reserve System, public hunting areas, wildlife and plant sanctuaries, and Natural Area Reserves. DOFAW’s 5-year (2014–2018) *Fire Protection Plan* addresses specific objectives and action items related to wildfire prevention, presuppression, and suppression; minimization of postfire effects; and other comprehensive approaches to providing fire protection. DOFAW has formal agreements with county, federal, and other land management organizations regarding how it responds to wildfires in predetermined wildfire response zones. DOFAW’s response varies based on whether the fire is within DOFAW’s jurisdiction, adjacent to DOFAW’s jurisdiction, or beyond its jurisdiction. Its response to fires outside its jurisdiction reflects the availability of resources and whether the fire is affecting DOFAW lands. In general, for DOFAW, priority landscape areas for wildfire consist of lands where DOFAW is the primary responder and/or its lands are a CAR in the WUI.

To adequately address the wildfire issues in Hawai‘i, it is important that DOFAW continue to secure funds and strengthen collaborative partnerships across areas of expertise and jurisdictional boundaries. It is also imperative that DOFAW pursue opportunities and work toward addressing data gaps, such as developing statewide maps on the distribution of fuel loads, developing fire behavior models specific to Hawai‘i, and exploring regulatory tools to better protect communities and natural resources.

Strategies for Issue 3: Wildfire

Wildfire								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Reduce the impacts of wildfires on native ecosystems and watersheds.	Forest Reserves, public hunting areas, wildlife and plant sanctuaries, Natural Area Reserves, watershed partnerships, and WUI.	Reduce erosion; improve coral reef health, wildlife habitat, native biodiversity, and water quality and quantity; reduce invasive species.	Cooperative Fire Assistance, Forest Stewardship, CREP, EQIP, Forest Health.	State civil defense, county civil defense, county fire departments, volunteer fire departments, NPS, FS, U.S. Army Garrison-Hawaii, USFWS.	DLNR Firefighter's Contingency Fund, State Fire Assistance and Volunteer Fire Assistance programs: WUI competitive grants.	Number of acres protected; number of acres of native forest protected; reduction of fire size; fire considerations incorporated into management planning documents.	1.2 2.1 2.2 3.1 3.3 3.5	1.2 1.5
2. Reduce the impacts of wildfires on communities and surrounding forest ecosystems. Engage teachers, students, community members, and planning and policy decision makers on wildfire concepts, impacts, and threat mitigation.	Communities at Risk from wildfire and the WUI.	Increase awareness to reduce human-caused wildfires, reduce need for costly fire suppression, improve cross-sector collaboration among agencies with respon-sibilities in the areas of planning, wildfire mitigation, and public safety.	Cooperative Fire Assistance, Forest Stewardship, EQIP, schools, community groups, Conservation Education and Project Learning Tree; environmental education organizations.	State Wildfire Management Organization, UH, county fire departments county civil defense, county planning and permitting departments, community associations.	State Fire Assistance; WUI competitive grants, schools, community groups, environmental education organizations.	Number of homes and structures protected; number of Firewise Communities established; number of CWPPs adopted; number of miles of firebreak constructed and maintained; reduced acres of invasive grasses and fire that cycle together.	2.1 2.2 3.3 3.6	1.2 1.4 1.5 2.2 3.1 3.2 3.3 6.2

Key:
CREP = Conservation Reserve Enhancement Program
CWPP = Community Wildfire Protection Plan
EQIP = Environmental Quality Incentive Program
DLNR = Department of Land and Natural Resources
FS = U.S. Forest Service
NPS = National Park Service
UH = University of Hawai'i
USFWS = U.S. Fish and Wildlife Service
WUI = Wildland-Urban Interface

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Issue 4: Urban and Community Forestry

Overview

In an article titled "High Heat" in *National Geographic* magazine, the authors stated that "the world will feel different in 2100, when average temperatures will have risen by several degrees. Every kind of landscape that humans inhabit will be affected: urban, suburban, rural, mountains, plains, and coasts."[1] The article discusses how trees in urban areas can help by providing shade and lowering surface temperatures of walls and buildings by more than 23˚F. Reflective "cool roofs" can block up to 65% of the sun's radiation. Reflective and permeable pavements in urban areas can lower surface summer temperatures that otherwise can reach close to 108˚F.

Trees are a critical component of our cities and a dynamic resource. Research indicates that healthy trees can lessen impacts associated with the built environment by reducing stormwater runoff, energy consumption, heat islands, and air pollutants. Trees improve urban life, making Hawaiʻi a more enjoyable place to live, work, and play, while mitigating the city's environmental impact.[2]

Trees make a city livable. As Geoffrey Donovan, a forester at the Pacific Northwest Research Center, has stated, "There is something fundamental about the human condition and exposure to the natural environment; cities make that problematic, and perhaps trees are one way of allowing us to survive in these environments."[3] The Hawaiian urban landscape is a complex mosaic of urban land uses, agriculture, undeveloped upland areas, invasive species, social geographies, recreation, and tourism—all competing in an island landscape.[4]

Figure 4.1. The 2015 Kaulunani staff and council members, October 2015.

Hawaiʻi's Urban and Community Forestry Program, Kaulunani (Figure 4.1), is funded by the U.S. Department of Agriculture (USDA) Forest Service (FS) and the Division of Forestry and Wildlife (DOFAW) in

Hawaiʻi. The program is managed in partnership with DOFAW and the non-profit (501C3) Smart Trees Pacific (STP), which delivers the Kaulunani program. The Kaulunani Council acts in an advisory capacity to DOFAW and the Kaulunani program. The council is a diverse group of professionals representing a broad sector of fields relating to urban forestry, including arboriculture, planning, forestry, landscape architecture, environmental law, and landscape industry.

Since its inception 1992, Kaulunani has awarded more than $2.6 million to more than 400 organizations across the state in the form of cost-share grants, which were matched with $7.1 million in cash and in-kind contributions. The key to the success of this program is the blend of partners, people, and projects. Kaulunani found that important indicators of successful urban forestry projects include advanced planning, strong leadership, volunteer commitment, community involvement, interagency partnership, appropriate plant selection, proper horticultural procedures and maintenance, and a demonstrated commitment to social and environmental change.

> ***Kaulunani's Mission Statement***
>
> *Balance the urban and natural environment by encouraging, empowering and equipping the people of Hawaiʻi to Mālama the trees in our ʻāina.*

Population and Land Use

Hawaiʻi encompasses approximately 4.1 million acres distributed over the Main Hawaiian Islands and the unpopulated Northwestern Hawaiian Islands.[5] Of this acreage, 48% is designated as conservation, 47% as agriculture, 5% as urban, and less than 0.5% as rural. The total resident population[i] and de facto population[ii] of Hawaiʻi, as of July 1, 2014, were approximately 1.4 million and 1.5 million, respectively.[5] Hawaiʻi's resident population of nearly 1 million is concentrated on the island of Oʻahu, particularly in the Honolulu urban core. The other islands are primarily composed of small towns and rural communities.

Hawaiʻi's Urban Realm

Urban forestry is about tree management in any area influenced and used by the urban population.[6] Urban forest stewardship is critical to our forests and reefs.[7] Our islands' ecosystems are more dramatically and intricately connected than those on continents. Because of

[i] The resident population is defined as the number of persons whose usual place of residence is in an area, regardless of physical location, on the estimate or census date. It includes military personnel stationed or homeported in the area and residents temporarily absent, but excludes visitors present.

[ii] The de facto population is defined as the number of persons physically present in an area, regardless of military status or usual place of residence. It includes visitors present but excludes residents temporarily absent, both calculated as an average daily census.

these tight connections, integrating urban forest issues into landscape and island-wide management efforts is necessary.

Urban forestry issues span from the mountains to the sea and include watersheds, stormwater runoff, sea level rise, cooling, tree care, fire and forest health, improved management of the trees, support for enforced ordinances to improve the health of the urban canopy, and education to citizens and government about the value of our urban trees.

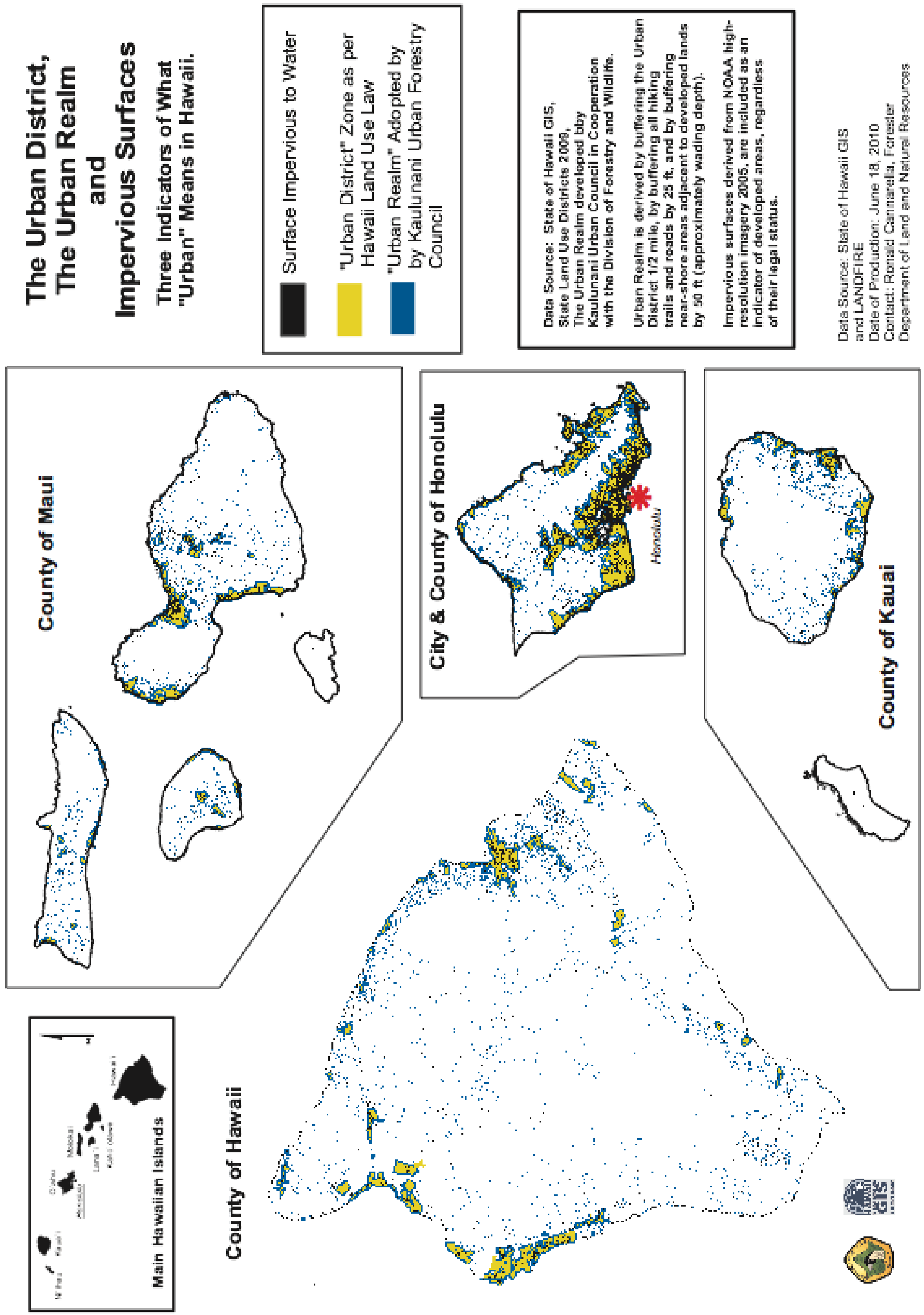
Map 4.1 shows the impervious surfaces, including roads and buildings, and the urban realm where people live, work, and play and where urban forestry is mainly focused. The proximity of urban areas to agricultural areas and to *makai* resources (Map 4.2) is the main reason why urban forestry must be considered when prioritizing land management of upland and lowland resources of the island.

Benefits

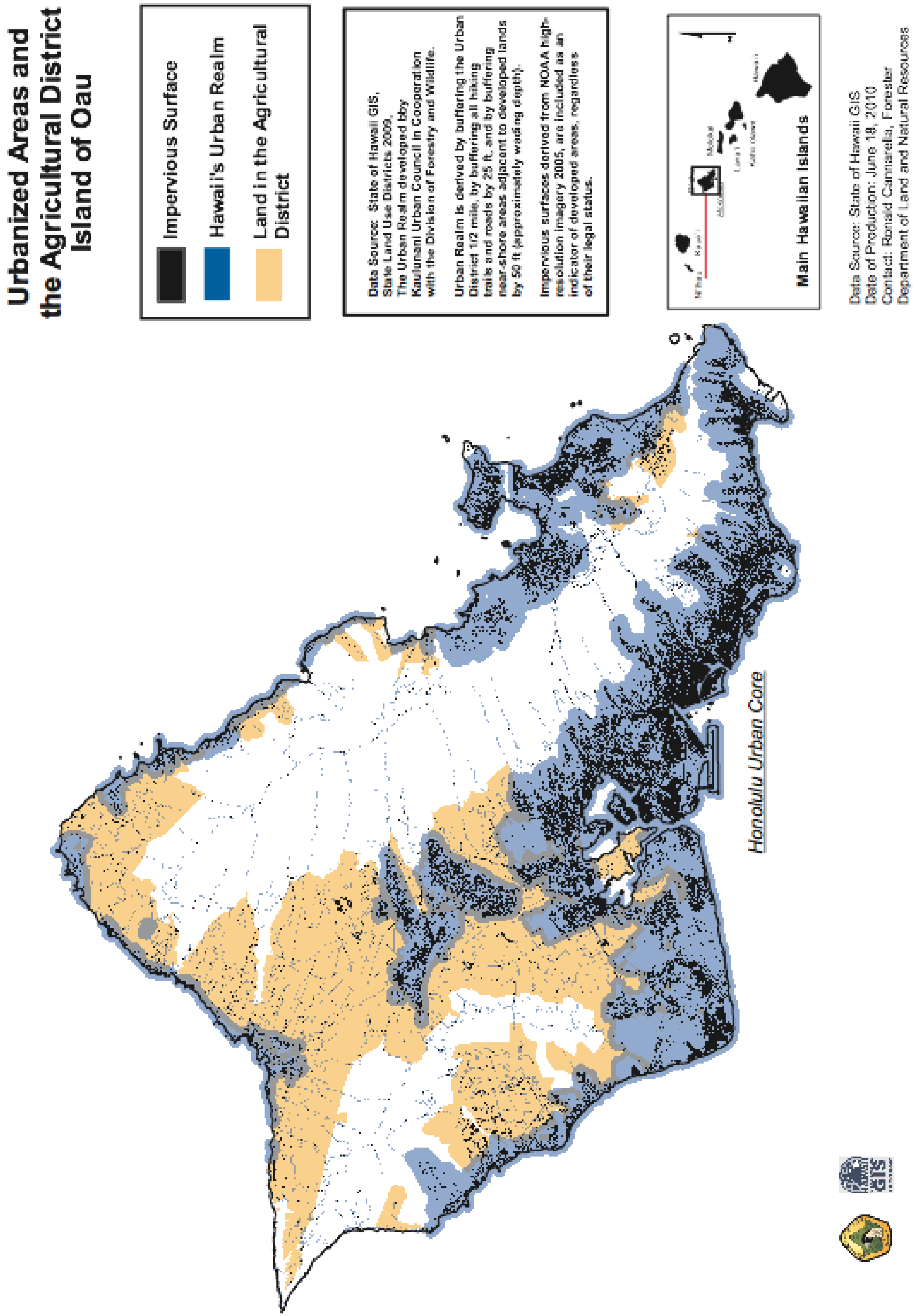
Urban forests, whether public or private, offer a multitude of benefits. Research indicates that healthy trees can decrease negative impacts of urbanization while improving human health. Trees and plants buffer wind and noise and generally are recognized as positive influences on health and well-being. Trees are one of the natural world’s most efficient multi-taskers. Trees can reduce energy costs, cool “heat islands” by providing shade, sequester carbon, trap pollutants, and slow storm runoff. The right tree in the right place can provide beauty, shady shelter from the sun, food, soil stabilization, increased property values, and conservation and cultural benefits.

Honolulu’s Street Trees

Hawai‘i’s urban forest is a mixture of young and mature canopies. In 2006, Kaulunani funded an assessment of Honolulu’s urban trees using the *Street Tree Resource Analysis Tool for Urban Forestry Managers* to gather baseline data on benefits of urban trees in tropical settings. Data from 43,817 street trees were analyzed by the Center for Urban Forest Research, Pacific Southwest Research Station. Hawai‘i’s urban trees were found to provide extensive environmental benefits. For example, the annual environmental benefits were calculated at $90 per tree, and each tree provides $2.98 in benefits for every $1 spent on tree care. The replacement value of urban trees was calculated at $1,665 per tree.[3] The report identified benefits such as electricity savings and climate effects, carbon storage, air pollution removal, and rain interception.



Map 4.1. The urban realm in Hawaiʻi.



Map 4.2. Map of the Island of O'ahu showing impervious surfaces, including roads and buildings; the urban realm where people live, work, and play; and the Agricultural District.

Value of a Tree in the Tropical Urban Forest

In a study called *The Value of a Tree in the Tropical Region*, researchers found that a large tree in the tropical region will provide $4,180 in environmental and other benefits over its lifetime. That is a 300% return on investment. The study states, "Over 40 years, 100 large public tropical trees' total costs are $138,160 and the total benefits are $418,440. The 40-year net benefit is $280,280."

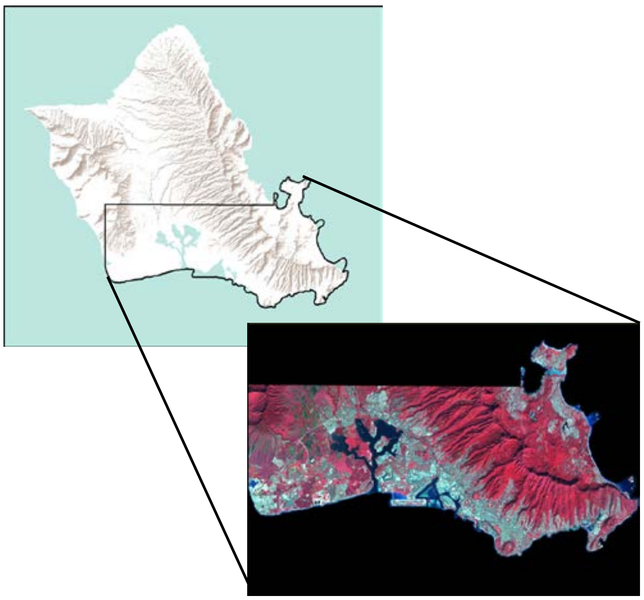


Figure 4.2. Urban tree canopy assessment in O'ahu from *Kāne'ohe* to *Kalaeloa*. Red areas indicate tree canopy cover.

In 2012, FS awarded a western competitive grant for the Hawai'i *Urban Tree Canopy Assessment* (UTC) of 250 square miles from Kāne'ohe to Kalaeloa on O'ahu (Figure 4.2). The assessment covered 15,274 acres of tree canopy, representing 20% of all land in the urban zone. An additional 53% (40,984 acres) of the urban zones could theoretically be modified to accommodate tree canopy. Of the 53%, 18% was classified as possibly impervious and 35% as possibly vegetated (Figure 4.3). Possibly vegetated areas, or areas with grass and shrubs, are more conducive to establishing new tree canopy, but establishing tree canopy in areas classified as possibly impervious will have a greater impact on water quality and summer temperatures. The primary data sources were Light Detection and Ranging (LiDAR) data acquired in 2009 and Worldview-2 satellite imagery acquired in 2010.[4]

In 2014, the National Oceanic and Atmospheric Administration released a comparable set of LiDAR photographs of O'ahu. This LiDAR data set gives us an opportunity to reassess our efforts to increase the urban canopy. In 2015, FS funded a second project to update the land cover geographic information system layer, identify the differences between the current and previous UTC, and provide a written assessment report. This project is slated for completion by December 2016.

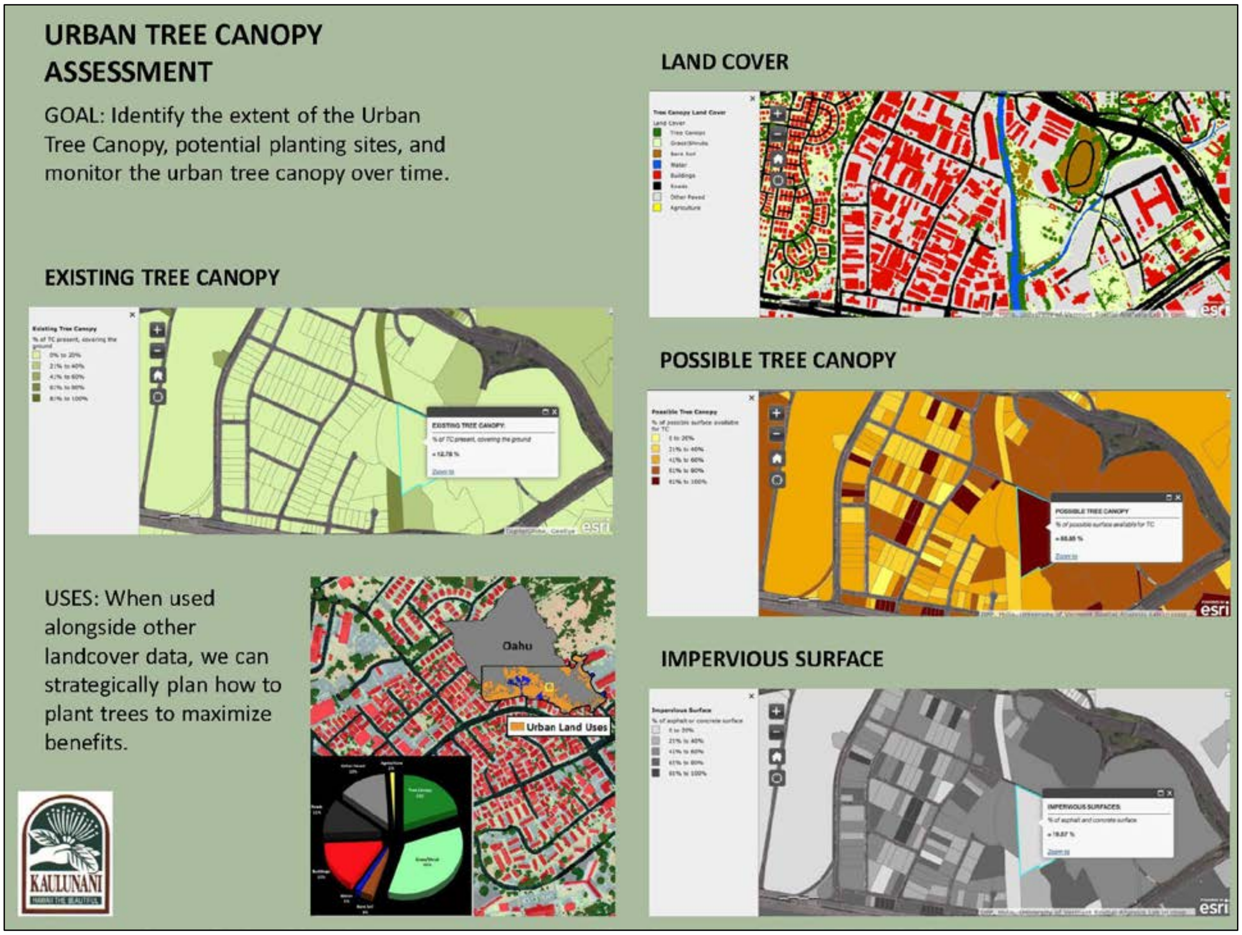


Figure 4.3. Results of urban tree canopy assessment on O'ahu: existing canopy cover (top right), vegetated and potential for canopy cover (left center), and impervious surfaces (bottom right).

Tree City USA and Tree Campus USA

Classification as a Tree City USA is the standard for excellence in urban forestry recognized by the Arbor Day Foundation. Hawai'i has doubled the number of Tree City USA communities to eight. Additionally, University of Hawai'i at Mānoa for the last 4 years has been recognized as a Tree Campus USA.

To qualify as a Tree City USA, a community must have (1) a tree board or department, (2) a tree care ordinance, (3) a community forestry program with an annual budget of at least $2 per capita, and (4) an Arbor Day observance and proclamation. Tree City USA communities in Hawai'i are listed in Table 4.1.

Table 4.1. Tree City USA communities of Hawaiʻi.

Tree City USA Community	Number of Years of Recognition
Āliamanu Military Reservation	3
Fort Shafter	3
Helemano Military Reservation	3
City and County of Honolulu	34
Joint Base Pearl Harbor Hickam	16
County of Maui	38
Schofield Army Base	6
Wheeler Army Airfield	3

Priority Issues and Areas in the Urban Forest

In 2009, the Kaulunani Council and key stakeholders identified important urban forestry issues throughout the state. In 2015, the council and stakeholders found that while some of the specifics changed, such as new invasive species threats and greater storm incidence, the overall issues and concerns of urban forestry identified in 2009 did not change. They are climate change, education and outreach, emergency management, health and well-being, invasive species, ordinances and legislation, urban tree care, water quality and green infrastructure, and Wildland-Urban Interface.

Federal Priorities for Urban and Community Forestry

- Mitigate and adapt to climate change.
- Protect and improve air and water quality.
- Conserve energy.
- Reduce the impacts of land use change, fragmentation, and urbanization on forest landscapes.
- Improve community health and well-being.
- Build urban forest resilience and mitigate the impacts of invasive pests and catastrophic events.

Climate Change

Present Conditions and Trends

According to the National Urban and Community Forestry Advisory Council report to the Secretary of Agriculture *Catastrophic Storms and the Urban Forests*, a storm's impact on the urban forest is a national problem, and its consequences affect our urban forests and our communities.[8] Moreover, the percentage of population living in coastal areas (53%) and the rising number of predicted high-intensity storms has created highly vulnerable coastal areas.

To begin to address these concerns, Kaulunani, in partnership with FS, the University of Hawaiʻi at Mānoa, and Spatial Informatics Group, has initiated several projects that investigate the effects of storms on the coastline in Hawaiʻi and other Pacific Islands. Some goals of these projects are (1) conducting a literature review of coastal/storm research, (2) identifying the type of vegetation that may survive tsunami and storm surge events, (3) gathering information on vegetation that grows near the shore in Hawaiʻi given different environmental factors, and (4) examining whether past or existing vegetation has an effect on mitigating beach erosion related to wave impact. Two completed projects are described in more detail below.

Effectiveness of Vegetation for Mitigating the Coastal Impact Related to Storm Surge and Tsunamis

A tsunami in 2009 inundated the southern coast of Upolu Samoa, killing more than 140 people and causing extensive property damage. In January 2010, a team was sent to make observations in Upolu to search for interactions between the tsunami and coastal vegetation. The team's observations lend support to the hypothesis that coastal vegetation mitigates the effects of a tsunami through several mechanisms: (1) coastal vegetation forms a physical barrier to an incoming wave, which may result in reduced damage to structures and reduced erosion; (2) coastal vegetation builds elevation at the coast by trapping organic matter and sand, and it provides a vertical escape for people trapped in the wave; and (3) coastal vegetation acts as a filter that prevents coral, ships, and debris carried by the wave from moving inland, where it can be destructive to people and property, and it prevent things from being carried out to sea and onto sensitive reefs.

Deflecting the Wave: Using Coastal Vegetation to Mitigate Tsunami and Storm Surge

A second project, "Deflecting the Wave: Using Coastal Vegetation to Mitigate Tsunami and Storm Surge," developed, based on the observations in Upolu, a method for restoring coastal areas primarily using native Hawaiian species. It also evaluated the effectiveness of this method and its effects on wave power and erosion. In particular, this project tested a planting method for establishing native plants after removal of *Casuarina equisetifolia* at Bellows Air Force Station in Waimānalo, Oʻahu. Results verified the effectiveness of using a temporary windscreen to protect against wind and salt spray. The final report also documents the irrigation system used on the project, includes photographs with a timeline of the establishment of the plantings, presents ground coverage and dry matter data collected 1 year after planting, and provides recommendations on native plants and their planting zones for coastal planting and landscaping in Hawaiʻi.

Gaps, Issues, and Concerns

"Issue 5: Climate Change and Sea Level Rise" addresses the various issues and concerns relative to climate change in Hawaiʻi. Regarding urban forestry, one of the biggest concerns is that there

is little or no recognition that trees and vegetation can be used to mitigate sea level rise. Other concerns are:

- increased risk to urban forests associated with an increase in frequency and severity of storms,
- increase in temperature and consequent changes to tree line in coastal areas,
- lack of projects aimed at reducing runoff and coastal erosion associated with sea level rise, and
- lack of effort to preserve and encourage maintenance of shoreline vegetation.

Strategies to Address Gaps

- Overlay UTC (possible urban forest) maps with sea level rise/inundation maps for the Hawaiian Islands to assist with strategically planting trees to mitigate impacts of storms and increased wave action associated with climate change.
- Prioritize trees for protection using the existing UTC analysis.
- Gain a better understanding of the suitability of specific trees for varying climate zones in the Hawaiian Islands.
- Gain a better understanding of the potential of specific trees to mitigate effects of climate change (e.g., flooding and saltwater intrusion).
- Communicate environmental urban ethics.
- Gain a better understanding of the resilience of specific trees under varying scenarios of temperature, rainfall, inundation, and so on.

Education and Outreach

Present Conditions and Trends

Urban forestry activities, celebrated on Earth Day and Arbor Day (Figure 4.4), are well received and involve public, private, and nonprofit partners. Kaulunani has been celebrating Arbor Day for 21 years.

Figure 4.4. Arbor Day in Hawai‘i.

Arbor Day in Hawai‘i officially falls on the first Friday in November, and traditionally most of the Arbor Day celebrations and tree giveaways across the state take place on the Saturday after Arbor Day. In 2015, 5,595 trees were given out at 10 sites across the state. Kaulunani awarded $29,052 to five organizations that was matched by $176,769 in cash and in-kind contributions.

In 2013, Kaulunani launched a speaker series called Learning @ Lunch to encourage a better understanding of urban forestry, its benefits, and how it relates to other forestry and land management issues. The program is now expanding to include a Holiday Tree Walk to engage citizens in the urban forest, and select Kaulunani council meetings for a broader audience now open with a speaker and informative presentation. In 2015, for example, we invited experts from the University of Hawaiʻi to discuss climate change and how it relates to the urban forest. Kaulunani also launched an e-newsletter that introduces relevant topics in the urban forest, giving the community the opportunity to learn more about current issues, invasive species, and tree-related events, such as Arbor Day.

Gaps, Issues, and Concerns

In 2009, the urban forestry stakeholders expressed concern about the lack of an overall marketing initiative regarding increasing awareness about urban trees and their benefits. In 2015, this issue continued to be a top concern of the Kaulunani Council and other stakeholders because many urban residents view trees as a nuisance rather than a benefit. Educational goals and gaps considered by the stakeholders covered a range of topics and addressed multi-tiered audiences. Marketing campaigns were suggested for policy makers, state agencies, and decision makers, as well as for homeowners and others in the community. Educational messaging on the benefits of trees, highlighted in the poster presented in Figure 4.5, needs a broader distribution to a wide range of audiences, including residents, homeowners, and policy and decision makers.

Strategies to Address Gaps

- Develop a broad marketing campaign to increase understanding of the importance of urban trees and vegetation and improve public perception of the value of trees, including ecosystem services and other benefits, such as health, food, cooling, and protection of the coastal strand.
- Ensure that informational material intended for policy makers, state agencies, and decision makers focuses on the Right Tree/Right Place and the economic and community values of urban forests.
- Begin a dialogue with homeowners and others in the community about urban forest values and needs.
- Develop stronger partnerships to increase public interest in the urban forest and to leverage possible marketing efforts. Potential organizations to partner with include Aloha + Challenge; Hawaiʻi Tourism Authority; local foundations; county planning, permitting, and development agencies; DOFAW; Livable Communities Hawaiʻi; FS; the State Department of Transportation; the U.S. Department of Housing and Urban Development; and the U.S. Environmental Protection Agency.

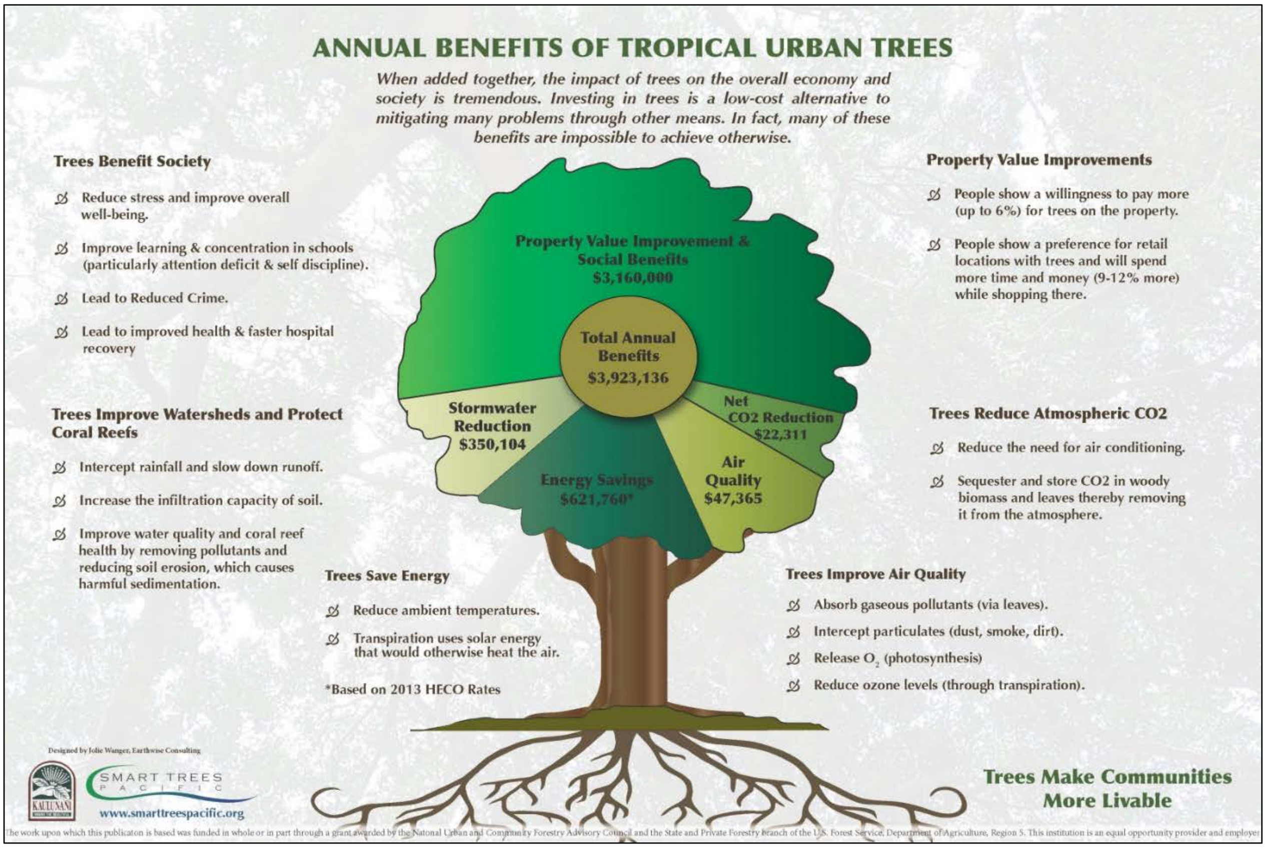


Figure 4.5. The poster, prepared by Kaulunani, illustrates the annual benefits of tropical urban trees.

Emergency Management

Present Conditions and Trends

It should not come as a surprise that we are in a new era of catastrophes.[7] There is a concentration of more people and assets in hazardous areas while at the same time new vulnerabilities and new hazards are emerging.[9] In fact, 91% of Americans live in places at a moderate-to-high risk of earthquakes, volcanoes, tornadoes, wildfires, hurricanes, flooding, or high-wind damage according to an estimate calculated for TIME Magazine by the Hazards and Vulnerability Research Institute at the University of South Carolina.

To increase the understanding of urban forestry and emergency management, in 2009, STP (organization that delivers the Kaulunani Program) received an FS National Urban and Community Forest Advisory Council grant to develop the *Urban Forestry Emergency Operations Planning Guide* for storm response (Figure 4.6). This user-friendly guide provides urban forestry professionals with concrete approaches to use when preparing for natural disasters that affect the urban forest. The guide covers planning, safety, communications, contracts,

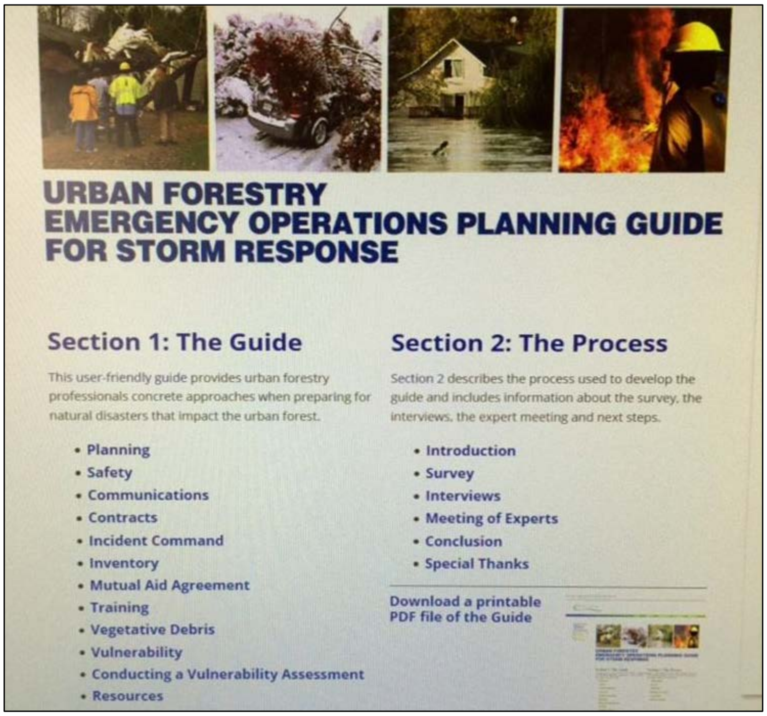


Figure 4.6. Information poster prepared by Smart Trees Pacific for its project—*Urban Forestry Emergency Operations Planning Guide.*

incident command, inventory, mutual aid agreements, training, vegetative debris, vulnerability, how to conduct a vulnerability assessment, and resources.

A second federal grant was awarded to STP to develop the *Urban Forestry Incident Command Engagement Model* (UFICEM) (Figure 4.7). Urban foresters need an understanding of the Incident Command System (ICS) and National Incident Management System (NIMS) to be fully integrated in the emergency management systems that provide readiness in advance of events and can greatly reduce response burden and resulting recovery time, effort, and cost.

A "Storm Resilient Communities Summit" was hosted by STP in conjunction with partners XLUR8, FS, the California Department of Forestry and Fire Protection Urban and Community Forestry Program, and Davey Trees on August 3, 2015, at the California Endowment Center in Los Angeles, California. The purpose of the summit was to present the model to policy makers, municipal professionals, non-profit tree groups, and other interested parties for feedback on the UFICEM. The purpose was to help urban foresters gain budgetary and other "whole community" support for their tree responsibility program through the incident command engagement model.

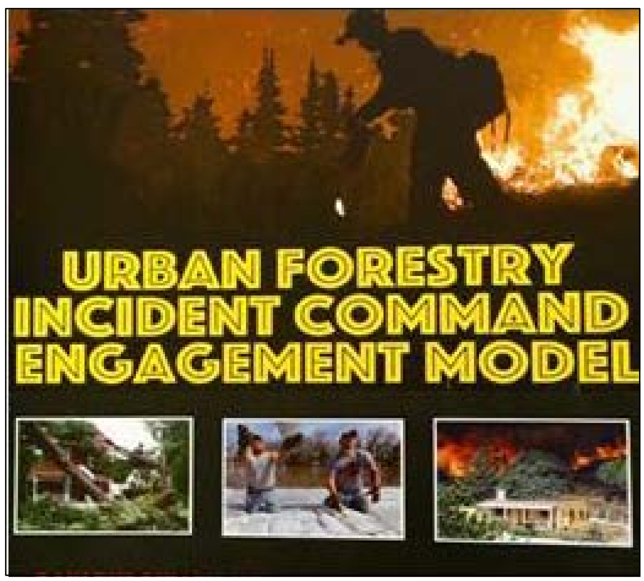


Figure 4.7. Information poster on Smart Tree Pacific's (Kaulunani's) project— Urban Forestry Incident Command Engagement Model.

Gaps, Issues, and Concerns

Urban foresters need an understanding of ICS and NIMS to be fully integrated in the emergency management systems.

Strategies to Address Gaps

- Integrate the UTC and ICS and storm preparedness. For example, identify the risk of albizia trees to roadways and utilities.
- Seek additional funding to create opportunities for emergency managers, policy makers, non-profits, and urban foresters to discuss how urban foresters can provide expertise to emergency managers.

Health and Well-Being

Present Conditions and Trends

Urban forests offer a multitude of benefits. Research indicates that healthy trees can decrease negative impacts of urbanization while improving human health. Trees and plants buffer wind and noise and generally are recognized as positive influences on health and well-being. In fact, public health officials and healing centers, such as hospitals, are now starting to plan for urban nature as an important contribution to disease prevention and health promotion. Simply being able to see trees, parks, and gardens while in the city has been scientifically linked to faster healing in hospitals, reduced mental and physical stress, better student performance in school, and better attention to tasks while at work.[10]

Parks, green spaces, and trees are more than the "lungs of the city" or "pollution scrubbers." They affect our everyday moods, activities, and emotional health. They improve our quality of life in ways that are sometimes understood and often underestimated. Whether we are active in urban nature (planting trees, growing gardens) or passively encounter city green (such as a stroll through a park), we experience personal benefits that affect how we feel and function. Proof of psychological and social benefits gives us more reasons to grow greener in cities![11]

Gaps, Issues, and Concerns

Many of the health and well-being issues overlap with proper tree care and education and outreach in the urban forest, such as:

- social justice and limited efforts to plant trees in lower income areas,
- lack of access to fruit trees and other trees for food,
- not planting trees strategically so that they can be used effectively to cool schools and heat islands in urban areas,

- lack of recreational hiking trails in and around urban areas,
- increased runoff of pollutants in waterways and oceans related to lack of natural erosion control measures like raingardens, and
- lack of food security—continued dependence of Hawai‘i to import nearly 80–90% of its food.

Strategy to Address Gaps

- Strategically plant urban trees to help improve the health and well-being in our communities by addressing social inequalities; plant more trees in low-income neighborhoods, increase access to fruit trees, reduce heat islands and cool urban schools, create more tree-lined urban trails, and help slow down stormwater runoff.

Invasive Species

Present Conditions and Trends

The Hawaiian Islands are at risk from the introduction of animals, plants, and diseases. It is estimated that 10,000 species have been introduced to Hawai‘i. The vast majority of them are non-invasive and not harmful; however, some (approximately 200 species) have become environmentally harmful. With more than 250,000 species of plants in the world and several thousand more insect species and with the high volume of goods imported to the islands, Hawai‘i is constantly under threat from the establishment of new invasive species. More than 85% of the invasive plant species found in the natural areas in Hawai‘i were intentionally introduced.[12] In addition, invasive pests and disease can cause devastating effects not only on natural areas but also on urban trees. For example, the coconut rhinoceros beetle has been damaging and killing coconut and other palm species that are prevalent and an important part of the urban forest (*see “Issue 2: Forest Health,” for more details*).

Weed Risk Assessment Working Group

In 2001, Kaulunani hosted a gathering of urban foresters, botanists, conservationists, and educators to discuss the relationship between invasive species in urban areas and those found in upland wild areas. This collaborative working group recommended an integrated course of action to reduce the negative impacts of invasive species on the native ecosystems. The Hawai‘i-Pacific Weed Risk Assessment (HP-WRA) was developed with the intent of identifying plants that pose a high weed risk in Hawai‘i and on other Pacific Islands. By the time this urban forestry project was completed in 2004, more than 600 plants had been analyzed and given a weed risk score. Presently, the HP-WRA is widely used and recognized as a tool to predict the potential of a plant to become invasive in Hawai‘i and other Pacific Islands. To date, more than 1,600 plants have been screened by the HP-WRA.[13]

Plant Pono

Kaulunani funded two projects to create and update the Plant Pono website, www.plantpono.org, which provides general information on plants and suggests alternative non-invasive plants that can be used in place of some commonly used but invasive landscape plant species. The website also promotes the use of the HP-WRA as an objective, science-based predictive tool. It also provides access to invasive plant experts in Hawaiʻi so that visitors to the site can make good planting decisions. Legal issues (federal and state) and other challenges hinder efforts to identify or regulate the importation and sale of invasive plants in Hawaiʻi. That is why initiatives like Plant Pono that promote the voluntary use of non-invasive plants in the urban and natural areas are important.

Erythrina Gall Wasp and Other Pests

In 2005, the *Erythrina* gall wasp was first detected in Hawaiʻi in Oʻahu's urban realm, which subsequently led to widespread death of *Erythrina* trees. Within 6 months, the wasp had spread to all the major Hawaiian Islands, severely affecting various species of *Erythrina*, including the native *wiliwili* (*E. sandwicensis*), which was a common urban street tree. The University of Hawaiʻi, along with collaborative partners from the Department of Agriculture, Department of Land and Natural Resources, Kaulunani, and FS, conducted trials using different cultural and chemical treatments to control the gall wasp.

Currently, we share information about any new threats through our readership of the *Kaulunani News*. Kaulunani stepped in to support the education effort on the coconut rhinoceros beetle by funding educational materials and door hangers. The Kaulunani Council meeting on the Island of Hawaiʻi in 2014 was specifically focused on albizia, *Molucca albizia* (*see "Issue 2: Forest Health"*) with key researchers and site visits to inform the council and see the devastating impact of this tree species on the urban areas.

Gaps, Issues, and Concerns

Early detection of pests at harbors and airports is our first line of defense against invasive species in Hawaiʻi. However, early detection and rapid response of invasive species in the urban realm, before they have had a chance to spread to our neighboring native ecosystems, is necessary to prevent their spread and avoid further economic and environmental damage.

Strategies to Address Gaps

- Mitigate impacts of the introduction and spread of invasive species in the urban forest and on native ecosystems by supporting educational outreach through the Kaulunani newsletter, Learning at Lunch, and other avenues.
- Engage the landscaping and urban forestry industry in reducing the importation of non-native potentially invasive plants.

Ordinances and Legislation

Present Conditions and Trends

There are numerous ordinances and laws regarding trees; however, landscape industry partners have indicated a concern about enforcement. Existing ordinances are poorly understood as they impact urban forestry and may benefit from a concerted effort to understand and identify gaps and model ordinances that could be adopted.

Gaps, Issues, and Concerns

There is increasing conflict between urban land use and trees (such as trees shading solar panels), leading to removal of large trees or increased tree topping. There are no regulations on tree removal (for example, requiring a replacement plan when trees are removed from public schools and libraries). This is leading to fewer large trees in urban areas.

In addition, there is a lack of regulation and enforcement of existing legislation and a need for new and revised landscape/stormwater management ordinances and legislation. For example, there are no incentives (e.g., tax credits for homeowners and property owners) to plant and maintain trees, install green infrastructure, and remove impervious surfaces.

Strategies to Address Gaps

- Bring knowledgeable people together to identify gaps and strategies that relate to urban forestry issues (e.g., advisory council, task force).
- Compile information about existing ordinances, rules, and laws and make it readily available to the public and the industry.
- Work with urban forestry leaders, Tree City/Campus USA communities, and government partners to establish tree canopy goals for municipalities or other entities.

Urban Tree Care

Present Conditions and Trends

In their paper, “A Model of Urban Forest Sustainability,” Clark et al. state that “Urban trees and forests are considered integral to the sustainability of cities as a whole. Yet sustainable urban forests are not born, they are made. They do not arise at random, but result from a community-wide commitment to their creation and management.”[14]

An urban tree’s life span is very short, and often trees are planted in small spaces and are poorly irrigated. Monocultures have become the norm, trees are often topped, and there is a lack of knowledge about basic tree pruning or a comprehensive county tree planting program. A diverse pallet of trees that is properly pruned can provide a community with benefits for many years.

Cultural respect for trees is an important social norm in Hawaiʻi because trees not only provide food and shelter but also are an integral part of cultural and spiritual traditions. The use of native trees and culturally important trees in urban areas has improved, and there is some state legislation in place that requires the planting of native trees around public buildings whenever possible. There is a lack of integration of traditional knowledge relating to urban trees and a need to develop a culturally appropriate strategy for restoring balance.

Although an inventory of trees exists for areas such as Schofield Army Base, the island of Lānaʻi, and certain Department of Transportation roads, there is no inventory of trees used by counties of Hawaiʻi. Lack of inventories can hinder efforts to model, plan, and manage the urban forest. Kaulunani received funds for a pilot inventory project using citizen forestry. The goal is to develop an inventory and mapping tool for the pilot area that is easy to use, transferable or collaborative, and based on a simple list of parameters necessary to manage the urban forest and calculate ecosystem services. The pilot area selected is in the UTC assessment area of interest so that we can maximize our understanding of the urban canopy by integrating the two. The goal is to include diverse stakeholders in the project.

Gaps, Issues, and Concerns

Although best management practices for the proper management and care of trees in the urban realm have been implemented, they are often inconsistently applied in both the public and private sector. There is a need for education and outreach about how to take care of trees over a tree's lifetime, incentives to implement trees as part of the transportation system, an expanded palette of trees used for landscaping, training in proper tree selection, planting the right tree in the right place, and an increase in number of large-canopy trees.

Strategies to Address Gaps

- Support tree inventory projects.
- Educate and train landscape industry workers, as well as the general public, about planting the right tree in the right place and about proper tree care.
- Support and incentivize the use of native Hawaiian tree species to increase tree species diversity in the urban realm, and provide opportunities for the integration of Hawaiian cultural practices in the urban realm.

Water Quality and Green Infrastructure

Present Conditions and Trends

Urbanization is occurring at a rapid pace. Water quality and quantity are affected by urbanization. Development practices have resulted in an increase in impervious surfaces (Figure 4.8). Roads, buildings, and parking lots prevent rainwater from soaking into the ground. This increases the volume and speed of water runoff, increases erosion, and washes pollutants through storm drains into streams and eventually into the ocean.[15] De-vegetation, topsoil erosion, and soil compaction have led to more frequent flooding. Strategically planting and maintaining trees in urban areas can positively affect all of these factors.

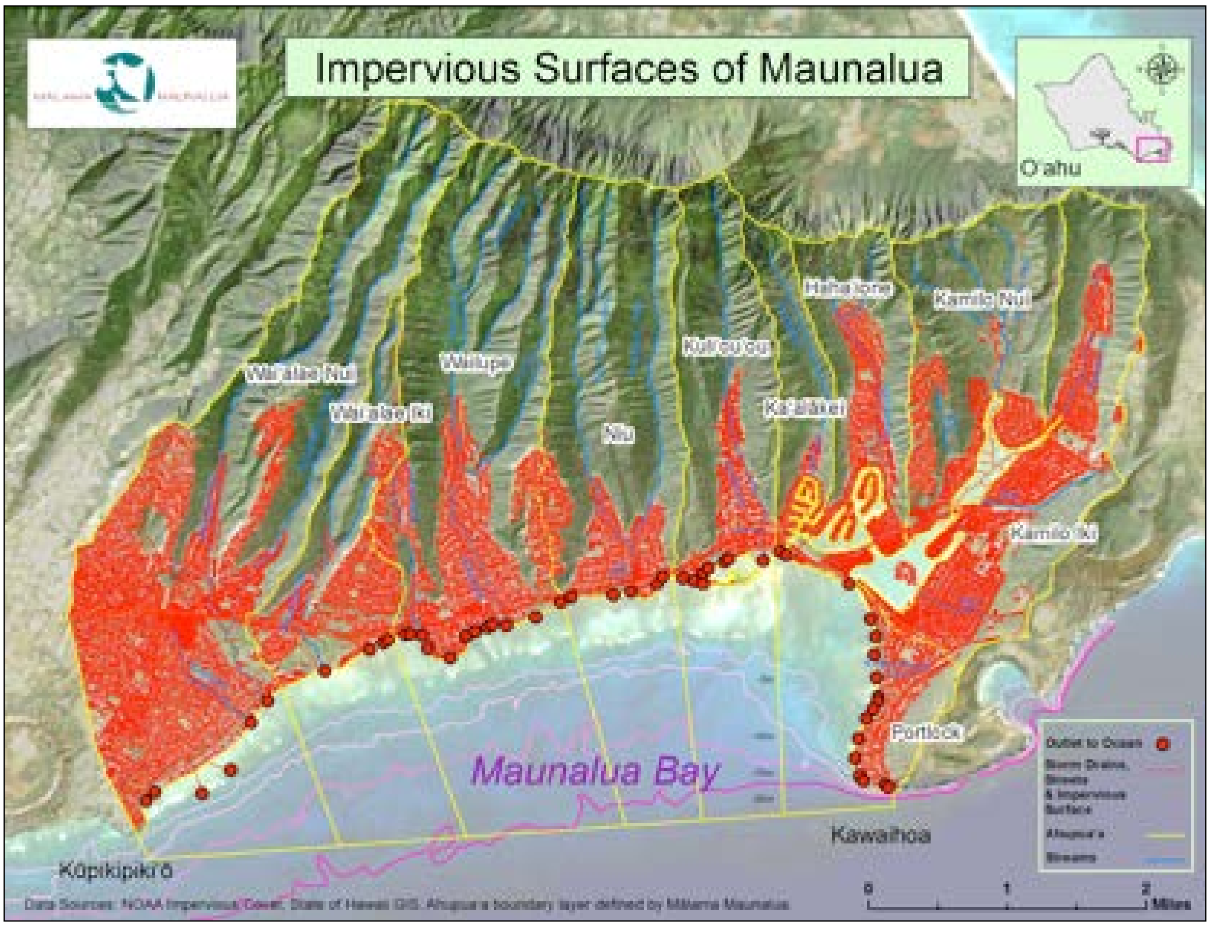


Figure 4.8. Impervious cover in the urbanized region of Maunalua, located in East Oʻahu. These surfaces, including streets, drainage canals, parking lots, driveways, and rooftops, cause excessive overland water flow into nearshore aquatic ecosystems. The increase in impervious cover decreases the extent of vegetation and groundwater percolation areas where water uptake and filtration would restore hydrologic function of the urban watersheds of Maunalua. Image courtesy of University of Hawaiʻi, Sea Grant Extension Program.

In 2013, Kaulunani and STP received funding for the *Applied Stormwater Practices at Hāmākua Marsh, Kailua, Hawai'i* project. This ongoing project will demonstrate how investment in stormwater urban forestry practices can be used to improve the water quality in an area where the industrial urban landscape directly interfaces with one of the largest remaining wetlands in the Hawaiian Islands (Figure 4.9). The project goals are to install a demonstration urban-watershed, to demonstrate the benefits that trees have in treating and infiltrating stormwater runoff, and to develop innovative solutions to maximize water quality benefits. The project is slated to be completed in 2016.

Figure 4.9. Raingardens being established as part of Kaulunani's applied stormwater management project.

Gaps, Issues, and Concerns

There is a need to better integrate Hawai'i's green infrastructure with its gray infrastructure and hardscapes. Hawai'i needs to proactively include green infrastructure and trees in the planning phase of project development. Important concerns include providing adequate space for trees, connecting green areas to the flow of water, and designing and maintaining plantings to maximize net benefits over the long term.[2]

Strategies to Address Gaps

- Determine which trees provide the most water quality/evapotranspiration benefits and which trees are most resilient.
- Use the UTC to identify areas most appropriate for planting trees to improve water quality.
- Work together with a broader network of partners to give trees a predominant role in green infrastructure.

Wildland-Urban Interface

Present Conditions and Trends

In general, the Wildland-Urban Interface (WUI) is the zone where structures and other human development meet and intermingle with undeveloped wildland or vegetative fuels. DOFAW has identified Communities at Risk (CARs) based on vegetation type, climate regimes, and fire history. The WUI for Hawai‘i is identified as a 1-mile buffer around these CARs irrespective of their high, medium, or low risk to wildfires (*see Map 3.1 in "Issue 3: Wildfire"*). An increase in residential and commercial development near wildland areas has increased the WUI in Hawai‘i. Also, there is a strong correlation between frequency of ignition and human population[16] (*see Figure 3.2 in Issue 3*), which tends to be higher in developed areas. Because the vegetation in the wildlands of the WUI mostly comprises invasive fire-prone grasses, fires started in the developed areas are carried rapidly and intensely by these fine fuel loads, thereby increasing the risk of wildfires to urban communities.

Gaps, Issues, and Concerns

DOFAW's priority areas for wildfire include CARs and the WUI. DOFAW engages homeowners in the WUI via the Firewise Communities Program. This program was born out of the National Firewise Communities Program, which is designed to encourage homeowners, community leaders, and others to take actions to protect people, property, and natural resources from the risk of wildfires before a wildfire starts. Although this program has been active in Hawai‘i since 2002, there is only one community in Hawai‘i, Kohala by the Sea, on Hawai‘i Island, that is recognized as a National Firewise Community. As identified in *Issue 3: Wildfire*, additional efforts are needed to alleviate wildfires in the WUI and increase the number of nationally recognized Firewise communities in Hawai‘i.

Strategies to Address Gaps

- Collaborate with organizations such as the Hawai‘i Wildfire Management Organization to increase the number of nationally recognized Firewise communities in Hawai‘i, particularly those CARs that fall within the urban realm.
- Reduce invasive grass fuel loads in the WUI by supporting projects that contribute to replacing these fire-prone grasslands with more fire-resistant tree species.
- Incorporate the message of fire safety into various Kaulunani education and outreach programs.

Summary

Urban forestry is about tree management in any area influenced and used by the urban population. About 5% of Hawai‘i’s land area is designated as urban. Trees are a critical component of our cities and a dynamic resources. They improve urban life, making Hawai‘i a more enjoyable place to live, work, and play, while mitigating the city’s environmental impact. Benefits of urban forests and trees also include reducing energy costs, cooling “heat islands” by providing shade, sequestering carbon, soil stabilization, trapping pollutants, slowing storm runoff, increasing property values, providing food, and conservation and cultural benefits.

Hawai‘i’s Urban and Community Forestry Program, Kaulunani, is funded by FS and DOFAW. The program is managed in partnership with DOFAW and the non-profit STP which delivers the Kaulunani Program. Urban forestry issues span from the mountains to the sea and include watersheds, stormwater runoff, sea level rise, cooling, tree care, fire and forest health, improved management of the trees, support for enforced ordinances to improve the health of the urban canopy, and education to citizens and government about the value of our urban trees.

Nine priority issues are identified as they relate to Hawai‘i’s urban forests. These include: 1) climate change—there is increased risk to urban forests due to increase in frequency and severity of storm; 2) education and outreach—there needs to be focused marketing effort to a wide range or audiences about the benefits of urban trees, 3) emergency management—the ICS needs to be better integrated in the urban forest management; 4) health and well-being—urban raingardens can help minimize runoff of pollutants in waterways and oceans; 5) invasive species—early detection of pests in urban areas like harbors and airports serve as the first line of defense against invasive species; 6) ordinances and legislation—rules and regulations as they pertain to urban trees should be readily available to the landscape industry and the general public; 7) urban tree care—the use of native Hawai‘i an tree species to increase diversity of trees in the urban areas should be incentivized and supported; 8) water quality and green infrastructure—use the urban tree canopy maps to identify areas most appropriate for planting trees to improve water quality; 9) WUI—reduce invasive grass fuel loads in the WUI by replacing grasses with more fire-resistant tree species.

Strategies for Issue 4: Urban and Community Forestry

Urban and Community Forestry: Education and Outreach Efforts								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Increase the public perception of the value and benefits of urban trees. Develop and coordinate outreach opportunities and a marketing campaign designed to increase the public perception of the benefits of the urban forest. Support conservation education.	See State-Wide Urban Realm Map; Industry.	Forge stronger partnerships to increase public interest in the urban forest; promote Arbor Day, Learning at Lunch, Tree Walks; build urban forest resilience by investing community in a greater appreciation of its value; focus on the industry, school-age students, public, and tourists. Learn about climate change issues and mitigation technologies elsewhere in the Pacific.	Hawai`i Tourism Authority, UH, DLNR-DOFAW, AAA, DOE, Hawai`i Islands Land Trust, Trust for Public Lands, ASLA, counties. UCF, CE, FSCG, counties , FSCG, UCF grants, UH, C&C, AAA.	Hawai`i residents, policymakers, Hawai`i Tourism Authority, DOH, DOT, counties. Practitioners, scientists, nonprofits, governments, Hawai`i Tourism Authority.	Nonprofits, Smart Trees Pacific, HFIA, HISC, CGAPS, TOC. Use UCF grant for inventory. Private/stakeholder donations, SOPAC, YCC, DOFAW EE, HFIA, SAF, FSCG, HEEA.	Integrated surveys and other means to gather metrics at education events such as Arbor Day; use of pilot Citizen Forestry project to explore attitudes toward trees, identification and catalog of records of participation at events and their affiliations. Support for the execution, dissemination and/or implementation of the State HELP.	1.2 2.2 3.1 3.2 3.4 3.6 3.7	1.2 3.4 All goals in HELP

Strategies for Issue 4: Urban and Community Forestry

Urban and Community Forestry: Climate Change Impacts to Urban Forests								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Identify how trees can be used to build urban forestry resilience. Investigate how trees and plants are a measure of protection in coastal areas vulnerable to storms. Use the UTC and other technology to identify where sea level rise and inundation is a concern and where to plant trees to mitigate sea level rise.	Hawai`i Urban Realm and global tropical islands.	Gain a better understanding of how trees and plants are best suited to mitigate the effects of climate change in the urban forest, including coastal areas.	State, UCF, competitive grants, donations, foundations, CZM, NOAA, NRCS, HFIA, AAA, FS PSWRS.	UH, state, counties, UCF, Hawai'i Tourism Authority.	Military, UH, FHUF, DOFAW, Sea Grant, Blue Line Project, Surfriders, UH CTAHR, CZM, GreenBlue Bog – Sustain-ability in the Urban Forest, United Nations-Climate Change.	Investigation and education of how trees protect coastal areas. Identification of which species can survive and thrive in coastal areas to reduce impacts and protect the coastline. Use of the UTC to increase the urban tree canopy.	3.1 3.2 3.4 3.6 3.7	
2. Urban Tree Care: Advocate for a more sustainable urban forest by promoting the use of practical tools such as inventory, tree care training, model ordinances and rules, and education and outreach. Compile information about existing ordinances, rules and laws and make it readily available to the public and industry.	See state-wide Urban Realm map.	Increase Tree City USA and Tree Campus USA communities.	UCF, AAA, FS, HI, municipalities, LICH, UH, NADF, Western State Foresters, ISA, SAF.	Municipalities, UH, state, arborists, landscapers, community.	NADF, ISA, SMA, UH, Arboretums, Botanical Gardens, Counties, nonprofits, STP, TNC, TOC, APWA good practice documents, UW, Stevens Point Urban Forestry Self-Assessment Tool, UCF grant, donations, foundations, APWA good practice documents.	An increase in urban tree care training. An increase in Tree City/Tree Campus USA communities, completion of pilot inventory and measurement of results. Compilation and accessibility of a list of tree ordinances in Hawai`i, made available at the website. Dissemination of information about ordinances, rules and laws.	1.2 3.1 3.2 3.4 3.6	1.2 1.4 2.2.d

Strategies for Issue 4: Urban and Community Forestry

3. Water Quality and Green Infrastructure: Work with a broad network to give trees a predominant role in green infrastructure. Investigate which trees provide the greatest resiliency and water quality benefits. Use the UTC Assessment to identify areas most appropriate for planting trees to improve water quality and resilience.	See state-wide Urban Realm map.	Improve water quality, reduce runoff and sedimentation on near-shore coral reefs.	Counties, planners, government, NGOs, community, landscapers, arborists, designers, developers, CCH.	Counties, state, private landowners.	Parks, nonprofits, friends, HISC, CGAPS, schools, env. ed. orgs.	More trees used in green infrastructure plantings. Improved knowledge of which trees are resilient and provide the highest-water quality benefits. Opportunity index maps for strategic tree planting.	3.1 3.4 3.7	1.2 1.4 2.2.d
4. Emergency Management: Increase the understanding of urban forestry and emergency management by building urban forestry resilience through storm preparedness and planning.	Hawai'i Urban Realm Map.	Integrate urban forestry into emergency management system.	States, FS, foundations, donations, private sector.	Private sector, states, APWA, Public Works, municipalities, nonprofits, arborists, FEMA.	State, federal, private stakeholders, grants, donations.	Increased education opportunities for urban foresters and emergency managers to engage. Development of pilot project to test urban forestry ICS engagement model. Number of known urban foresters who have a seat at the emergency management table.	1.2 2.2 3.3 2.4 3.6 3.7	
5. Invasive Species: Mitigate impacts of invasive species from the urban forest on native ecosystems by supporting educational outreach and reducing importation of potentially invasive species.	See state-wide Urban Realm map and WUI.	Support Forest Health efforts to mitigate and reduce invasive species in the urban forest.	State, UCF, competitive grants.	Private nurseries, UH, colleges, botanical gardens, ASLA, DLNR, DOFAW, HISC.	State, federal, UH, CGAPS; use UCF grant for inventory. Private/stakeholder donations, SOPAC, DOFAW, HFIA, SAF, FSCG.	Support of educational opportunities through Kaulunani newsletter, learning at lunch, and other avenues.	1.2 2.2 3.3 3.6 3.7	1.2 2.2

Strategies for Issue 4: Urban and Community Forestry

6. Health and Well-Being: Strategically plant urban trees to help improve health and well-being in communities.	See state-wide Urban Realm map.	Decrease negative impacts of urbanization, improve human health, reduce heat islands, cool schools, create more tree-lined urban trails, increase access to fruit trees, address social inequalities by planting more trees in low-income neighborhoods.	DOH, counties, DOE, UH, DLNR, DOFAW, AAA, nonprofits, FS, community groups, Blue Line Project Hawai'i.	DOH, counties, community, nonprofits.	UTC, Coastal Readiness projects, Blue Line Project.	Increased canopy and number of trees, increase in measurable ecosystem services.	1.2 3.1 3.2 3.4 3.6 3.7	

Key:
AAA = Aloha Arborists Association
APWA = American Public Works Association
ASLA = American Society of Landscape Architects
CCH = Conservation Council for Hawai'i CGAPS = Coordinating Group on Alien Pest Species
CTAHR = College of Tropical Agriculture and Human Resources
CZM = Coastal Zone Management
DLNR = Department of Land and Natural Resources
DOE = U.S. Department of Energy DOFAW = Division of Forestry and Wildlife
DOH = Department of Health
DOT = Department of Transportation
EE = Environmental Education
env. ed. orgs. = environmental education organizations
FEMA = Federal Emergency Management Agency
FHUF = Friends of Hawai'i Urban Forest
FS = U.S. Forest Service
FSCG = Forest Service Competitive Grants
HEEA = Hawai'i Environmental Education Alliance
HELP = Hawai'i Environmental Literacy Plan
HFIA = Hawai'i Forest Industry Association
HI = Hawai'i
HISC = Hawai'i Invasive Species Council
ISA = International Society of Arboriculture
LICH = Landscape Industry Council of Hawai'i
NADF = National Arbor Day Foundation
NGOs = nongovernmental organizations
NOAA = National Oceanic and Atmospheric Administration
NRCS = Natural Resources Conservation Service
PSWRS = Pacific Southwest Research Station
SAF = Society of American Foresters
SMA = Special Management Area
SOPAC = Special Operations Command Pacific
STDP = Special Technology Development Program
STP = Smart Trees Pacific
TNC = The Nature Conservancy
TOC = The Outdoor Circle
UCF = Urban and Community Forestry Program
UH = University of Hawai'i
UTC = Urban Tree Canopy
UW = University of Washington
WUI = wildland/urban interface
YCC = Youth Conservation Corps

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Issue 5: Climate Change and Sea Level Rise

Overview

According to the Intergovernmental Panel on Climate Change (IPCC), global average temperatures have risen by 1.5°F since 1970 and can be expected to rise another 2 to 11°F by the end of the 21st century, depending on future greenhouse gas emission levels. Scientific modeling suggests that the surface temperature will continue to increase beyond the year 2100 even if concentrations of greenhouse gases are stabilized by that time.[1]

Mounting evidence indicates that Hawai‘i's climate is changing in ways that are consistent with the influence of global climate change. Data show a rapid rise in air temperature in the past 30 years (averaging 0.3°F per decade), with stronger warming at higher elevations (Figure 5.1).[2] The general consensus in the recent literature identifies an increase in annual and monthly average temperatures in Hawai‘i over the past century.[3] Most studies associate the increase in average annual temperature with an increase in minimum temperatures at night. Additionally, higher-elevation and urban areas experienced a greater rate of increasing temperatures. This response to global climate change is consistent with similar trends observed in North America.[4]

Along with an increase in surface air temperature, average precipitation levels have decreased across the state since the 1970s, and decreased by over 15% in the past decade.[3] Other documented climate changes in Hawai‘i include:

1. decreased stream flows,
2. increased rain intensity,
3. sea level rise,
4. rising sea surface temperatures, and
5. ocean acidification.[5]

Because changes in Hawai‘i's climate will continue and will intensify, scientists anticipate growing impacts on water resources, forests, native wildlife, marine systems, coastal communities, and the economy.

Future climate projections for Hawai‘i, based on current data and trends, indicate that climate change will result in an increase in the mean annual air temperature of approximately 1.5°F to 5°F by the latter half of the 21st century.[3] Precipitation will vary across the state, with O‘ahu and Maui experiencing decreasing precipitation trends, while the Big Island will have potentially increasing trends. Some studies conclude that the region should expect more frequent tropical cyclones and an increase in the frequency of heavy rainfall events, while other studies project a decrease in heavy rain events. Downscaling climate change models predict, on average, a decrease in rainfall and reduced availability of freshwater resources.[6] Regarding distribution of rainfall, the downscaling model for Hawai‘i predicts that most areas will have a decrease in wet-season rainfall, with the exception of the trade wind–dominated wet regions along and above the eastern slopes of the mountains, which are expected to see slight increases or remain stable in rainfall amounts. The leeward, climatically dry areas of the islands are predicted to have drier than normal conditions during both the wet and dry season.[6]

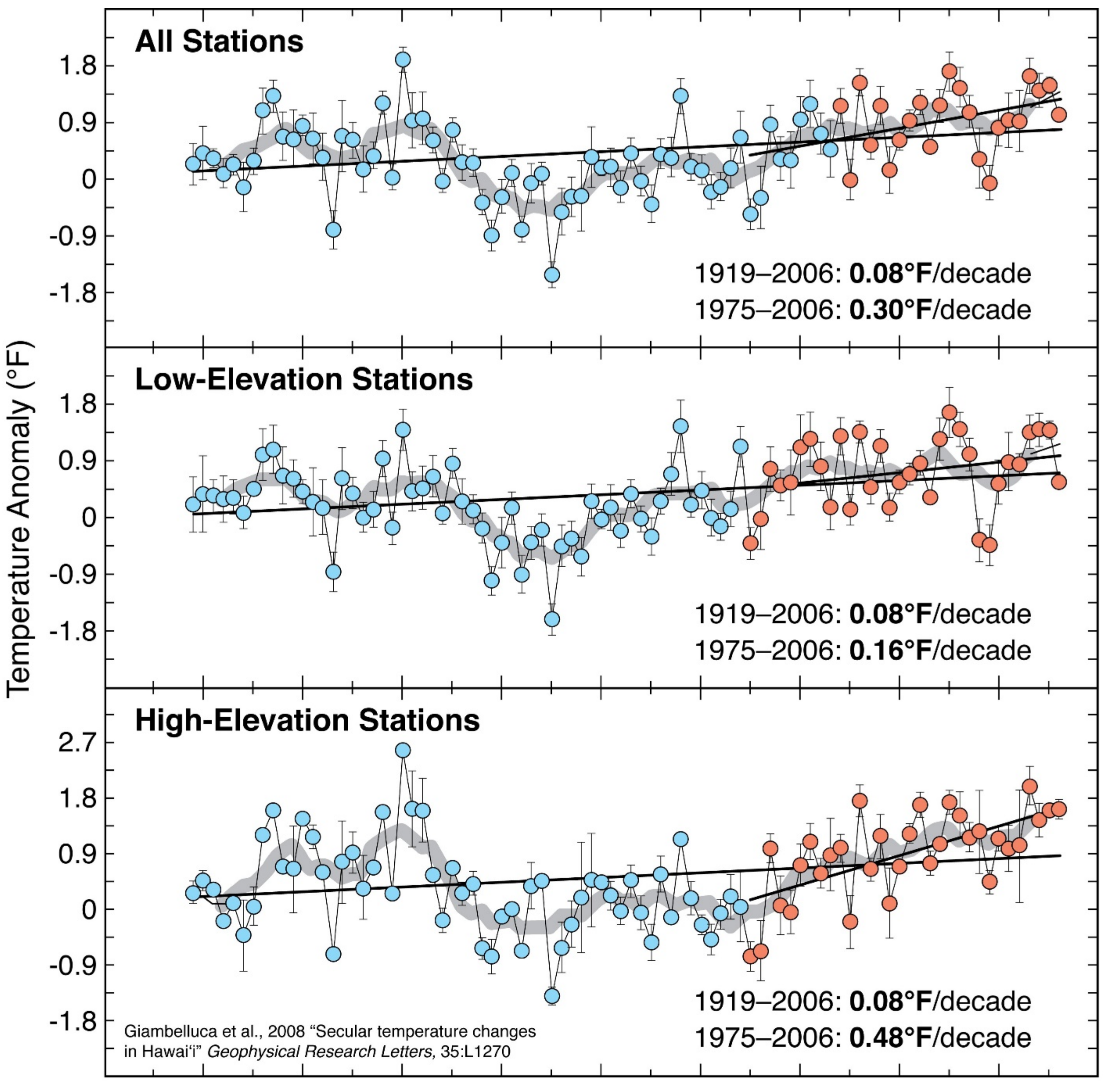


Figure 5.1. Data show a rapid rise in air temperature in the past 30 years (averaging 0.3°F per decade), with a stronger warming at higher elevations.[2]

Based on these projections, climate change in Hawai‘i is expected to:

- reduce the amount of fresh water available;
- decrease Hawai‘i's forest health and biodiversity;
- increase the frequency, size, and intensity of wildfires;
- increase flash flooding, landslides, agricultural losses, and infrastructure damage; and
- negatively affect beaches, coral reefs, and key marine resources on which the state's economy depends.

Climate change threatens forest health, but Hawai‘i's forest resources, appropriately managed, have the potential to mitigate global climate change and promote resilience for ecosystems, communities, and the islands. Mitigation involves actions to reduce emissions and enhance sinks of greenhouse gases, so as to lessen the impacts and effects of climate change.[7] Tropical forests sequester and store high amounts of carbon, and managing forests for maximum carbon sequestration can enhance forests' capacity to decrease atmospheric carbon dioxide levels.

Although mitigation is essential to promoting a productive global future, climate change is already affecting Hawai‘i. It is timely to consider facilitated adaptation, involving initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects.[7] Presently, Hawai‘i's forests offer many benefits that will help safeguard Hawai‘i's communities in a changing climate. Forests, however, are facing other stressors that severely limit their adaptive capacity. Healthy urban forests can provide cooling shade, lessen flooding, and offer natural protection during extreme weather events. Upland forests support the highest concentration of native terrestrial plant and animal species in Hawai‘i, and they generally represent the most intact portions of the watersheds upon which residents and visitors depend for ecosystem services, agricultural productivity, manufacturing, recreation, and household water consumption. Enhanced conservation of existing forests and facilitated adaptation will help preserve Hawai‘i's ecosystems and human communities.

In order to adapt resource management and forestry practices to the changing climate, there is a significant need for sustained and enhanced climate monitoring and assessment activities. Assessing the vulnerability of key resources, infrastructure, and ecosystems can inform the process of setting goals, determining management priorities, and deciding on appropriate adaptation strategies.

Given the broad spatial and temporal scales associated with climate change, implementing strategies for protecting forests and human communities will require a high level of collaboration and cooperation among state and local agencies and federal and community partners. It is critical to engage stakeholders, the public, educators, learners, and policymakers. Recognizing this need, in 2014, the Hawai‘i State Legislature passed the Hawai‘i Climate Adaptation Initiative Act (Act 83, Session Laws of Hawai‘i, 2014) and set up the Interagency Climate Adaptation Committee

(ICAC) to address the effects of climate change in order to protect the state's economy, health, environment, and way of life. The Department of Land and Natural Resources (DLNR) and the Office of Planning were assigned as co-chairs of the committee. One of the first acts of the ICAC will be to develop a statewide sea level rise vulnerability assessment and adaptation report.

Threats

Reduction in Rainfall and Fresh Water

Figure 5.2. The forested mountains play a key role in capturing rain and fog, mitigating flash flooding and recharging groundwater. Photo courtesy of Chip Fetcher.

Perhaps nothing is more critical to life in the islands than rain, and in Hawai‘i shallow cumulus clouds formed by trade winds that are blown across the Pacific and intercepted by our forested mountains are the most reliable and abundant source of rainfall and fresh water (Figure 5.2). Atmospheric circulation in the tropical Pacific has decreased because of global climate change, and although it is still unclear how Hawaiian trade winds will change in the future, the results of modeling studies indicate that rainfall will decrease. Indeed, studies of records confirm that rainfall has steadily declined (about 15%) over the past two decades.[3, 8] Global climate models predict that net precipitation at sea level near the Hawaiian Islands will decrease during the cool season (November through April) an additional 4–6% by 2100, with no significant change during the drier summer months (May through October).[1] More specific modeling done for Hawai‘i predicts, on average, a decrease in rainfall and reduced availability of freshwater resources.[6] The modeling predicts that most areas will experience a decrease in wet-season rainfall, with the exception of the trade wind–dominated wet regions along and above the eastern slopes of the mountains, which are expected to see slight increases or remain stable in rainfall amounts. The leeward, climatically dry areas of the islands are predicted to have drier-than-normal conditions during both the wet and dry season.

Rain recharges groundwater aquifers, which are the principal sources of municipal water supplies in Hawai‘i. Groundwater also feeds Hawai‘i's streams and provides water for agriculture and aquaculture systems. However, base stream flow supplied by groundwater discharge has declined around the state since the early 1940s, likely because of decreased rainfall.[3, 9]

Another concern is the potential for increased rates of evapotranspiration (the emission of water vapor through the leaves of plants) in the presence of higher air surface temperatures. Higher evapotranspiration rates would return more water to the atmosphere and reduce the amount going into streams and groundwater. Effects of warming on evapotranspiration are as yet unknown, but changes could further affect water resources that are already being affected by reduced rainfall.[5]

Impacts of Rising Air Temperatures and Reduced Rainfall on Forest Health and Biodiversity

In Hawai‘i, rainfall and extreme topography result in unique ecosystems that support a diversity of plants and animals. The combination of decreased rainfall and rising air temperatures threatens these ecosystems and the diversity they support. The potential effects of climate change on the state’s biodiversity are of particular concern considering that many of Hawai‘i’s endemic species are specialists, restricted to small geographic areas with limited populations (Figure 5.3).

Figure 5.3. Maui parrotbill, *kiwikiu* (*Pseudonestor xanthophrys*), is a forest bird likely to be displaced because of climate change. Photo courtesy of Robby Kohley.

In Hawai‘i, temperature increases are not consistent at all elevations. For example, at elevations below 2,600 feet, the recorded increase per decade of 0.16°F is less than the global rate of about 0.36°F per decade; however, the increase per decade at elevations above 2,600 feet, 0.48°F per decade, is greater than the global rate. The rapid warming trend at high elevations is a significant threat for a number of reasons. First, most remaining intact native forests occur at higher elevations. Second, most native land birds are restricted to cool, high-elevation forests, which are inhospitable to the non-native diseases and their vectors that have devastated the Hawaiian avifauna at lower elevations.[10] Warming will result in a reduction of disease-free forest area. Finally, the warming pattern will likely result in reduced rainfall at higher elevations because of a reduction in the width of the inversion layer, or cloud zone, which is a source of rain and fog drip. This will prevent the establishment of forest above the current tree line,[11] and only plants that can tolerate drier conditions will persist.

Micro-habitats that support rare plants and animals are often isolated, and natural migration (without human intervention), in many cases, is unlikely and would be catastrophic in some cases. For instance, all 10 remaining at-risk Hawaiian forest bird species will lose more than 50% of their disease-free high-elevation range by 2100. Three of these on Kauaʻi, the *ʻakekeʻe* (*Loxops caeruleirostris*), *ʻakikiki* (*Oreomystis bairdi*), and *puaiohi* (*Myadestes palmeri*), will lose all high-elevation range. Three others, Hawaiʻi *ʻakepa* (*Loxops coccineus*), *ʻakohekohe* (*Palmeria dolei*), and Maui parrotbill, *kiwikiu* (*Pseudonestor xanthophrys*), will lose 90% of their range.[10] Likewise with native plants: modeling suggests that numerous species are vulnerable and unable to respond as necessary to persist under climate change and either tolerate projected changes, endure in microrefugia, or migrate to new climate-compatible areas. Of particular concern are those that will have no compatible-climate areas remaining by the year 2100. These tend to be species of conservation concern because they also are threatened by non-climatic factors such as competition, predation, land-use changes, or limited geographic range. Species associated primarily with dry forests have higher vulnerability scores than species from any other habitat type. Coastal species and species with decreasing range size are also more vulnerable to climate change impacts.[12]

Greater Risk of Larger and More Frequent Wildfires

Although it remains unclear how wildfire behavior and frequency will change in Hawaiʻi as a result of climate change, studies in the western mainland U.S. have found that warmer temperatures are increasing the frequency, intensity, and duration of large fires.[13] Warmer, drier weather causes fires to spread more quickly, particularly when associated with high winds. In Hawaiʻi, rainfall is expected to decrease during the winter and early spring months (historically, the rainy season), a change that may lead to a longer wildfire season. Such an increase in the duration of wildfire season has already been observed in Western states.[13] In addition to the increased suppression costs and potential economic damages, changes in fire size and frequency would affect vegetation distribution and forest conditions, and generally would increase risks to property, natural resources, and human life.

More Severe Tropical Storms and Increasing Rain Intensity

Although global climate change will result in a reduction in fresh water, the intensity of storms will likely increase. Typhoons and hurricanes will become more forceful, with larger peak wind speeds and greater precipitation.[1, 3] Warming will cause the global average intensity of tropical cyclones to increase by 2–11% by 2100. Modeling consistently projects decreases in the global average frequency of tropical cyclones, by 6–34%, but the frequency of the most intense cyclones is predicted to increase.[14] Although global models generally predict a decrease in the number of cyclones worldwide, more specific and recent modeling for Hawaiʻi indicates that, by the last quarter of this century, Hawaiʻi could see a two-to-three-fold increase in tropical cyclones.[15, 16] Such storms can devastate forests as well as threaten Hawaiʻi's communities and infrastructure. Damage from high winds associated with hurricanes will exacerbate changes to forest structure and species composition, spread exotic species, affect critically endangered plants and animals, reduce carbon storage, and elevate vulnerability to fire.[17] In 1992, Hurricane *Iniki* forcefully demonstrated the destructive force of cyclones on Hawai‘i when it struck Kaua‘i with sustained winds of 130 miles per hour and caused more than $2.3 billion in property damage.[18] Healthy coastal forests can play a significant role in reducing the impact of storm events, including damage associated with storm surges and tsunamis. *(See "Issue 4: Urban and Community Forestry," for additional information.)*

Rain intensity is also increasing. Between 1958 and 2007, the amount of precipitation in the heaviest 1% of all rainstorm events in Hawai‘i increased by approximately 12%.[19] Intense rains result in flash flooding, mudslides and debris flows, road and business closures, infrastructure damage, and loss of public services, especially to isolated communities. In March 2006, 41 straight days torrential rains caused more than $80 million dollars of damage in Mānoa Valley and Lā‘ie on O‘ahu, cut off town of the town of Hana from the rest of Maui for weeks, and swept houses off their foundations in Hilo, Hawai‘i. Although these events cannot be directly tied to global climate change, they illustrate the severe impacts associated with intense rains.[5]

Impacts of Sea Level Rise on Beaches, Coastal Forests, and Human Communities

Figure 5.4. Unusually high tides, like this one on Waikiki Beach, will become more frequent as sea level rises affect coastal infrastructure and displace coastal plant communities. Photo courtesy of Chip Fletcher.

According to the IPCC's Assessment Report 5, at the current rate of greenhouse gas production, global mean sea level is likely to rise 1 foot by mid-century and over 2 feet by the end of the century.[20] Hawai‘i and other central Pacific islands are expected to experience significantly greater-than-average sea level rise.[21] The consequences of sea level rise for Hawai‘i are severe compared to many other coastal states, because the majority of our population and public infrastructure is located on low-lying coastal plains that are highly susceptible to coastal hazards.

Long-term sea level rise will exacerbate coastal erosion, coastal flooding, and drainage problems, all of which are occurring in Hawai‘i (Figure 5.4). Sea level in Hawai‘i has risen at approximately 0.6 inch per decade over the past century[22] and probably longer.[23] This long-term trend has increased the effects of short-term fluctuations in coastal sea level and tides, leading to episodic flooding and erosion along the coast.[24] Shoreline retreat, larger storm surges, and water-table salinization will likely diminish the health and integrity of forests and wetlands close to sea level.[25] For coastal native plant communities, modeling suggests numerous species will be vulnerable by 2100, particularly those that have no compatible climate areas remaining. Coastal species, and particularly those species already of conservation concern and with decreasing or limited range size, are more vulnerable to climate change impacts according to the climate change modeling.[12]

Although coastal erosion occurs for a variety of reasons, and is not uniquely tied to climate change, high sea levels will likely exacerbate this problem. Waves, currents, and human structures are the principal causes of erosion. Sea level rise increases erosion, potentially affecting beaches that were previously stable. Chronic erosion of developed lands has led to seawall construction, resulting in beach loss.[26] Approximately 25% of beaches on O‘ahu have been narrowed or lost because of seawall construction. Losses are similar on other islands, where the average long-term rate of coastal erosion is about 1 foot per year.[27] On Kaua‘i for instance, 72% of beaches are chronically eroding, and at 24% of these, erosion is accelerating.

Because of global climate change, sea level rise is expected to continue and accelerate for several centuries. Research indicates that sea level may exceed 3 feet above the 1990 level by the end of the 21st century.[28] Continued sea level rise will increase marine inundation of coastal roads and communities. Saltwater intrusion will intensify in coastal forests, wetlands, and groundwater systems, agricultural land, estuaries, and elsewhere. Although extreme tides already cause drainage problems in developed areas, Hawai‘i communities located at the confluence of intensifying storm runoff and rising ocean waters will experience increased flooding.[5]

Pressure on Resources Important to Recreation and Tourism

The state’s largest industry, tourism, depends on scenic beach parks, coral reefs, fisheries, and unique montane forest and coastal ecosystems (Figure 5.5). Higher sea levels, as well as accelerated beach erosion, greater damage from sea surges and storms, and reduced water supply, will likely affect the coastal tourism economy.[29] Two additional climate-related factors, increasing sea surface temperature and ocean acidification, are likely to affect marine ecosystems and thus also will affect the economy.

Figure 5.5. Healthy coral reefs are vital to our economy, our environment, and our culture. Photo courtesy of Chip Fletcher.

Marine researchers at the University of Hawaiʻi and cooperating institutions have measured an increase of sea surface temperature of 0.22°F per decade. Because of global climate change, this rate is likely to rise, exposing marine ecosystems to negative impacts, including coral bleaching.[30] Coral bleaching and disease, brought on by climate change and events like El Niño, are the largest threats to coral reefs around the world.[31] These climate-related impacts are already beginning to affect Hawaiʻi. Two bleaching events have occurred in Hawaiʻi in the past 2 years. The first began in 2014, when a widespread coral bleaching event occurred throughout the state as sea temperatures spiked at 86°F. Coral in shallow waters off Oʻahu, Kauaʻi, Molokaʻi, and Maui were affected, and severe bleaching was also observed on several reefs in the Northwestern Hawaiian Islands, where certain sites suffered 85 to 100% mortality.[32] Bleaching continued in 2015 across the entire archipelago, from Kure Atoll to the Big Island.[33]

Coral bleaching has become a widespread problem, affecting reefs across the state and worldwide. Although corals can recover from mild bleaching, severe or long-term bleaching is often lethal. After corals die, reefs quickly degrade and the structures corals have built erode. This provides less shoreline protection from storms and fewer habitats for fish and other marine life, including ecologically and economically important species. Warmer ocean temperatures associated with El Niño were forecast to continue into 2016, with continued bleaching a possibility.[31] The Main Hawaiian Islands were under a coral bleaching watch alert from July into October 2016, with the potential for low-level thermal stress, but as of October, sea surface temperatures had remained below the bleaching threshold.[34]

Increasing ocean acidification is another threat to coral reef and marine ecosystems. As rising carbon dioxide in the atmosphere mixes with seawater, the ocean acidifies. Measurements taken at station ALOHA over two decades document that the surface ocean around Hawaiʻi has grown more acidic.[35] Increases in seawater acidity reduce the availability of dissolved carbonate, vital to shell and skeleton formation in corals, shellfish, and other marine organisms, putting at risk the entire ocean food web. This rapidly emerging issue has raised concerns across sectors because declining coral reefs will affect coastal communities, tourism, fisheries, and overall marine biodiversity.

Trends

Management of Forests in Response to Climate Change

If managed properly, Hawaiʻi's forests will help to mitigate the effects of climate change and promote adaptation and resilience for Hawaiʻi's communities.[36] The commitment of the state to protect and manage high-priority watershed forests under the state's *Rain Follows the Forest* plan and the governor's *"30 by 30 watershed forest target"* initiative under the Aloha+ Challenge is a positive trend that will help to mitigate the anticipated effects of a decrease in rainfall and reduced availability of freshwater resources due to climate change. *(See "Issue 1:*

Water Quality and Quantity," for additional information). Other positive trends that are occurring in the state that will help mitigate climate change include development of biomass and biofuel facilities to reduce use of fossil fuels and initiation of reforestation projects (for habitat restoration or forest product development) that sequester carbon.

Climate Change Mitigation

Tropical forests, such as those on Pacific Islands, can help curtail climate change by sequestering carbon from the atmosphere and storing it in trees, understory vegetation, and soil. Globally, forests contain 1.2 trillion tons of carbon, just over half the total in all terrestrial vegetation and soils.[37] Forests take in carbon at a rate that is determined by a number of factors, including the type of forest, its location, and its age. Tropical forests are able to take in and store carbon at a greater rate than boreal forests. The IPCC estimates that about 65% of the total mitigation potential of all forests is located in the tropics and about 50% of this total potential could be realized by reducing deforestation.[38]Although deforestation is not a major source of greenhouse gas emissions in Hawai‘i, the state could develop sound sustainable forestry strategies that maximize carbon sequestration and storage and share these best practices with other Pacific Islands. *(See "Issue 8: Forest Products and Carbon Sequestration," and "Issue 9: U.S. Tropical Island State and Territorial Issues," for additional information.).*

Another way that Hawai‘i's forests can help reduce carbon emissions is through development of biomass facilities to meet future renewable energy needs. Development and use of dedicated biomass crops such as *Eucalyptus* or opportunistic use of invasive trees such as albizia (*Falcataria moluccana*) to generate electricity could replace oil-fired electrical generation, which is a major contributor to carbon emissions in the state.[39] Although operation of a biomass facility would generate carbon dioxide, emissions from biomass facilities historically have been considered to be carbon neutral, based on the premise that the atmospheric carbon absorbed in the growing trees equals or is greater than the carbon emitted when burnt for fuel, resulting in no net increase of carbon to the on-going carbon cycle. Therefore, the burning of biomass should not be considered an increase in greenhouse gases. By comparison, the combustion of fossil fuels such as oil emits carbon that has been out of the current carbon cycle for millennia and therefore does contribute to an increase in greenhouse gases.[39]

In this scenario, a 10-megawatt biomass facility would produce about 70,000 megawatt-hours of electricity per year and reduce oil consumption from electricity generation by about 4.7 million gallons, with a corresponding reduction of greenhouse gas emissions of about 43,000 metric tons CO_2 equivalent.[39] Similarly, use of biomass to produce biofuels and replace imported fossil fuels for transportation would provide a benefit in reducing greenhouse gases.

Climate Change Adaptation

Healthy forests and sustainable forest management can decrease the vulnerability of Hawai'i's communities to the impacts of climate change. Tropical deciduous forests have been shown to regulate floods associated with cyclones. A long-term ecological study in the Chamela Region on the Pacific Coast of Mexico reported that, in tropical deciduous forests, a constant leaf litter layer on the forest floor protects the soil from the direct impact of raindrops associated with cyclones that regularly hit the area.[40] The leaf litter helps maintain high infiltration rates in the soil, preventing runoff and soil erosion, and thus reducing floods. Studies also suggest that loss of forest vegetation increases vulnerability of human populations to landslides and storm surges during tropical cyclone events.[41]

Healthy forests and wetlands help protect coastal communities and infrastructure in other, less obvious ways as well. Forests can rehabilitate degraded land and maintain water quality by trapping sediments, taking up nutrients, and immobilizing toxic substances. Thus, forests and wetlands help cool streams and fresh water discharged into estuaries and bays, and reduce land-based sources of erosion, runoff, and the transport downstream of pollutants, which are the primary causes of coral reef ecosystem degradation.

Besides degrading reefs, sedimentation and marine pollution can also be a cause of the failure of coral to recover after a mass bleaching event. When a mass bleaching event occurs, recovery is very slow and dependent on new, young corals settling and growing on the reef. Re-growth of reefs that have been severely damaged by bleaching may take years. Recovery is especially difficult for reefs in locations suffering from other stresses such as siltation, pollution, or smothering by invasive algae. Coral reefs are a source of subsistence fishing and harvesting, as well as of vital tourist income for island destinations. They are frequently essential in protecting low-lying islands, such as those in the Pacific and Indian Oceans, from storm surges, sometimes where human-made protection is unlikely to succeed.

Although forests and other ecosystems have the potential to reduce the impacts of climate change on human communities, many of Hawai'i's ecosystems are currently threatened by a number of stressors, including invasion by non-native species and expanded human development. Continued and improved efforts to promote biodiversity and forest health may help facilitate ecosystem adaptation to climate change. For example, eliminating invasive weed species and reestablishing native plants will help preserve the availability of fresh water in forests, as well as prevent the spread of avian diseases.[42] *(See "Issue 2: Forest Health: Invasive Species, Insects, and Disease," and "Issue 6: Conservation of Native Biodiversity," for additional information.)*

Priority Issues and Areas for Climate Change and Sea Level Rise

Effectively addressing the large-scale nature of climate change at an ecologically meaningful scale will require close coordination within and between state and federal agencies. The clear evidence of a changing climate and the increasing acceptance among the public and political and business leaders has catalyzed new policies, programs, and initiatives.[43] Collaboration is occurring among state and local agencies, nongovernmental organizations (NGOs), the private sector, scientists, universities, and federal partners to develop workable solutions to climate change problems, including adaptation and mitigation strategies, but the task requires a significant commitment of staff and resources.

As listed below, several state and federal agencies, NGOs, and the University of Hawaiʻi are involved in research, planning, and coordination of policy and programs to address natural resource–related climate issues in Hawaiʻi:

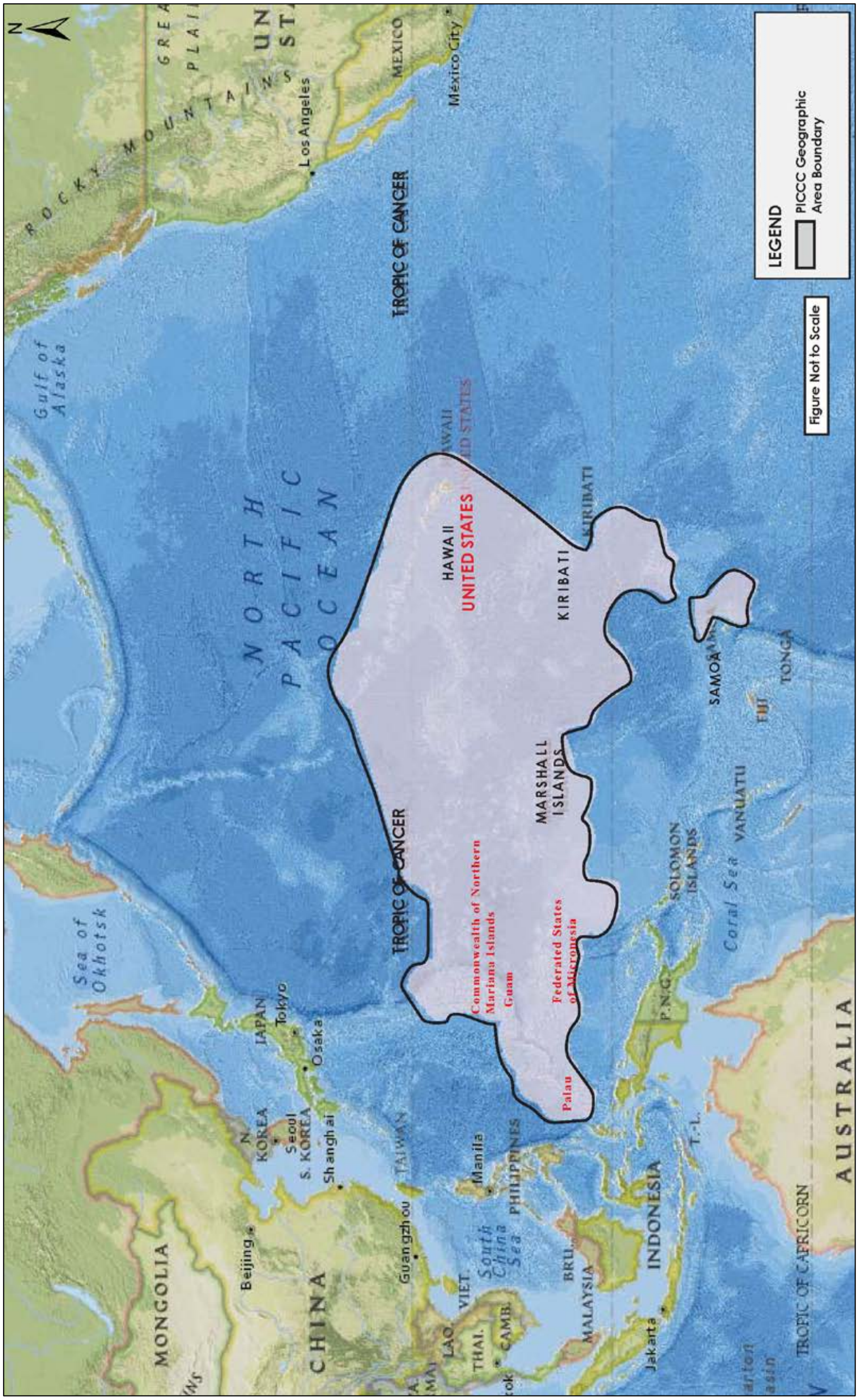
- ICAC, established by the Hawaiʻi Climate Adaptation Initiative Act (Act 83, Session Laws of Hawaiʻi, 2014) to address the effects of climate change in order to protect the state's economy, health, environment, and way of life
- Office of Planning, Coastal Zone Management Program, Ocean Resources Management Plan (ORMP) working group
- Center for Island Climate Adaptation and Policy (ICAP), University of Hawaiʻi Sea Grant College Program, School of Ocean and Earth Science and Technology
- Pacific Islands Climate Change Cooperative (PICCC)—one of the 22 national Landscape Conservation Cooperatives
- Institute of Pacific Islands Forestry (IPIF), U.S. Forest Service
- Pacific Island Ecosystems Research Center, U.S. Geological Survey
- Regional Climate Service Center, Pacific Region of the National Oceanic and Atmospheric Administration (NOAA)
- Pacific Islands Climate Science Center, U.S. Geological Survey
- Hawaiʻi Conservation Alliance (HCA)
- State and federal natural resource management agencies
- University of Hawaiʻi programs and researchers

Each of these and many others are contributing to moving the state forward in regard to managing the impacts of climate change. Examples of collaborative efforts include guidance documents such as *A Framework for Climate Adaptation in Hawaiʻi*,[43] developed by the ORMP working group and ICAP to encourage and facilitate the adaptation planning process. Another example is the partnership between HCA and PICCC (Map 5.1 shows the region addressed by

PICCC). Together, HCA and PICCC are developing scientific assessments of climate change impacts on physical and ecological systems at a scale relevant to conservation planning.[44] HCA has developed another program, the Effective Conservation Program, so that its member agencies and the public may assess and plan Hawaiian biodiversity conservation.[45] Through the program, member agencies and the public can identify and select viable biodiversity targets, achieve protective designation for them, engage in active management of threats, and build strong stakeholder support for conservation. When the program is used with climate change modeling, it may help guide management strategies to reduce the impacts of climate change on biological communities. This tool is helpful in identifying important habitats on which to focus monitoring and where adaptive management can be used to minimize or mitigate the impacts of climate change on natural resources.

The research, management, and planning entities listed above have produced numerous studies, vulnerability assessments, predictive models, and management recommendations to advance the awareness and understanding of tools and actions needed to protect natural resources from adverse changes associated with climate change. With additional support and collaboration, state and local entities and federal and community partners can develop statewide adaptation strategies and adjust management practices to ensure a sustainable future for Hawai‘i.

As the climate changes, it will be difficult or even impossible to achieve forest management and resource conservation goals that are dependent on static conditions. Future goals and decisions should therefore be informed by current data and projected future climate conditions and explicitly address whether they aim to lessen the impacts of climate change on natural and human systems, promote resilience, accommodate changing conditions, and/or mitigate climate change. Because of the uncertainty and complexity of climate change, future planning and decision processes should be iterative to allow for informed decisions and early implementation of adaptive strategies. Where there is a high level of uncertainty about specific impacts, agencies should focus on “no regrets” conservation actions—those likely to be beneficial regardless of future climate conditions. These can include reducing non-climate forest stressors, managing for ecological function and biodiversity, and maintaining and restoring coastal resources.[46] An emerging need is to develop appropriate decision-making tools that can help assist managers in making the best decisions. These tools can also help to engage the public and gain support for needed actions.



Map 5.1. PICCC Geographic Area.

One of the most pressing and immediate issues is how to deal with sea level rise. Sea levels are projected to rise 2 to 3 feet this century, and low-lying coastal areas will be periodically or permanently inundated, with impacts on coastal wildlife habitats, ports, and infrastructure.[44] The Hawaiian islands are relatively small, with population centers located along the flat coastal areas. Most economic activity also occurs in close proximity to the ocean: Waikīkī Beach is by far the most important source of employment and revenue in the state, and the commercial shipping facilities and Honolulu International Airport are all located on the coast, as are many power generating facilities, oil refineries, and sewage treatment plants. Some of the nation's most strategically important assets, including Kāne'ohe Bay Marine Corps Base, Pearl Harbor Naval Station, and Pearl Harbor Naval Shipyard, are also located on the coast. The emerging consensus in Hawai'i and the Pacific Islands is that we will face a suite of challenges related to climate change, but that the most immediate threat, and the one that we must directly address, and soon, is sea level rise. Recognizing this need, the Hawai'i Climate Adaptation Initiative Act directed ICAC to develop a statewide sea level rise vulnerability assessment and adaptation report as its first priority. The drafting of that report is currently in progress.

Another issue to address is our preparedness and capacity for emergency response, both in the urban area and in managed forest lands. There will need to be an increase in capacity and ability to respond to more frequent and larger storms, drought, fires, and other public safety emergencies. More frequent tropical storms and hurricanes will cause increased flooding, treefall, and damage to infrastructure and facilities and natural resources, and rescue and public protection services will require more agency support and resources. DLNR's Division of Forestry and Wildlife has a good foundation and capacity to use the Incident Command System for emergency response and incident management. It can also provide training in these tools to partners.

One other aspect of dealing with increased disturbance related to climate change is our capacity to restore damaged areas. Landscape-scale damage that can occur with storms and fires presents an opportunity to restore areas to improve their status, condition, conservation value, and ability to withstand future climate-related natural disasters.

Because the potential for uncertainty and controversy associated with climate change could be high, state agencies should consider public participation planning and strive to improve the public's understanding of the impacts of climate change. Gaining public support or acceptance is a prerequisite for making successful adjustments in management plans and policies in response to observed or anticipated climate changes. The *Hawai'i Environmental Literacy Plan*[47] has identified goals and objectives to improve both youth and adult educational opportunities, to enhance knowledge and understanding about the environment and conservation and, in particular, about climate change. How this plan's goals and objectives integrate with forest management and climate change is identified in the strategy matrix for climate change and sea level rise.

Data Gaps and Opportunities

Monitoring of Resource Vulnerability to Climate Change

Despite the certainty that climate change is underway and having an impact on natural resources, there are still many unanswered questions about how these climate effects will play out at local, state, and regional scales and how ecosystems will respond to those changes. Determining which natural and human systems are most at risk from climate change can guide our future management decisions. We can no longer plan based solely on historical data because climate change is a moving target, requiring continuous monitoring.

Successful adaptation strategies in Hawaiʻi will require that we gain intimate knowledge of local economies, cultures, and ecosystems and pay attention to changes such as carrying capacities, wildfire, climate-driven immigration, disease vectors, and invasive species. Observing trends and modeling the future impacts of climate change on forest systems and resources will require localized data collection. It is imperative to set up instrumentation to close existing climate and biodiversity data gaps and to monitor climate and ecosystem variables in the future.

Improved and Down-Scaled Modeling

Though some climate models exist for the Pacific region, the diversity of microclimates in Hawaiʻi presents a challenge for predicting future climate impacts on landscapes. We need down-scaled models that anticipate climate change scenarios at specific locations and microclimates, such as urban and coastal zones, and areas that support unique native ecosystems and species, such as dry forests and anchialine pools. In addition, to find the most effective management solutions, it is important to assess the effects of climate change under multiple climate scenarios.

Complex systems, in particular, need improved modeling. Fire is a major mediator of terrestrial climate, yet there are presently few models that predict the impacts of climate change on wildfire and suppression effectiveness in Hawaiʻi. Likewise, we have little information about how changes in climate will affect the threat of invasive species and our strategies for control.

Another example of a complex, changing system that requires careful monitoring and improved modeling efforts is sea level rise. This complexity is due, in part, to the fact that winds and ocean currents affect sea level, and all of those are changing as well.[5]

Using climate scenario modeling and ecological knowledge, we can identify potential climate change impacts on natural systems, community and environmental infrastructure, operations across planning sectors, and key resources on which Hawaiʻi's residents and communities depend. It is necessary to: (1) determine the degree to which natural and built systems will be directly or indirectly affected by changes in climate conditions; and (2) assess their ability to accommodate changes in climate with minimal disruption or minimal additional cost. A vulnerability assessment, conducted collaboratively, would accomplish these two goals and indicate the susceptibility of systems to harm from climate change impacts. This type of assessment would help in the process of prioritizing areas on which to focus climate adaptation efforts and funding.

Information Management

Because no one agency can collect the variety and amount of data necessary to monitor climate and ecosystem changes, sharing information among partners is important in planning for climate change adaptation and for coordinating landscape-scale conservation. A central clearinghouse of current climate change data and publications documenting best management practices for climate adaptation could serve as a tool for managers in many sectors of government, NGOs, and community groups. PICCC and HCA currently provide some of these services, but the extent to which specific island-based products, data, and access for managers and the public are provided can be expanded.

Additionally, an effective information and education program is needed to inform the public and policymakers about the impacts of climate change on natural and cultural resources and to garner their support for the actions and resources that will be needed to best protect and sustain resources for the future.

Long-Term Monitoring

The network of long-term climate change monitoring stations and research and monitoring programs needs to be expanded to cover all the key ecosystems and geographic areas of the state to provide a clear picture of how climate change is affecting resources and communities and the effectiveness of adaptive management to mitigate impacts.

Also, there remains some uncertainty about the carbon neutrality of using biomass as a replacement for fossil fuels.[39] The U.S. Environmental Protection Agency is developing final permitting rules for biogenic carbon dioxide emissions. Even so, research and monitoring is needed to determine and document the value of using locally grown biomass (instead of imported oil and coal) for electricity generation and transportation fuels, and to document the amount of carbon dioxide and greenhouse gas emissions offset in the process.

Summary

Hawai‘i’s climate is changing in ways that are consistent with the influence of global climate change. Climate projections for Hawai‘i anticipate an increase in mean annual air temperature of approximately 1.5°F to 5°F and a decrease in rainfall with leeward, climatically dry areas of the islands predicted to have drier than normal conditions during both wet and dry seasons. These changes in Hawai‘i’s climate are expected to reduce the amount of fresh water available; decrease Hawai‘i’s forest health and biodiversity; increase the frequency, size, and intensity of wildfires; increase the amount of flash flooding, the number of landslides, the extent of agricultural losses, and the extent of infrastructure damage; and negatively affect beaches, coral reefs, and key marine resources on which the state’s economy depends. Global climate change also is expected to cause sea level rise and larger storm surges, which will inundate low-lying islands and shorelines, causing coastal erosion, flooding, and damage to coastal communities and infrastructure.

Proper management of Hawai‘i’s forests can help to mitigate the effects of climate change and promote adaptation and resilience for Hawai‘i’s communities. Protecting and managing high-priority watershed forests helps to maintain freshwater resources and biodiversity; protecting coastal forests and wetlands protects coastal communities and infrastructure from flooding and storm damage; and maintaining healthy forest overstory, understory, and ground cover reduce erosion and pollutant runoff onto coral reefs. Maintaining tropical forests, such as those on Pacific islands, can help curtail climate change by sequestering carbon from the atmosphere and storing it in trees, understory vegetation, and soil. Many state and federal agencies, nongovernmental organizations, and the University of Hawai‘i are involved in research, planning, and coordination of policy and programs to address natural resource–related climate issues. Implementing strategies to protect forests and human communities will require a high level of collaboration and cooperation among state and local agencies and federal and community partners and increased levels of monitoring, ecological knowledge, modeling, and information sharing among partners.

Strategies for Issue 5: Climate Change and Sea Level Rise

Climate Change: Identify Missing Data, Assess Trends, Develop Adaptation Strategies								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Develop and implement a coordinated statewide instrumentation, research, and monitoring strategy to identify data gaps and enhance data collection and monitoring systems. If possible, make analyzed data available and accessible to the general public.	Statewide.	Affect future policy pertaining to use and practices in upland, coastal, and marine areas; focus on broad env. ed. messages.	Fire and aviation, forest health protection, UCF, conservation education, schools, volunteer groups, LSR.	HCA, PICCC, USFWS, NPS, USDA, HDOA, DOT, TNC, NOAA Office of Ocean and Coastal Resource Management, NOAA National Weather Service, DOD, CWRM, SOEST, USGS, NWHI, EPA, USACE.	USFWS (on NWHI), USGS, SOEST, NOAA and National Weather Service, NASA, FS, IPIF, USACE, CAO, DAR.	New instrumentation, research, monitoring, and understanding for improving the evaluations of local and regional trends in climate and ecosystems; new monitoring that fills existing gaps in baseline knowledge of Hawaiian biodiversity; monitoring systems are sufficient for assessing the effectiveness of management activities designed to facilitate climate adaptation.	1.1 2.2 3.3 3.6 3.7	1.2 1.4 1.5
2. Assess the vulnerabilities, risks, and opportunities for protecting and maintaining important resources, rare climate-sensitive species, infrastructure, and ecosystems, using knowledge of trends and future scenarios of climate change.	Urban and coastal zones, Conservation District, watersheds, native ecosystems supporting species sensitive to climate change, coral reefs.	Affect future policy pertaining to use and practices in upland, coastal, and marine areas; develop material for better grant applications; create resource for educators to use in teaching about climate change and its impacts.	UCF, forest health protection, watershed partnerships, fire and aviation, EQIP, Forest Legacy, LLCP, FSP, CREP, FSCG.	HCA, NOAA Office of Ocean and Coastal Resource Management, NOAA Pacific Services Center, OHA, DOD, HTA, USFWS, NPS, DOT, OP, HDOA, TNC, DPCH, DPCM, DPCK, BWS, C&CH DOH, MCZAC, USACE, USCG, UH Sea Grant Program.	PICCC, IPIF, ICAP at UH, DOFAW, DAR.	Vulnerability assessments that describe exposure, sensitivity, and capacity to adapt to climate change scenarios for ecosystems, resources, and landscapes; program areas prioritize actions with the most beneficial outcomes based on risk analyses and assessments of how land management activities can contribute toward facilitated adaptation.	1.1 2.2 3.3 3.6 3.7	1.2 1.4 1.5

Strategies for Issue 5: Climate Change and Sea Level Rise

Climate Change: Develop Adaptation Strategies and Outreach Activities

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Develop and implement facilitated adaptation strategies for forest and resource conservation management. Increase resiliency of forests to withstand climate change impacts, mitigate impacts of severe storms and other climate events, and monitor effectiveness. Continually incorporate new information and adjust actions as needed.	Urban and coastal zones, Conservation District, forested watersheds, native ecosystems supporting species sensitive to climate change, coral reefs.	Develop best management practices for climate change remediation, minimization of adverse impacts on climate-sensitive species and habitats, conservation of rare species and ecosystems, reduction in sediment on coral reefs, and minimization of impacts on coastal and riparian areas.	Urban and community forestry, forest health protection, watershed partnerships, fire and aviation, EQIP, forest stewardship, CREP, Forest Legacy, USDA competitive grant proposal, LSR, DAR Coral Reef Program, and water quality programs of CZM, DOH, EPA, and NOAA.	HCA, NOAA, DAR, OHA, DOD, HTA, USFWS, NPS, DOT, OP, HDOA, TNC, MCZAC, DOH, USACE, USCG, UH Sea Grant Program, DPCH, DPCM, DPCK, BWS, C&CH.	ICAP, PICCC, USFWS, UHSOE, IPIF, HAWP, watershed partnerships.	Adoption of a statewide climate change adaptation plan; implementation of actions intended to prevent serious disruptions in forests and ecosystem services due to changing climate; implementation of actions that take advantage of human-made or natural disturbance events to facilitate adaptation to future climate; re-iterative processes, continual monitoring, and the use of new science in planning, policies, and implementation decisions.	1.1 1.2 2.2 3.1 3.5 3.6 3.7	1.5 2.3
2. Help landowners, conservation managers, and the public understand changing conditions. Establish strong alliances and partnerships with other programs, agencies, and stakeholders to ensure a coordinated and collaborative approach to climate change adaptation. Provide support for increased understanding on socio-economic impacts of climate change.	Statewide.	Develop new and creative incentive programs for private landowners, promote community participation in watershed conservation, and develop climate change mitigation projects.	Conservation education, forest health protection, urban and community forestry, fire and aviation, EQIP, FSP, CREP, USDA competitive grant programs (LSR), UCF, HISC, CGAPS, watershed and water quality programs.	Coastal industries, landowners, schools, HTA, HCA, NOAA Office of Ocean and Coastal Resource Management, NOAA Pacific Services Center, USFWS, NPS, USACE, TNC, UH Sea Grant Program.	FSP, conservation education, PICCC, UH, NRCS, USFWS, HCA, HFIA, schools, community groups, env. ed. orgs.	Number of trained individuals, specializing in climate change adaptation and mitigation, who educate landowners, managers, and the public; institutional and public support and encouragement for implementing innovative approaches for facilitated adaptation; strategies, policies, and actions for addressing climate change are integrated across all programs areas. Implementation of the Hawai'i Environmental Literacy Plan.	2.2 3.1 3.3 3.6 3.7	All goals in HELP, especially 1.2 1.4 1.5 2.1.b 3.1 3.2 3.3

Strategies for Issue 5: Climate Change and Sea Level Rise

Key:
BWS = Board of Water Supply
C&CH = City and County of Honolulu
CAO = Carnegie Airborne Observatory
CGAPS = Coordinating Group on Alien Pest Species
CREP = Conservation Reserve Enhancement Program
CWRM = Commission on Water Resources Management
CZM = Coastal Zone Management
DAR = Division of Aquatic Resources
DOD = State Department of Defense
DOFAW = Division of Forestry and Wildlife
DOH = State Department of Health
DOT = State Department of Transportation
DPCH = Department of Planning for County of Hawai‘i
DPCK = Department of Planning for County of Kaua‘i
DPCM = Department of Planning for County of Maui
env. ed. orgs. = environmental education organizations
EPA = U.S. Environmental Protection Agency
EQIP = Environmental Quality Incentive Program (a program of the NRCS)
FS = U.S. Forest Service
FSCG = U.S. Forest Service Competitive Grants
FSP = Forest Stewardship Program
HAWP = Hawai‘i Association of Watershed Partnerships
HCA = Hawai‘i Conservation Alliance
HDOA = Hawai‘i Department of Agriculture
HELP = Hawai‘i Environmental Literacy Plan
HFIA = Hawai‘i Forest Industry Association
HISC = Hawai‘i Invasive Species Council
IPIF = Institute of Pacific Islands Forestry
ICAP = Island Climate Adaptation and Policy
LLCP = Legacy Land Conservation Program
LSR = Landscape Scale Restoration
MCZAC = Marine and Coastal Zone Advocacy Council
NASA = National Aeronautics and Space Administration
NOAA = National Oceanic and Atmospheric Administration
NPS = National Park Service
NRCS = Natural Resources Conservation Service
NWHI = Northwestern Hawaiian Islands
OP = Office of Planning
PICCC = Pacific Islands Climate Change Cooperative
SOEST = School of Ocean and Earth Science and Technology
TNC = The Nature Conservancy
UCF = Urban and Community Forestry (Kaulunani)
UH = University of Hawai‘i
USACE = U.S. Army Corps of Engineers
USCG = U.S. Coast Guard
USDA = U.S. Department of Agriculture
USFWS = U.S. Fish and Wildlife Service
USGS = U.S. Geological Survey

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Issue 6: Conservation of Native Biodiversity

Overview

The Hawaiian Islands are the most isolated archipelago in the world, situated in the middle of the Pacific Ocean more than 2,000 miles from the nearest continent. Because of its extreme isolation and climatic conditions, Hawai'i is characterized by high levels of endemism in both its native animals and plants, with over 10,000 species found nowhere else on earth. Although thousands of Hawaiian species have yet to be described, the estimated number of native species is thought to include more than 14,000 terrestrial, 100 freshwater, and 6,500 marine taxa. For more than 70 million years, the evolution of new species vastly exceeded losses to extinction. However, after the arrival of humans to the islands, about 700 years ago, numerous extinctions have occurred and many more species are threatened. These losses include more than half of the endemic birds, including flightless ducks, rails, and ibis; hundreds of plant species; and possibly thousands of lesser-known taxa such as terrestrial insects and spiders that were lost before they ever were described.

Because of the extreme isolation, relatively few species have colonized the archipelago and only a subset of these successfully established populations over the islands' 70-million-year history. Those that did, however, found a diversity of habitat types owing to the archipelago's elevation and climate gradients. Extremely limited or no gene flow from their distant, original populations facilitated the rapid adaptation of colonists to their novel environments. For many such colonists, unique adaptations occurred simultaneously among populations isolated from one another, both within and between islands. Hawai'i provides a textbook example of adaptive radiation, the process by which many new species evolved from a single common ancestor in a relatively short time span.

Although representing less than 0.2% of the land area of the U.S., the Hawaiian Islands hold more than 40% of the nation's federally listed endangered or threatened species, comprising 454 taxa of plants and animals.[1, 2] Unique and varied habitats also are found across the islands. As a result, Hawai'i presents both an opportunity and a challenge for conservation.

In 2005, Congress required all states to develop a Comprehensive Wildlife Conservation Strategy (CWCS).[3] In Hawai'i, this provided the opportunity for resource managers to develop and modify a comprehensive planning process to help manage all of Hawai'i's unique native wildlife. In 2015, the state updated the CWCS, which is now referred to as the State Wildlife Action Plan (SWAP).[4] Hawai'i's SWAP lays the foundation for conservation of native wildlife and their habitats for the next 10 years. The SWAP assesses threats to species and their habitats and their conservation needs at three levels: statewide, island-wide, and taxa-specific. The SWAP recognizes the importance of protecting all native terrestrial animals, all endemic aquatic wildlife, other aquatic species threatened with decline, and a broad range of native flora. The plan identifies important species and habitats, objectives and strategies for their conservation, and a framework to measure the effectiveness of these strategies. On the ecological level, the SWAP takes a habitat management approach, adopting a landscape view that takes into account the complex inter-relationships between species and their habitats and the need for change and adaptability. By taking a proactive approach, Hawaiʻi's SWAP also takes a fiscally responsible approach. By emphasizing measures that benefit multiple species groups and habitats in which they reside, the SWAP represents an improvement over single-species management, aiding many species for the same cost. This plan builds on and synthesizes information gathered from existing conservation partnerships and cooperative efforts. Additionally, it highlights partnerships and their efforts in Hawaiʻi, with a goal of enhancing and expanding existing partnerships and creating new partnerships, ultimately increasing support for implementing Hawaiʻi's wildlife strategy.

The Department of Land and Natural Resources (DLNR) coordinated the development of Hawaiʻi's CWCS and its update (the SWAP), with joint cooperation by the Division of Forestry and Wildlife (DOFAW) and the Division of Aquatic Resources (DAR), which are charged with protecting the state's terrestrial and aquatic resources in collaboration with local, state, and federal agencies, nongovernmental organizations, private landowners, and interested citizens. The foundation for this assessment of Hawaiʻi's biodiversity is based on the best available science and up-to-date data on Hawaiʻi's habitats and species, contributed collaboratively by experts at DLNR and other agencies and organizations. The assessment provides an overview of the range of species found in Hawaiʻi and offers a number of strategies that could positively influence the conservation of biodiversity in these islands.

Benefits and Services

In present-day Hawaiʻi, the link between Hawaiian culture and native species continues to be demonstrated in belief systems as well as traditional practices such as gathering of native plants and animals for *hula*, traditional medicines, food, structural materials, carving, weaving, tool making, jewelry, and ceremonies. For many Hawaiians, the relationship with the land and native ecosystems is integral to their identity and sense of well-being. The special relationship that Hawaiians have with native species and ecosystems in the islands is perhaps best reflected in Hawaiians' increasing role in natural resource management in places such as Kahoʻolawe; Limahuli and Lumahaʻi Valleys on Kauaʻi; Moʻomomi, Molokaʻi; and Keauhou, Hawaiʻi, where traditional management practices such as *kapu* (taboo) and *ahupuaʻa* (watershed-scale) thinking predominate.

Native biodiversity is important to many forest users, Hawai‘i residents, and visitors to the islands. Local lifestyles include activities such as hiking, backpacking, snorkeling, boating, fishing, and hunting, all of which are enhanced by interactions with the native wildlife and ecosystems unique to the Hawaiian Islands. Based on a 2004 survey "Wildlife Values in the West," a large majority of Hawai‘i's residents (71.4%) strongly agree that it is important to take steps to prevent the extinction of endangered species.[5] Economically, wildlife viewing expenditures in Hawai‘i far exceed those of hunting and fishing,[6] and wildlife viewing is also an important part of the state's more than $14-billion tourism industry, the largest contributor to the state's economy.[7]

Hawai‘i's native wildlife species and their habitats also provide essential goods and services to residents such as water quality, soil stabilization, carbon storage, and climate control. A University of Hawai‘i study conducted in 1999 of the economic value of these services estimated that they are worth between $7.4 to $14 billion in the Ko‘olau Mountains on O‘ahu alone.[8] Specific examples of ecological services provided by native habitats include protection by coral reefs of beaches, homes, and businesses from erosion, storms, and tsunamis; filtration of the water supply, mitigation of pollution, and slowing of stormwater runoff by wetland habitats; and social and human health benefits gained through recreation in natural areas, exposure to natural beauty, and fostering of a spiritual connection to nature (*see "Issue 7: Hunting, Nature-Based Recreation, and Tourism"*). As the local wisdom of *kupuna* (elders) holds, the conservation of both land and water resources is inextricably tied together: unless we conserve our *mauka* (land) resources like our forests, *makai* (ocean) resources like *limu* (seaweed beds) and coral reefs will suffer.

Threats

The current, most pervasive threats to native biodiversity in Hawai‘i are plants, animals, and diseases that are non-native, invasive, and habitat-modifying, as well as the conversion of land to other uses. For many endangered species, small populations make recovery difficult. Other threats include some that are pervasive across all conservation areas in the archipelago and some that are specific to particular habitats or individual species or groups of species (Tables 6.1, 6.2, and 6.3). For example, fire, residential development, and military training are important threats at specific locations.

Table 6.1. Principal threats to native terrestrial habitats.

Terrestrial Habitat	Principal Threats
Alpine	Alien insects (e.g., Argentine ant)
Subalpine	Introduced ungulates: sheep, mouflon, pigs, goats, and cattle that browse native vegetation and disperse invasive plants
Montane wet	Rooting pigs (pigs also spread habitat-modifying invasive plants); unsustainable harvesting; conversion to pastureland

Terrestrial Habitat	Principal Threats
Montane mesic	Wildfire; conversion to pastureland or other agricultural uses (e.g., coffee farms); invasive grasses; feral goats, axis deer, cattle, sheep, and pigs; unsustainable harvesting and conversion to non-native tree plantings; residential development
Montane dry	Wildfire; invasive plants; grazing by feral goats, sheep, and mouflon; residential development; conversion to agricultural uses
Lowland wet	Establishment and spread of invasive plants, especially *kahili* ginger (*Hedychium* spp.)and strawberry guava (*Psidium cattleianum*); degradation of the understory by feral pigs; residential development; conversion to agricultural uses
Lowland mesic	Most has been converted to agricultural uses, including areas cleared for ranching or sugarcane or pineapple crops; subject to unsustainable harvesting practices; remaining is threatened by invasive plant species, wildfire, and feral ungulates and introduced game animals, particularly goats, pigs, and axis deer
Lowland dry	Most has been converted to urban and residential use; degraded by wildfire, grazing, and invasive grasses, particularly fountain grass (*Pennisetum setaceum*), beard grass (*Andropogon glomeratus* var. *glomeratus*) and natal red top (*Melinis repens*), which constitute a major fire threat
Coastal	Conversion to residential development; introduced plant species; off-road vehicles; arson
Subterranean	Degradation of habitat; habitat loss to development; invasive invertebrates

Table 6.2. Principal threats to native terrestrial habitats.

Aquatic Habitat	Principal Threats
Streams	Sedimentation caused by grazing animals, development, water diversions (dams, channelizing/concreting stream bottom and sides, introduced gamefish); lack of vegetation along banks reducing shade, nutrient inputs from decaying plant matter, and shelter provided by tree roots; excessive vegetation adjacent to streams, leading to decline in native aquatic organisms
Bogs	Ungulate grazing; rooting of native plants by pigs; displacement of endemic species by invasive species; predation by insects and rats

Aquatic Habitat	Principal Threats
Wetlands	Invasion by invasive plants like California grass (*Urochloa mutica*) and pickleweed (*Batis maritima*); predation of endemic waterbird eggs and chicks by non-native predators such as cats, mongooses, and rodents; predation of native wetland invertebrates (e.g., damselflies) by non-native fish; climate change and sea level rise; human-induced pollution and development
Anchialine pools	Contamination of water sources; introduction of invasive species; filling or direct modification of substrate
Estuaries	Similar to streams: sedimentation; development; invasive species; boat harbors and other sources of human disturbance
Sandy bottom	Pollution, human impacts such as eutrophication due to addition of nutrients
Coral reefs	Human impacts such as overfishing, creation of marine debris, vessel groundings, and introduction of invasive species; non-point source pollution from terrestrial land use practices; excessive inundation with fresh water during storm events, which can inhibit successful establishment of coral larvae; invasive algae; disease; global climate change
Bathypelagic, mesopelagic, and pelagic	Offshore aquaculture (a potential new threat to these areas)
Additional marine habitats	Direct and indirect impacts because of proximity of habitats to coastal development

Table 6.3. Principal threats to native taxa.

Native Taxa	Principal Threats
Plants Over 1,000 distinct flowering plants evolved from approximately 295 successful plant colonists. There are over 150 native taxa of ferns and fern allies. More than 400 plants are listed as threatened or endangered.	Habitat loss due to development; displacement by invasive plants; damage by invasive insects and pathogens; browsing and grazing by feral ungulates; climate change; fire; drought
Invertebrates There are about 5,000 terrestrial invertebrates, with over 90% being endemic.	Habitat loss; predation by non-native insects, amphibians, and reptiles; vulnerability to stochastic events due to small population sizes and low reproductive rates; insufficient information for species assessments

Native Taxa	**Principal Threats**
Hawaiian hoary bat The *‘ope‘ape‘a* (Hawaiian hoary bat) (*Lasiurus semotus*) is the only land mammal native to the Hawaiian Archipelago and is federally listed as endangered.	Habitat loss; roost disturbance; pesticides; collision with structures in the built environment
Forest birds There are only 33 extant species of native Hawaiian forest birds in the Main Hawaiian Islands—less than half the number known from historical and fossil records—and one-third of those remaining are extremely rare or possibly extinct. Twenty-one are federally listed as endangered.	Conversion of land from forests to agricultural and other uses; degradation by ungulates and invasive plant species; introduction of avian malaria virus and avian pox; predation of nests, nestlings, and incubating adults by rats, feral cats, and mongooses; competition for food and nest resources with alien bird and arthropod species
Raptors The *‘io* (Hawaiian hawk) and *pueo* (Hawaiian short-eared owl) are the only extant native raptors in Hawai‘i. Historically there were at least two additional species of hawks/eagles and four owls.	Predation by introduced rodents and cats (particularly for the ground-nesting *pueo*); habitat loss
Waterbirds Six species of extant, endemic waterbirds occur in Hawai‘i: the endemic Laysan duck (*Anas laysanensis*), *nene* (Hawaiian goose), and *koloa maoli* (*Anas wyvilliana* [Hawaiian duck]), and the native *‘alae ‘ula* (*Gallinula chloropus sandvicensis* [Hawaiian moorhen]), *alae keokeo* (Fulica *alai* [Hawaiian coot]), and *ae‘o* (Hawaiian stilt). At least eight species of duck/geese, three species of ibis, and 12 species of rails have been lost.	Loss and degradation of wetland habitats; predation (primarily by feral cats, also by mongooses and dogs [*Canis familiaris*]); hybridization between non-native mallards and the *koloa maoli* (Hawaiian duck); disease

Native Taxa	Principal Threats
Seabirds Forty species have been observed, and at least 20 are known to breed in Hawai‘i. Two are endemic: *‘ua‘u* (*Pterodroma sandwichensis* [Hawaiian petrel]) and *a‘o* (*Puffinus newelli* [Newell's shearwater]). Many are of global or national importance: over 95% of the world’s *moli* (*Phoebastria immutabilis* [Laysan albatross]) and *ka‘upu* (*Phoebastria nigripes* [black-footed albatross]) populations nest in the Hawaiian Archipelago.	On main islands: predation by feral cats, rodents, and mongooses; loss or degradation of habitat due to habitat-modifying invasive plants or animals; human disturbance (including coastal lighting) At sea: fisheries bycatch; pollution (including oil spills)
Migratory shorebirds and waterfowl Many species of migratory shorebirds and waterfowl winter in Hawai‘i: *kolea* (*Pluvialis fulva* [Pacific golden plover]), *‘akekeke* (*Arenaria interpres* [ruddy turnstone]), *‘ūlili* (*Heteroscelus incanus* [wandering tattler]), *kioea* (*Numenius tahitiensis* [bristle-thighed curlew]) are regular migrants that have been identified as important (by the U.S. Shorebird Conservation Plan[9]) because the populations in Hawai‘i are hemispherically significant or relatively large.	Loss or degradation of habitat; predation by feral cats and dogs

Invasive Alien Species

The continuing invasion of alien weeds, predators, herbivores, pathogens, and competitors into native ecosystems is the primary contributor to Hawai‘i’s extinction crisis. Since the establishment of forest reserves during the first three decades of the 20th century, alien invasion—not direct habitat destruction by humans—has been the dominant threat to native species and ecosystems across the Hawaiian Islands.

Hawai‘i is extraordinarily vulnerable to human-accelerated alien species invasions because of (1) its geographic position as the hub of Pacific travel and trade, and (2) its exceptional range of hospitable habitats for new species to occupy with limited competition and predators. The estimated rate for successful new colonization of the islands by a plant or animal species before human arrival was once every 25,000–50,000 years. In contrast, over the past 30 years, newly established species have been recorded in Hawai‘i at the rate of once every 18 days. According to the Coordinating Group on Alien Pest Species, more than 300 new marine species, 40 terrestrial reptiles, six amphibians, and over 8,000 plant species have been introduced to date. The existing complement of established invasive aliens has the capacity to overwhelm most remaining native habitat if left unchecked.

In the human history of the islands, several major groups of alien species have emerged as the most damaging to native ecosystems and species. These are discussed in the subsections below.

Invasive Plants

Through a history of increasing introduction of alien plants, there are now more naturalized alien vascular plant species (more than 8,000) in the wild in Hawaiʻi than there are native plant species (approximately 1,245). An estimated 200 of these naturalized alien plants are extremely aggressive, habitat-modifying weeds. For example, invasive fire-adapted grasses such as fountain grass (*Pennisetum setaceum*), guinea grass (*Megathyrsus maximus*), and buffel grass (*Cenchrus ciliaris*) have changed the wildfire regime in Hawaiʻi. These grasses can spread to wooded habitats, and readily burn and proliferate after each fire, converting forests to grasslands.[10] A short list of invasive plant species that pose a significant threat to native plant communities and require aggressive management includes *Miconia* (*Miconia calvescens*), fire tree (*Morella faya*), fountain grass, albizia (*Falcataria moluccana*), blackberry (*Rubus argutus*), mangrove (*Bruguiera gymnorrhiza* and *Rhizophora mangle*), and strawberry guava (*Psidium cattleianum*).

Invasive Animals—Ungulate Grazers/Browsers and Predators

Ungulates in Hawaiʻi include pigs (*Sus scrofa*), goats (*Capra hircus*), sheep (*Ovis aries*), mouflon sheep (*Ovis musimon*), Columbian black-tailed deer (*Odocoileus hemionus columbianus*), and axis deer (*Axis axis*), and to a lesser extent, feral cattle (*Bos taurus*). Because the islands lack any native herbivorous mammals, Hawaiian flora is not adapted to ungulate browsing or trampling. Feral ungulates directly and indirectly affect native biodiversity in a variety of ways, such as by browsing and grazing native plants, trampling seedlings, compacting and eroding soil, dispersing seeds of invasive plants, destroying the nests of ground-nesting birds (e.g., the *nene* [*Branta sandvicensis*, Hawaiian goose and state bird]), and contributing to the spread of mosquito-borne avian disease (e.g., pig wallows create mosquito breeding habitat). Feral ungulates continue to degrade remaining native ecosystems, particularly in the lowlands.

Hawaiʻi's terrestrial plants and animals are also extremely vulnerable to predation by rats (*Rattus* spp.), feral cats (*Felis silvestris*), and the Indian mongoose (*Herpestes auropunctatus*). The long-term ecological effects of herbivorous, omnivorous, and predatory small mammals has drastically reduced populations of native flora and fauna species, sometimes to extinction. Small mammals such as rats, mongooses, and feral cats prey on native birds. Rodents, particularly rats, damage lowland forests; they are implicated as wholesale vegetation modifiers via selective seed predation. Rodents seem particularly damaging in the Waiʻanae conservation area of Oʻahu, where they affect endangered tree snails, rare native plants, and an endangered forest bird, the ‘*elepaio* (*Chasiempis sandwichensis gayi*).[19] Predatory invertebrates such as ants and other social Hymenoptera have greatly disrupted invertebrate communities at all elevations.

Invertebrate Pests and Diseases

Pests and diseases can play an important role in reducing the viability of native species and, indirectly, of the natural communities and ecosystems composed of these species. Pests that are a threat to native species and in some cases a direct cause of their population decline include mosquitos (with mosquito-borne diseases such as avian malaria and pox); ants (various species but recently the little fire ants [*Wasmannia auropunctata*]); coconut rhinoceros beetle (*Oryctes rhinoceros*); *Erythrina* gall wasp (*Quadrastichus erythrinae*); two-spotted leafhopper (*Sophonia rufofascia*); slugs (various species); and black twig borer (*Xylosandrus compactus*). (*See details in "Issue 2: Forest Health: Invasive Species, Insects, and Diseases"*). Often the role of pathogens is tied to other threats. For example, avian diseases affecting native forest bird concentrations are spread by mosquitos, and the spread of mosquitos into forest bird habitat is tied to wallows of feral pigs, which create mosquito breeding sites where none otherwise existed. Proliferation of diseases across taxa can be common in Hawai‘i, owing to the fragility and vulnerability of its ecosystems.

A newly identified fungal pathogen *Ceratocystis fimbriata*, also known as ‘*ōhi‘a* wilt or Rapid ‘*Ōhi‘a* Death, is threatening to wipe out ‘*ōhi‘a* trees, Hawai‘i's most widespread and ecologically important tree species, one which defines forest succession and ecosystem function and provides critical habitat to rare, threatened, and endangered birds and insects.[11] After the appearance of symptoms (crowns turning yellow then brown), trees die with a few weeks. As of 2016, 50,000 acres on the Big Island had been infected with stands showing greater than 50% mortality. The disease is easily transmitted, but details on how it spreads and how to control it are still being investigated. This disease is limited to the Big Island and has not yet been reported on other islands; however, it threatens ‘*ōhi‘a* trees statewide.[12]

Successful conservation in Hawai‘i requires keeping remaining, relatively uninvaded native areas intact by preventing the establishment of new invasive species, restoring degraded areas needed for species-specific conservation goals, and devising practical strategies to limit the impact of widely established invasive species. Table 6.1 shows that alien species such as ungulates and weeds are prominent and ubiquitous in the different habitats in Hawai‘i.

Climate Change

Global climate change, bringing changes in baseline moisture and temperature conditions and thereby rising sea levels, increased climate variability, and increased flooding, is expected to have multiple disastrous effects on Hawai‘i's native biodiversity (see "*Issue 5: Climate Change and Sea Level Rise*"). Effects of sea level rise on the islands include increased water levels, erosion, salinity, and flooding, all of which threaten our coastal wetlands, waterbirds, nesting seabirds, monk seals, and sea turtles.

Future climate conditions will threaten native plants and communities by causing shifts or even complete losses of climate niches for some species.[13] With an increase in temperature, some plant species and assemblages might be able to adapt to higher elevations, but those species already at the highest elevations may have no place to go. Furthermore, climate change impacts are expected to contribute to the spread on invasive species in the islands, making their control and the conservation of native biodiversity even more challenging. Increased temperatures will allow avian disease pathogens and vectors to expand into higher-elevation forests that currently support the last remaining populations of native birds.

Climate change models for the Hawaiian Islands for the remainder of this century predict a reduction in average rainfall and the availability of fresh water.[14] The resultant prolonged drought conditions will affect wildlife populations by reducing habitat and food availability. Prolonged drought conditions have already contributed to the decline of *palila* (*Loxioides bailleui*) on Mauna Kea of the Island of Hawai‘i.[15] Another impact associated with drought is the increase in the risk of wildland fires. Climate change will invariably continue to play a role in the frequency of fires across the Hawaiian Islands, especially as wet and mesic forests experience seasonal droughts and leeward forests receive less total rainfall. (*See "Issue 3: Wildfire," and "Issue 5: Climate Change and Sea Level Rise."*)

Development

Widespread conversion and development of the lowland areas of Hawai‘i began with the first human arrivals to the islands and continue to present day. Following statehood, the implementation of strong conservation zoning laws has largely limited development of the highest-elevation lands, which include the state's Conservation Districts, natural areas, forest reserves, and much of the watershed partnership areas. However, incremental conversion of lower-elevation native ecosystems continues on the most densely populated island (O‘ahu), as well as on the largest island (Hawai‘i), particularly in windward Mauna Loa and the North and South Districts of Kona. Remaining native forests found in the state's Agricultural District, in particular, are threatened by conversion to other agricultural uses, such as pastureland, coffee farms, and macadamia nut orchards. Also, urban, rural, second home, and other development affects important agricultural areas and thereby makes human populations more dependent on imports for daily needs.

Grazing

Clearing of forest for production of cattle has a 200-year history in Hawai‘i. Cattle have the same effects on native vegetation as other ungulates, and the devastating effects of cattle in Hawai‘i are well documented. Today, there are still a number of very large private ranches, several of which occur within native ecological systems or former native forest areas. Ranching-related loss of native ecosystems is active in the North and South Kona District conservation area in particular. There is a long history of the state providing extremely low-cost leases to ranchers on state lands, which perpetuates grazing impacts on already degraded lands and the loss of more cattle (which become feral) into forested areas.

Unsustainable Harvesting

Although logging and other high-intensity harvesting is not practiced widely in Hawai‘i (most high-value timber areas were cleared in the last century), these and other land-clearing practices are still of concern in some conservation areas on the Island of Hawai‘i. Unsustainable commercial harvesting of native *koa*, ‘ō*hi‘a*, sandalwood (*Santalum* spp.), and *hapu‘u* tree ferns (*Cibotium* spp.) are approaching the limits of available resources. The forest products industry recognizes and supports planting programs to restore former forest lands. On the Hāmākua coast on the Big Island, vast mesic and lowland areas formerly dominated by sugarcane have been planted with Eucalyptus species in the hope of providing timber resources for a developing industry. Additionally, a number of private landowners, the University of Hawai‘i, Hawai‘i Agricultural Research Center, and other partners have begun efforts to replant native hardwoods for production and restoration purposes. Development of an industry for native timber, non-timber products, and non-native forest products could stimulate the harvest of more forest products, potentially reduce the damage from natural-stand harvesting, and fill the need for aggressive replanting and sustainable harvest practices. *(See "Issue 8: Forest Products and Carbon Sequestration," for additional information.)*

Most minor forest and stream products or "commodities" (e.g., plant materials for *lei* making, flower arrangements, and herbal use; stream fishes and invertebrates for food) can be harvested for home and cultural use on a sustainable basis. However, these activities generally are not sustainable at the commercial scale, and are restricted by permit systems. Native plants that are important food sources or habitat for native birds and invertebrates, as well as native snails, are sometimes illegally collected for lei making, flower arrangements, jewelry, and medicinal use. The illegal take of these resources makes sustainable management challenging, especially when coupled with the dearth of inventory information regarding non-timber forest products. Similar issues apply to the seaweed and fishing industries. *(See "Issue 8: Forest Products and Carbon Sequestration," for additional information.)*

Military Training Activities

Live-fire training, large-scale troop movements, and heavy equipment operations are serious threats to native species at U.S. Army training facilities in areas of O‘ahu and the Big Island. Training operations have resulted in vegetation clearing, increases in wildfire frequency, and the introduction and spread of unwanted alien species. The U.S. Army has instituted an ecosystem management program to mitigate these impacts, and is now among the state's most active and well-funded stewards of native systems. The U.S. Army and other military branches in Hawaiʻi also provide acquisition buffer programs that have played important roles in acquiring important threatened and endangered species habitat. *(Refer to "Appendix C: Forestry-Related Assistance Programs," for more information.)*

Recreational Overuse

Typical recreational uses in native ecosystems include hiking, camping, hunting, and off-road vehicle touring. The indirect effects of recreational activities, such as the spread of invasive weeds via hiking and soil erosion due to off-road vehicle use, have been documented. Some restrictions in the state Conservation District and on designated public lands reduce damage associated with recreational use. However, the increase in popularity of guidebooks and internet sites that reveal the locations of sensitive habitats has led to increased visitation or overuse of such sites by people. Many sensitive habitats such as anchialine ponds, lava tubes, cave habitats, rare species locations, and offshore islands are compromised or destroyed by people.[2] Hunting is also a very important sport and means of acquiring food for many people in Hawaiʻi. Because hunters target feral ungulates, there is much disagreement on how to manage these animals so that they do not devastate native forests but also continue to provide viable hunting opportunities. *(See "Issue 7: Hunting, Nature-Based Tourism, and Recreation," for additional information.)*

Stream Diversion

Native stream communities are highly dependent on continuous stream flows to the sea that support the diadromous life cycles of their dominant aquatic animals. Most of the state's streams are already partially or fully altered (channelized, diverted, or de-watered via groundwater pumping), and those that remain are vulnerable as the demand for fresh water outstrips the current yield. The Hawaiʻi State Water Code[16] provides mechanisms for protecting stream flow, which have been tested in court and upheld. In-stream flow standards are now being developed statewide.[17]

Wildfire

In fire-adapted ecosystems, fire plays a vital role in forest successional patterns and other ecological functions; however, in Hawaiʻi and many other Pacific islands, fire is not a large part of, and rarely positive for, the native ecosystems. Fire-adapted aliens (especially grasses and short-lived shrubs) are established in lower, leeward slopes and some subalpine areas of Hawaiʻi. When ignited, these weeds fuel major wildfires that can carry into native forests. Native forests are destroyed and replaced with fire-adapted weeds in a trend that increases the range and intensity of these fires. This grass/fire cycle perpetuates itself and, without intervention, can render native ecosystems permanently altered and unable to be restored to a natural state. According to DOFAW biologists, many native plant and animal species are just one fire away from extinction. For example, seven out of the remaining eight Hawaiian gardenia (*Gardenia brighamii*) plants known to occur on O‘ahu were wiped out in a fire in Nānākuli in May 2015. And, if a fire swept through the core *māmane* forest on Mauna Kea, it could wipe out the endangered *palila* birds that depend on this forest. *(See "Issue 3: Wildfire.")*

Other Threats

Other non-biological factors that threaten conservation of biodiversity in Hawai‘i include limited inventory information and insufficient information management; uneven compliance and enforcement of existing conservation laws, rules, and regulations; constraints in management capacity; and inadequate funding.

Trends

Approximately 20% (843,000) of land area in Hawai‘i is identified as priority watershed. In 2011, slightly over 10% (90,000) of these priority watersheds were protected. Trend in forest conservation is increasing. Since 2011, watershed protection efforts have accelerated and currently, approximately 15% are under a high level of protection. Under Governor Ige's administration, the *Aloha+ Challenge,* and the World Conservation Congress Legacy Commitment of "30 by 30 Watershed Forests Target", the State of Hawai‘i is committed to protecting 30% (253,000 acres) of our highest priority watershed forests by 2030.[18] Strategy to protect forested watershed continue to entail:

- Fencing and removal of nonnative hooved animals in targeted core areas
- Control of invasive plants in priority native forests
- Prevent and control wildfires
- Combat forest diseases and pests
- Plant native trees

Although the threats to Hawai‘i's native species persist, recent years have seen greater awareness of the need to take action to conserve biodiversity with a more assertive political will to address these problems, as well as wider community involvement in project implementation. These changes have resulted in positive steps toward the recovery of many of Hawai‘i's endangered species and in the protection of species that remain common, so that they do not become endangered. Success stories include 120,000 native trees planted over the last 5 years by Watershed Partnerships, 210 listed endangered plants and animals protected by watershed partnerships, release of the ‘alalā (Hawaiian crow, *Corvus hawaiiensis*) in the Pu‘u Maka‘ala Natural Area Reserve on Hawai‘i Island ending a decade long of extinction in the wild, recovering the *nene* from the edge of extinction, increasing populations of *honu* (*Chelonia mydas agassizi* [green sea turtle]), protecting numerous important habitats, and implementing community-led restoration efforts such as in Waimanalo streams, which encouraged the return of the endangered *ae'o* (*Himantopus mexicanus knudseni* [Hawaiian stilt]). However, despite these success stories, Hawai'i continues to face major conservation challenges in protecting its more than 10,000 native wildlife species, some of which are critically endangered, such as the Hawaiian monk seal (*Monachus schauinslandi*).

Collaborative Working Groups and Partnerships

Conservation of Hawai'i's unique habitats and species requires cooperation across land ownerships and organizations. Some examples of successful collaborative partnerships protecting and conserving habitats and species are as follows:

- The Hawai'i Association of Watershed Partnerships (HAWP) comprises 11 island-based Watershed Partnerships that work collaboratively with more than 71 public and private partners on five islands to protect over 2.2 million acres of vital forested watershed lands.
- The Hawai'i Conservation Alliance (HCA) is a collaboration of conservation leaders representing governmental, cultural, educational, and non-profit organizations from across the state. Collectively their mission is safeguarding the biodiversity of Hawai'i's ocean, land, and streams.
- Island-based Invasive Species Committees (ISCs) represent voluntary partnerships of government, the private sector, non-profit organizations, and concerned citizens working on five islands to prevent, control, or eradicate the most threatening invasive species in the islands and protect our watersheds, ecological resources, and economy.
- The Coordinating Group on Alien Pest Species (CGAPS) is a voluntary partnership of federal, state, and nongovernmental organizations that works to close the gaps in Hawai'i's terrestrial and aquatic invasive species prevention and response systems through greater coordination, planning, and management.
- The Hawai'i Rare Plant Recovery Group (HRPRG) is a working group composed of many public and private agencies to prevent the extinction of native Hawaiian plants and provide for their recovery through a combination of on-site and off-site management strategies. The Plant Extinction Prevention Program, an implementation arm of HRPRG, is focused on the conservation of rare plants with fewer than 50 individuals in the wild.
- The Hawaiian Bat Research Cooperative, a partnership composed of government agencies, non-profit organizations, and private landowners, was formed to prioritize and fund needed bat research.
- The Hawaiian Forest Bird Recovery Team, a cooperative effort involving multiple government agencies and non-profit organizations, guides forest bird conservation work, including the development of the *Draft Revised Recovery Plan for Hawaiian Forest*

Birds[19] and five-year implementation plans for identified critical species, propagation of captive birds, annual surveys for forest bird, and implementation of other identified research and management projects.
- Dryland Forest Working Group (DFWG) is an ad hoc partnership formed in the early 1990s. In 1993, DFWG began to advise and participate in a cooperative restoration project and an agreement between the Hawai‘i Forest Industry Association (HFIA) and the U.S. Fish and Wildlife Service (USFWS). It is the driving force behind restoration science at Ka‘ūpūlehu dryland forest and, since its formation, has expanded to public and private dry forest restoration sites. DFWG hosts an annual symposium of dry forest restoration initiatives on the islands.

Innovative Management Techniques

Listed below are several innovative biodiversity management techniques that have been applied and continue to be improved upon for the conservation of Hawai‘i's biodiversity.

- Effective Conservation Program (ECP) is a framework or tool developed by the Hawai‘i Conservation Alliance for native biodiversity management. This framework defines Effective Conservation as a combination of conditions that together ensure that native ecosystems and species have a maximal chance of maintaining their viability into the future. The four conditions of the framework are 1) *presence of viable conservation targets*, typically ecosystems and/or species; 2) *protective designation* applied to an area with the intent to limit incompatible land uses and enable or facilitate conservation management; 3) *active management* to prevent/mitigate threats, and enhance viability of ecosystems and species; and 4) *stakeholder involvement and support* of conservation efforts. By analyzing the extent to which these four conditions are active in a geographical area, the framework can comprehensively track conservation progress island-wide and statewide, identify needs, and focus our collective efforts more effectively. The ECP can also serve as a powerful external communication device to express to the public and decision-makers, a multiple-scale context for conservation.[20]
- Predator-proof fencing technology, developed in New Zealand, prevents the ingress of all mammals, including animals as small as a house mouse. Animals are prevented from digging under or climbing over the fence.[21] Use of predator-proof fencing has significantly increased the effectiveness of predator control in Hawai‘i by shifting the focus from control to eradication within the fenced area. Some places in which predator-proof fences have been established for the conservation of native biodiversity in Hawai‘i are in Ka‘ena Point Natural Area Reserve and on Mauna Loa in Hawai‘i Volcanoes National Park for the protection of seabirds, in the Saddle Road Pu‘uō‘ō area on the Big Island for protection of *nene*, and in the central and southern Wai‘anae mountains on O‘ahu for the protection of tree snails.

- Forward-looking infrared (FLIR) technology is an imaging technology for detecting the infrared radiation typically emitted from a heat source. This technology has made it possible for conservation staff in DOFAW and other organizations to locate habitat-damaging feral ungulates that may be hiding in dense undergrowth and which would otherwise go undetected to monitoring and control efforts.
- The combination of hyperspectral imaging and Light Detection and Ranging (LiDAR) technology has significantly contributed to mapping and monitoring of vegetation, particularly the spread on invasive plants in Hawaiʻi's watersheds, by being able to detect not just the canopy but also elements of the understory vegetation.
- Herbicide ballistic technology has made it possible to control invasive plants such as *Miconia* in areas that cannot be accessed by foot, by delivering small amounts of herbicide into plant tissue from a distance. The herbicide is delivered via a projectile from a device similar to a paintball gun.
- The use of Unmanned Aerial Vehicles (UAVs) is being explored for conservation work. For example, early detection of weeds, traditionally a ground-based effort, can become challenging in terrains that are hard to traverse by foot. The Big Island ISC (BIISC) is investigating the efficacy of using UAV for the early detection of its target weeds like gorse (*Ulex europaeus*) on Mauna Loa.
- Captive propagation has been employed for the recovery of native bird species in Hawaiʻi, but recently this technique has begun to be used for the conservation of native invertebrates such as the Kamehameha butterfly and native yellow-faced bees (*Hylaeus* spp.).

Funding for Conservation

Since the arrival of humans, more than half of the Hawaiian Archipelago's known endemic bird taxa have been lost. Of the taxa that remain, 35 bird species are federally listed under the U.S. Endangered Species Act, and some species have populations of fewer than 1,000 individuals.[4] Nevertheless, expenditures for the recovery of listed Hawaiian bird species have not been proportionate to spending on listed birds nationwide. Previous studies have documented a geographic disparity in recovery expenditures on listed species, but none have specifically focused on Hawaiian birds. To draw attention to this disparity with the aim of improving Hawaiʻi bird conservation, DOFAW Wildlife Biologist David Leonard summarized recovery expenditures on listed birds from 1996 to 2004, comparing mainland and Hawaiian taxa in the context of their degree of endangerment. Federal and state spending on the 95 listed bird taxa over this 9-year period totaled $752,779,924. At the time, Hawaiian birds represented a third of the listed bird taxa (n = 31), yet dedicated recovery expenditures for these species were only $30,592,692, or 4.1% of the total spent on all listed birds. Despite having similar priority ranks assigned by USFWS, listed mainland birds received over 15 times the funding that Hawaiian birds received. In general, the threats to island taxa are unlike those of mainland taxa (e.g., there are more non-native predators), management actions are expensive, and in many cases actions must be conducted in perpetuity. Because of the status of many Hawaiian birds and the threats facing them, current recovery expenditures are inadequate to prevent additional extinctions.[22]

Hawai'i ranks near the bottom (48th) in the nation for state spending on fisheries and wildlife, although the state Forest Reserve System ranks 11th in size and the state boasts the largest marine protected areas in the United States. In Fiscal Year 2015, DLNR was allocated $139 million (1.14%) of the state's $12.1 billion executive budget. With this, DLNR must manage the state's marine and freshwater resources (e.g., commercial fisheries, aquaculture, aquatic resources protection, recreational fisheries), protect threatened and endangered species, manage state-owned lands (both those for lease and those set aside as forest reserves, natural areas, plant and wildlife sanctuaries, and for parks/recreation), provide assistance to private landowners on managing their natural resources, manage statewide ocean recreation and coastal area programs (i.e., boating), oversee permitting associated with the Conservation District, implement the state's historic preservation mandates, maintain the statewide recording system for title to real property, and enforce DLNR's rules and regulations.

A conservative estimate of the amount of state funds actually dedicated solely to conservation of native wildlife and their habitats was approximately $35 million dollars for Fiscal Year 2015.[4] Though no comprehensive cost estimates exist for the protection and recovery of wildlife in Hawai'i, the inadequacy of current funding levels is obvious based on costs included in recovery plans for endangered species. For example, the *Draft Revised Recovery Plan for Hawaiian Forest Birds* (2003) estimates the cost of recovering 21 species of forest birds at nearly $2.5 billion over the next 30 years—an annual cost ($83 million) which is more than half of the budget for all of DLNR. Costs associated with the recovery of endangered whales, sea turtles, seabirds, waterbirds, invertebrates, and plants would add tens of millions more per year.

In 2015, the state switched funding sources for the Natural Area and Forest Reserve Systems, forest stewardship, and watershed protection programs from a dedicated special fund to annual general fund appropriations. It is yet to be seen whether the long-term support needed to fund natural resource management and conservation can be maintained and increased to meet the needs identified in the SWAP[4] and this plan, especially when these needs compete with other general fund programs such as public health, public safety, and education.

Funding levels from federal sources also are inadequate and inequitably apportioned. In 2014 Hawai'i received 16% of the national appropriation under the Endangered Species Act (the traditional Section 6 Program) and only 1% of the national appropriation under the State Wildlife Grants Program. However, through related competitive grant programs within the Section 6 program, additional funding for conservation on private lands and for land acquisition *(see "Appendix C: Forestry-Related Assistance Programs"*) has become available. Though Hawai'i has been successful in securing a portion of these grants because of extensive and progressive partnerships with landowners, lack of sufficient overall funding to implement recovery programs, especially on state lands, leaves both critically endangered species and lesser-known native species (e.g., terrestrial invertebrates) with little support.

Loss and Degradation of Habitat

Loss, fragmentation, and degradation of habitat have been primary contributors to the extinction and rarity of native bird species and are suspected to play an important role in the decline of native invertebrate populations. Historically, unsustainable harvesting, agriculture, grazing, military use, wildfire, and urban and residential development have claimed more than half of Hawai‘i's native habitats. At lower elevations where development pressures are greatest, less than 10% of native vegetation remains. Alterations of streams, non-point source pollution, sedimentation, and stormwater runoff have decreased, fragmented, or degraded freshwater habitats. Marine systems downstream are affected by changes in stream systems, especially by any increase in sediment load. Corals, in particular, are susceptible to both pollution and excessive sedimentation. Anchialine ponds are threatened by the filling and trampling of the ponds, and the photosynthetic organisms (algae) that form the base of their food chain are easily disturbed. For other sensitive areas such as subterranean systems or nearshore reefs, the increase in human visitation, particularly by tourists, cumulatively affects habitat quality and is a growing cause for concern.

Populations of many species are limited by the amount of suitable habitat available. This results in multiple problems that increase the probability of future extinction. Because many of the Hawaiian plant and animals co-evolved with one another, the extinction of one species could lead to cascading extinctions of other species. While the current land use zoning of the Conservation District limits further loss of forested habitat to development, this designation confers only the coarsest protection. Without active management, these lands remain threatened by invasive plant and animal species or require restoration to support native wildlife. In addition, zoning does not protect the entire remaining high-quality habitat from being converted to other land uses.

Present Conditions

The Hawaiian Archipelago possesses a wide range of habitats, from wet forests to extremely dry coastal grasslands and subalpine areas. With the arrival of humans and consequent clearing of native habitats for agriculture, the introduction of invasive species, and, more recently, development, many of these habitats have declined. Maps 6.1, 6.2, and 6.3 depict the extent of major vegetation types before human arrival and currently (maps prepared in 2005). An estimated 90% of Hawai‘i's tropical dryland habitats, 61% of the mesic habitats, and 42% of wetland habitats have been lost. Today, native vegetation occurs on less than 40% of the islands' land area. Similarly, much of the habitat for freshwater species has declined, with 58% of the perennial streams in the state having been altered in some way.

Terrestrial Habitats

The distribution of terrestrial habitats in Hawaiʻi is influenced by elevation, climate, and substrate. Using elevation zones and moisture gradients, Hawaiʻi can be classified into nine terrestrial habitat types. These nine habitat types can be further refined based on the dominant plants and structural characteristics of the vegetation. The *Manual of the Flowering Plants of Hawaiʻi*[23] recognizes 33 native forest communities, 36 native shrubland communities, eight native grassland communities, and four native herbland communities. Subterranean systems form a tenth habitat type defined by geology rather than elevation zones and moisture.

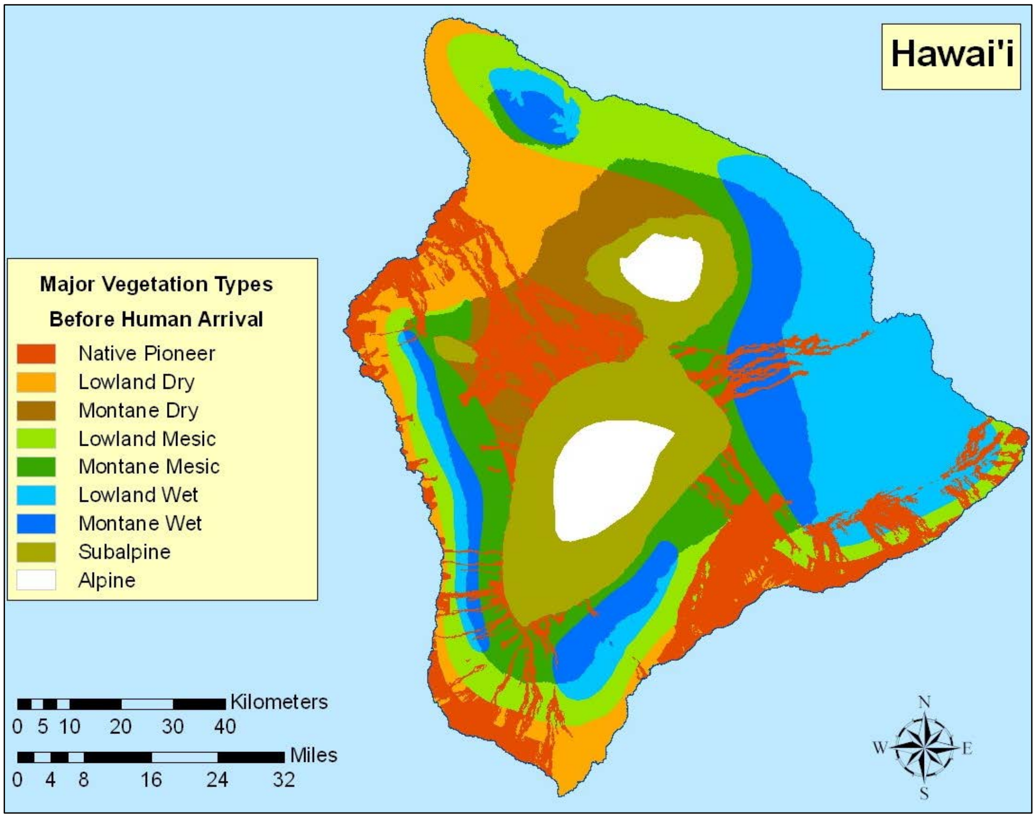
Aquatic Habitats

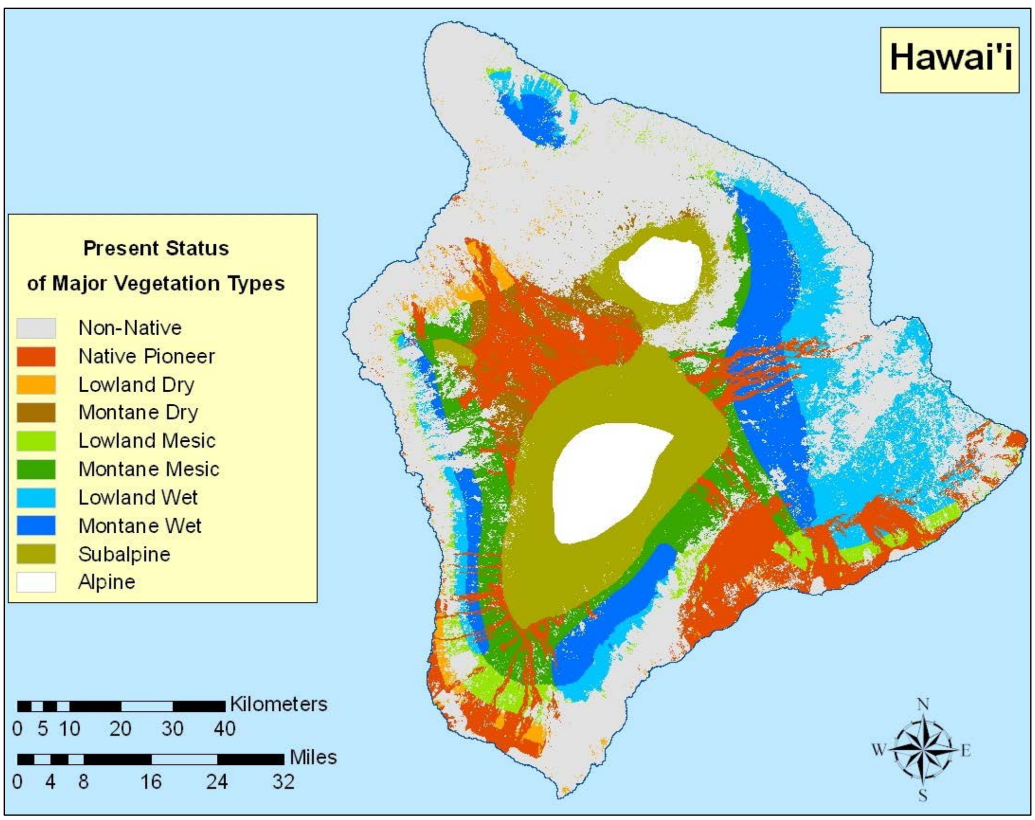
Hawaiʻi's aquatic habitats include streams, estuaries, sandy bottom habitats, coral reefs, and the bathypelagic, mesopelagic, and pelagic zones of ocean.[2] These aquatic habitats link together most of Hawaiʻi's terrestrial habitats. Streams and groundwater flow play an important role in providing water for plants and animals throughout the ecosystem. The flow of water that rains down on the high mountaintops transports nutrients and organic matter through the various forest and shrubland areas into estuaries and wetlands at low elevations and then finally into the ocean. Many of Hawaiʻi's native freshwater aquatic animals migrate between the ocean, estuaries, and upper reaches of streams as part of their life cycles.

As discussed in "*Issue 1: Water Quality and Quantity*," this interconnected network of aquatic habitats and adjacent land areas collectively is referred to as a watershed, which is similar to the traditional Hawaiian land division *ahupuaʻa*. Activities or threats that affect one part of this interconnected system will affect some other part, thus affecting the whole system. To effectively protect watersheds, including the important marine ecosystems that are influenced by pollution and onshore activities, the entire *ahupuaʻa* must be effectively conserved.

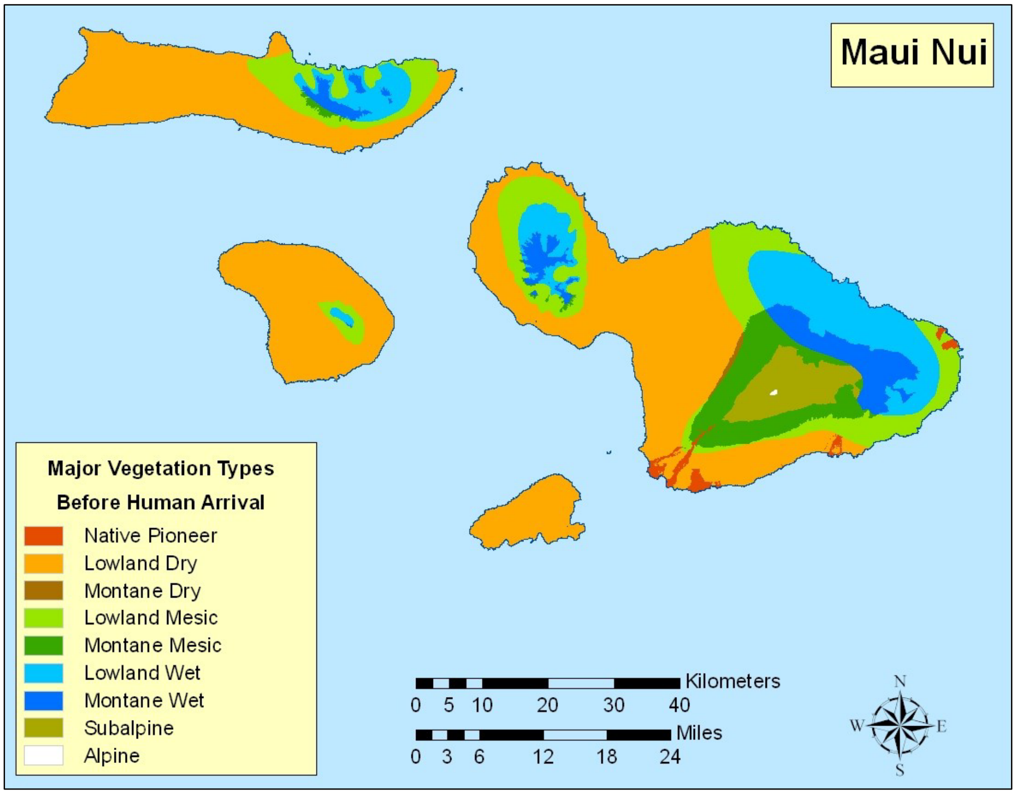
Native Taxa

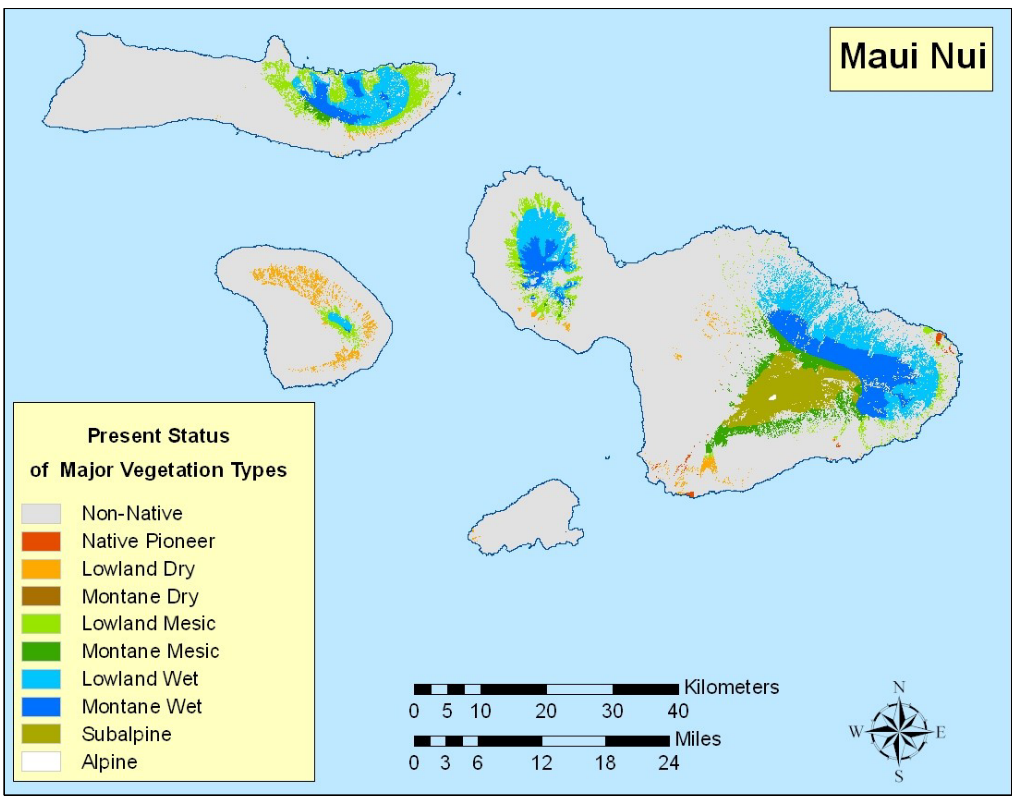
Because of the extreme isolation and distance, relatively few life forms successfully colonized the Hawaiian Archipelago over its 70-million-year history. Those species that did, however, found habitats that varied enormously over very short distances. As a result, the archipelago has some of the world's best examples of evolution, having created countless new lineages of plants and animals through natural selection and adaptive radiation. Rates of endemism (i.e., percent of species found nowhere else on earth) are typically 99 to 100% for terrestrial insects, spiders, and land snails, 90% for plants, more than 80% for birds, and 15 to 20% for aquatic fauna.[2]



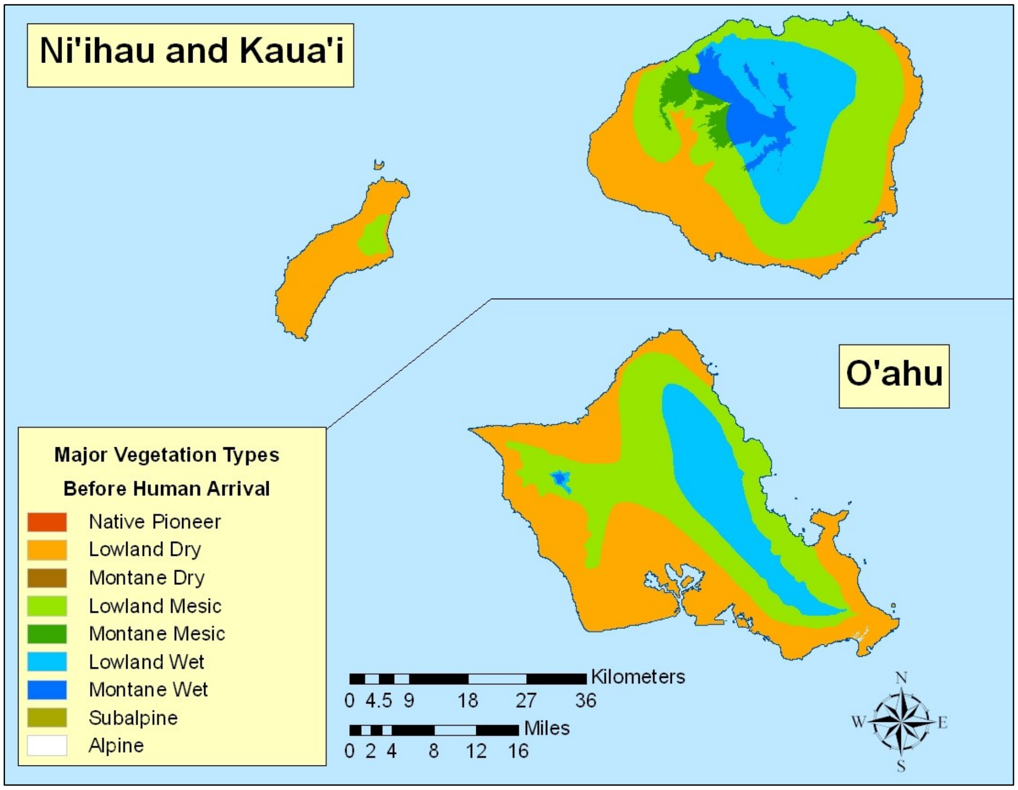


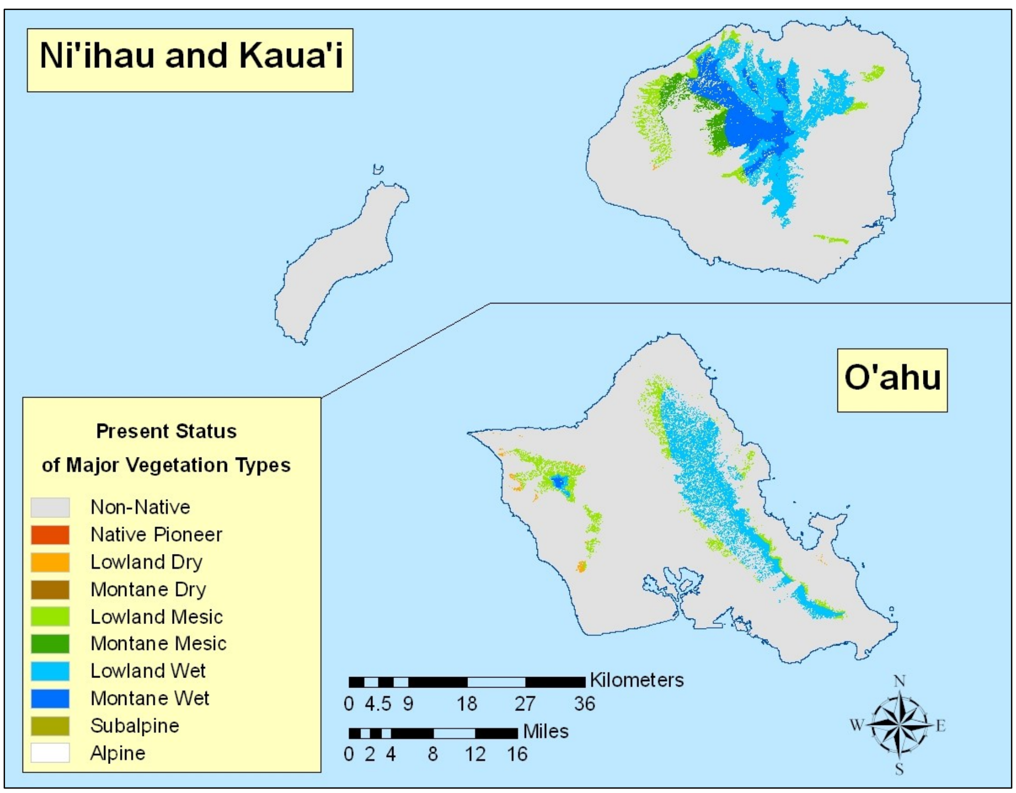
Map 6.1. Major vegetation types for the Island of Hawai'i before the arrival of humans and in 2005. Map by Page Else, Hawai'i Conservation Alliance.





Map 6.2. Major vegetation types for the Maui Nui (Maui, Lāna‘i, Moloka‘i, and Kaho‘olawe) before the arrival of humans and in 2005. Map by Page Else, Hawai‘i Conservation Alliance.





Map 6.3. Major vegetation types for the Kaua‘i, Ni‘ihau, and O‘ahu before the arrival of humans and in 2005. Map by Page Else, Hawai‘i Conservation Alliance.

Seventy-five percent of plant and animal extinctions documented in the U.S. have occurred in Hawai‘i. Today, Hawai‘i has the highest number of threatened and endangered species in the country, accounting for more than 40% of all federally listed taxa. The decline in native species is also mirrored by the loss of native habitat, with less than 40% of the land surface covered with native-dominated vegetation today.

The Hawai‘i SWAP[4] selected a large cohort of taxa to identify as Species of Greatest Conservation Need. These consist of one terrestrial mammal, 78 birds, more than 5,000 terrestrial invertebrates, more than 756 plants, six species of endemic terrestrial algae, 12 freshwater invertebrates, five freshwater fishes, 24 species of endemic freshwater algae, 20 anchialine-pond associated fauna, 26 marine mammals, six marine reptiles, 151 marine fishes, 197 marine invertebrates, and 79 species of endemic marine plants or algae.

Priority Issues and Areas for Conservation of Native Biodiversity

Public Outreach and Education

Education and outreach is critical to the successful conservation of Hawai‘i’s native biodiversity as well as to the continued protection of Hawai‘i’s natural resources for future generations. There is a lack of awareness about Hawai‘i’s avifauna and native plant communities. Hawai‘i’s residents and visitors generally have little or no acquaintance with Hawaiian birds. Unlike most mainland areas, many listed Hawaiian birds are restricted to remote, high-elevation forests where access is difficult or impossible, so the opportunities to see native birds are limited. Similarly, many Hawai‘i residents have little connection to, or knowledge, of native taxa, and without this connection, there is little demand from the public for increased funding. Comprehensive education, outreach, and service programs foster a sense of responsibility for native biodiversity conservation in the public and promote voluntary compliance with conservation rules, regulations, and laws.

Improved Information Access and Management

Huge gaps in knowledge exist regarding many native species, including their life history/cycles, habitat needs, ecosystem niches, inventory, and reliable population counts. Gaps in information are often magnified by the challenges inherent in sharing information across institutions. Building on existing efforts to centralize information storage in a spatial database could better identify data gaps; provide a more comprehensive view of the status of a particular species, its habitat, and the ecosystem as a whole; and allow management decisions to be made using the most up-to-date and accurate information.

Priority Areas for Conservation of Native Biodiversity

Priority landscape areas for the conservation of native biodiversity consist of all lands that are either classified as critical habitat by the USFWS, or are designated as essential habitat for the recovery of plants, forest birds, seabirds and water fowl (Map 6.4). The vast majority of DOFAW managed public lands and lands with Forest Legacy projects are included in these priority landscape areas for conservation of native biodiversity. The management categories described below are based on the condition of the native ecosystems and can be used as guidance to prioritize management efforts within the priority areas for conservation in the islands

Category 1: Intact Native Ecosystems, Highest Biodiversity

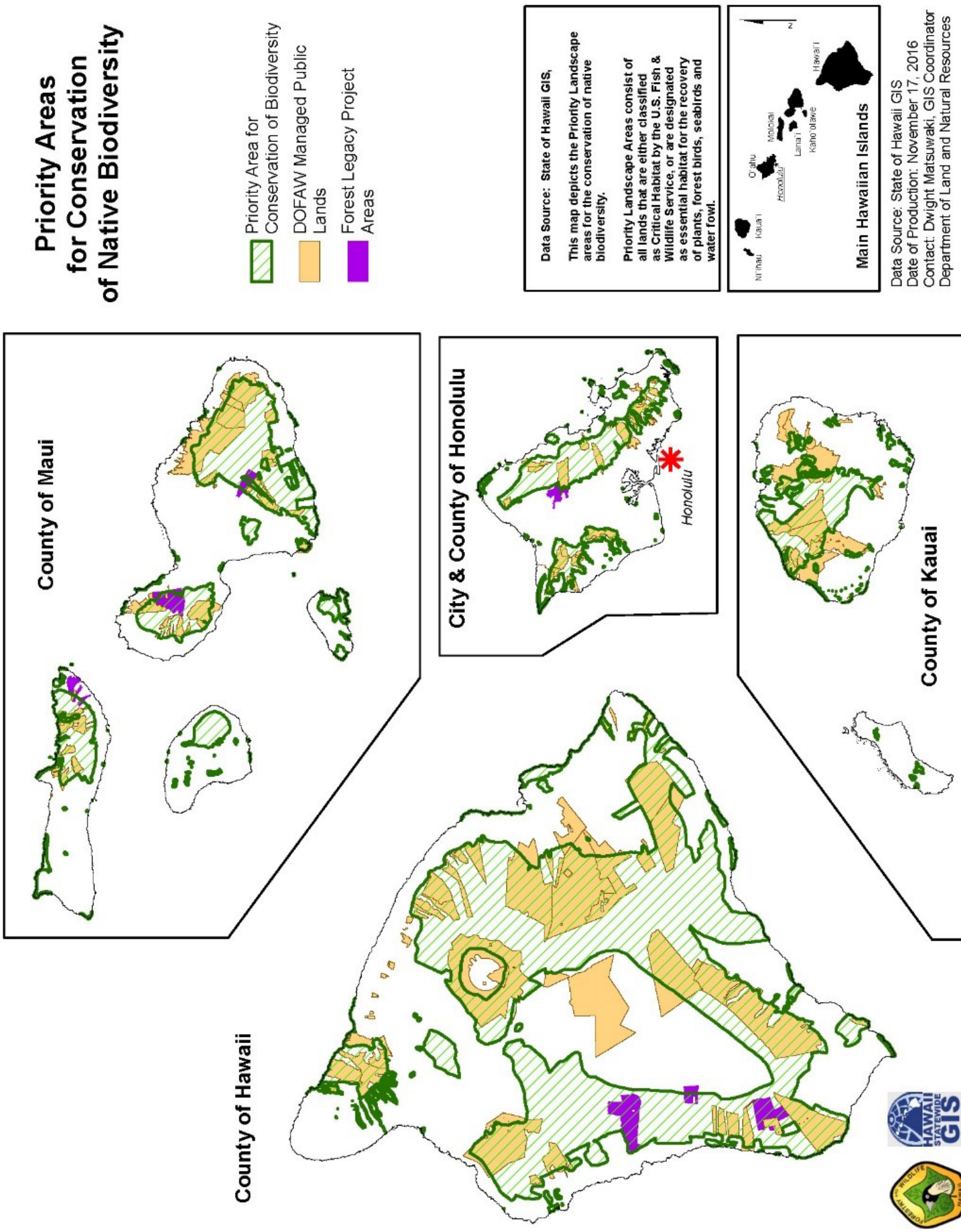
Areas that fall under this category are important for maintaining native ecosystems and forest birds. These high-quality native-dominated areas (as identified by a habitat quality analysis developed from a combination of Hawai‘i Gap Analysis and LANDFIRE datasets) have more intact structure and function, have historically documented high plant diversity, and contain some of the most important areas in which to conserve forest birds. Within these areas, for example, native seed banks and other ecosystem components needed for persistence of native biodiversity are likely present and functional. These areas also have the potential to support a number of plant species and are considered to be highest priority areas for maintenance of biodiversity.

Category 2: Intact Native Ecosystems, High Natural Biodiversity

Areas that fall under category 2 are important for maintaining native-dominated ecosystems, waterbirds, and coastal vegetation. While also native-dominated, these areas have the potential to support fewer species of plants and forest birds than the Category 1 areas. Category 2 areas include those supporting core waterbird concentrations as designated by USFWS, and any areas containing high-quality coastal vegetation, including islets.

Category 3: Rapidly Degrading Native Ecosystems

Areas under category 3 would include lands that have the highest potential for restoration. Although native plant species are no longer dominant on these lands, there are still remnants of native biodiversity and, by definition, the lands are located near native-dominated ecosystems. This category also includes areas that support a high number of native forest and seabirds. Native seed banks and other ecosystem components needed for native biodiversity may still be present and functioning. Restoring these areas can help de-fragment and reduce threats to adjacent areas.



Map 6.4. Priority Conservation Areas for Conservation of Native Biodiversity.

Category 4: Non-Native Ecosystems with High Recovery Potential

Areas that fall under category 4 offer high potential and opportunity for habitat improvement. While dominated by non-natives, they also display high potential to increase species richness, representing opportunities to enhance populations of species that have experienced a significant loss in historical range.

Category 5: Degraded Ecosystems

Lands under this category present opportunities for localized native habitat restoration. They would comprise of degraded ecosystems dominated by non-native species and not located adjacent to substantial native vegetation areas. These areas may or may not contain native elements or pockets of native biodiversity, but at a large scale, they have potential for improving their capacity for providing ecosystem services such as nutrient cycling, soil and moisture retention, and pollination. Degraded ecosystem areas also include secondary areas for protecting waterbirds and coastal vegetation.

Category 6: Native Ecosystems No Longer Exist

This category of lands represents areas where habitat conversion was severe enough to have minimized chances for restoration of native biodiversity without significant financial investment, because the areas have been paved over or contaminated, or because natural processes have been interrupted in the area. Alternative habitat uses like development and agriculture have destroyed seed banks, soil composition, and/or natural processes needed for native biodiversity. The very limited opportunities for restoration in these areas would require extensive reconditioning of the area before restoration could be possible. These areas are currently absent of substantial native biodiversity value (e.g., they are developed areas, intensive current and former agricultural areas, and managed non-native timber plantations). Incorporation of native species, when appropriate, into landscaping or managed non-native plantations is encouraged (*see "Issue 4: Urban and Community Forestry"*).

Data Gaps and Opportunities

Information Quantity and Management

Resource managers must typically make decisions based on incomplete data and information. Data on the effects of different threats to native species is often lacking, as is information on the effects of different management techniques or actions on natural resources. Management decisions based on inadequate data can result in a misallocation of extremely limited conservation dollars.

For example, Hawai‘i’s forest birds have been systematically surveyed for the past 25 years, yet for some species, current information on population size or distribution in certain areas remains sparse. Limited funds restrict surveys mainly to currently managed lands and may not accurately reflect a population’s full distribution or abundance. Accurate population estimates for many Hawaiian waterbirds, seabirds, fishes, and invertebrates also are not available. Large numbers of native invertebrates have not even been described, making assessment of their populations and consideration of the consequences of proposed management actions problematic at best.

Huge gaps in knowledge exist regarding many native species. Population censuses cannot provide data on basic demographic parameters or determine threats to specific species. Yet such information is often necessary to direct management, especially for those species persisting at low populations. For example, for many Hawaiian forest birds, plants, and invertebrates, virtually nothing is known about their reproductive behavior, demography, survival, or dispersal tendencies.

Gaps in information are often magnified by the challenges inherent in sharing information across institutions. Multiple agencies and organizations in Hawai‘i collect and manage data on a variety of species and habitats. This information is often collected in different formats and for different purposes. There are no comprehensive computerized spreadsheets or databases that list even the names of all known Hawaiian species. Building on existing efforts to centralize information storage in a spatial database could better identify data gaps, provide a more comprehensive view of the status of a particular species or habitat, and allow management decisions to be made using the most up-to-date and accurate information.

Furthermore, lack of subject matter experts, taxonomists, and dedicated funding for baseline monitoring and data collection contribute to the lack of information on Hawai‘i’s unique native biodiversity.

Funding for Conservation

Sufficient, sustained, and long-term funding is needed to implement biodiversity conservation actions identified in the SWAP and this plan. New sources of funding for conservation, such as from recreational gear taxes, visitor taxes, airport landing fees, new or expanded licenses, or user fees, could be pursued. Existing programs could diversify funding criteria and objectives to accommodate biodiversity conservation on state and private lands. For example, several forestry-related landowner assistance programs (*see Appendix C*) that are designed to promote the forest products industry could incorporate the need to also grow tree species that support native biodiversity of certain bird or insect taxa.

Summary

Hawaiʻi is home to the greatest number of threatened and endangered species in the U.S. The decline in our native species is mirrored by the loss of native habitat, with less than 40% of the land surface covered with native-dominated vegetation today. Hawaiʻi's native habitats and wildlife are important to residents and visitors. They provide essential goods and services such as good water quality, soil stabilization, and climate control, and also serve as the backbone of Hawaiʻi's multibillion-dollar tourism industry. Nevertheless, Hawaiʻi's native biodiversity continues to be threatened by the impacts of invasive species, widespread conversion and development of lowland areas, loss of forest land for grazing, unsustainable harvesting practices, military training activities, recreational overuse, wildfire, and climate change. Because many Hawaiian plants and animals co-evolved, extinction of one species could lead to cascading extinctions of other species. Also, because of the interconnectedness of land and water systems, forest conservation plays a critical role in maintaining the health of ocean resources like coral reefs.

Several collaborative groups are working toward the conservation of biodiversity, and innovative management techniques are being applied, but successful conservation in Hawaiʻi requires keeping the remaining, relatively uninvaded native areas intact, stemming the establishment of new invasive species, restoring degraded areas needed for species-specific conservation goals, and devising practical strategies to limit the impact of widely established non-native species. Despite these needs, funding and information continue to fall short of what is needed for effective conservation of biodiversity. Hawaiʻi continues to face major conservation challenges in protecting its more than 10,000 native species.

Strategies for Issue 6: Conservation of Native Biodiversity

Biodiversity Objective/Management Strategy for Lands with Intact Native Ecosystems (Categories 1 and 2)

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Maintain intact native ecosystem and species.	Categories 1 and 2: All intact native ecosystems in lands currently managed by state, federal, and private organizations and partnerships. Also all lands designated by USFWS as critical habitat and/or recovery habitat that contain native-dominated communities.	Address all other ecosystem services, including water quality and quantity, flood control, carbon storage and sequestration, open space, ecotourism, and education.	Forest health protection and monitoring, co-op fire, forest stewardship, forest legacy, conservation education, USDA FS competitive grants programs (LSR).	Public and private landowners, TNC, NAPP, NARS, FSP clients, Forest Legacy clients, USFWS, OHA, NPS, and others.	FSCG, NRCS, USFWS, DAR, non-profits, NOAA, DOD, U.S. Army, watershed partnerships, FLP, Bishop Museum, Duke Foundation, and others. Facilities and infrastructure (e.g., captive breeding facilities, seed storage, nurseries); research and monitoring technologies and partnerships (e.g., aerial imagery, IPIF, PEP, PICCC, HAWP, private landowners, SWCD).	Invasive species removed; acres fenced, ungulate-free habitat created and maintained; acres of predator-controlled habitat; acres protected by fire fuel breaks created and maintained; native species out-planted; plant genetic materials secured in seed storage facilities; long-term monitoring of forest health and rare plant and animal populations; acres of land under conservation easements that limit habitat-altering activities.	1.1 1.2 2.1 2.2 3.1 3.5 3.6	1.5
2. Maintain native-dominated ecosystems (50 to 100% native), including waterbird habitat and intact coastal sites.	Same as above. Also areas with USFWS-designated core waterbird concentrations and any coastal area designated by TNC as good to very good.	Same as above.	Same as above.	Same as above.	Same as above.	In addition to the measures detailed above, this strategy would also measure acres of habitat maintained for waterbirds; acres of land under conservation easements that limit habitat-altering activities; new policy incentivizing private landowners or participation in existing programs to engage in this type of land management.	1.1 1.2 2.2 3.1 3.5 3.6	1.5

Strategies for Issue 6: Conservation of Native Biodiversity

Biodiversity Objective/Management Strategy for Lands with Rapidly Degrading Native Ecosystems and Non-Native Ecosystems with High Recovery Potential (Categories 3 and 4)								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Address resource threats to natural recovery of native forest and enhance native-dominated habitat with formerly widespread plant species that are now limited in range.	Categories 3 and 4: All rapidly degrading native ecosystems and non-native-dominated systems with high potential for recovery in lands managed by state, federal, or private organizations or partnerships. Also lands designated by USFWS as critical habitat and/or recovery habitat within Categories 3 and 4.	Same as above.	Same as above.	Same as above.	Same as above, plus CREP.	See #1 above. Establish two or more rare plant nurseries on each of the Main Hawaiian Islands; add seed storage facilities; fully operational PEP programs.	1.1 1.2 3.1 3.5 3.6	1.5
2. Restore landscapes with high potential for successful restoration due to their proximity (within 0.62 mile [1 km]) of substantial areas of native-dominated vegetation.	Same as above, and focus on high-quality restoration sites 0.62 mile (1 km) from native-dominated landscape.	Same as above.	Same as above.	Same as above.	Same as above.	Invasive vegetation removed; natural native plant regeneration; length of barriers created to control introduction of habitat-modifying weeds and predators; miles of fuel break created and maintained; native species re-introductions; rare plants cultivated in nurseries for out-planting; rare plants regularly monitored.	1.1 1.2 2.2 3.5	1.5

Strategies for Issue 6: Conservation of Native Biodiversity

Biodiversity Objective/Management Strategy for Lands with Degraded Native Ecosystems and Where Native Ecosystems No Longer Exist (Categories 5 and 6)								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai‘i Environmental Literacy Plan Goals**
1. Conduct localized restoration in non-native-dominated areas with localized potential for restoration. Incorporate native biodiversity consideration into commercial forest management and urban landscaping projects.	All lands designated by USFWS as critical habitat and/or recovery habitat and that are in Category 3, 4, 5, or 6.	Develop information, promote education.	Same as above.	Public and private landowners, OHA, and non-profit organizations.	CREP, non-profits, HFIA, SWCD Kaulunani.	Number of common native plant populations established; number of constituent native plants genetically and historically appropriate to location; soil improvement if necessary.	1.1 2.2 3.5	1.5

Conservation of Native Biodiversity: Education and Outreach								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai‘i Environmental Literacy Plan Goals**
1. Develop environmental education curriculum that supports the link between Hawai‘i’s unique cultural traditions, native biodiversity, and student learning objectives.	Statewide.	Develop information, promote education, increase preservation of cultural knowledge.	HELP, HEEA, HIDOE, Hawai‘i Association of Independent Schools.	Communities and schools, Hawaiian cultural organizations.	HEEA, educational non-profits.	Env. ed. aligned with HIDOE standards; curriculum in use in all schools public and private; curriculum available for use by informal programs.	3.6	1.1 1.2 1.4 1.5 2.2 3.1 3.2 4.4 6.1 6.2 6.3

Strategies for Issue 6: Conservation of Native Biodiversity

2. Work with existing programs, community groups, and schools to increase public awareness and engagement in conservation and biodiversity issues, including involving the public in restoration projects and increasing public access to lands with intact native ecosystems.	Statewide.	Develop information, promote education, increase partnerships.	HEEA.	Same as above.	DOFAW env. ed., UCF, CZM, NARS, community organizations, non-profits, watershed partnerships, TNC.	Number of outreach events and presentations; number of participants in outreach events; number of volunteers participating in restoration projects; increased public access.	3.6	1.2 1.4 1.5 2.2 6.2

Key:
CREP = Conservation Reserve Enhancement Program
CZM = Coastal Zone Management
DAR = Division of Aquatic Resources
DOD = Department of Defense
DOFAW = Division of Forestry and Wildlife
env. ed. orgs. = environmental education organizations
FLP = Forest Legacy Program
FS = U.S. Forest Service
FSCG = Forest Service Competitive Grants
FSP = Forest Stewardship Program
HAWP = Hawai'i Association of Watershed Partnerships
HEEA = Hawai'i Environmental Education Alliance
HELP = Hawai'i Environmental Literacy Plan
HFIA = Hawai'i Forest Industry Association
HIDOE = Hawai'i Department of Education
HISC = Hawai'i Invasive Species Council
IPIF = Institute of Pacific Islands Forestry
km = kilometer
LSR = Landscape Scale Restoration
NAPP = Natural Area Partnership Program
NARS = Natural Area Reserves System
NOAA = National Oceanic and Atmospheric Administration
NPS = National Park Service
NRCS = Natural Resources Conservation Service
OHA = Office of Hawaiian Affairs
PICCC = Pacific Islands Climate Change Cooperative
SWCD = Soil and Water Conservation District
TNC = The Nature Conservancy
UCF = Urban and Community Forestry Program
USDA = U.S. Department of Agriculture
USFWS = U.S. Fish and Wildlife Service

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Issue 7: Hunting, Nature-Based Recreation, and Tourism

Protecting Hawaiʻi's natural resources is essential for the quality of life of residents, the environment, and the future of Hawaiʻi's visitor industry, which is the top revenue-producing industry in the state. Nature-based recreation and tourism includes such diverse activities as hiking and other trail use (e.g., mountain biking, horseback riding, all-terrain vehicle [ATV] tours), camping, using ziplines, beach activities, ocean sports, wildlife viewing, and hunting. Hunting in Hawaiʻi is a popular recreational activity for residents and some visitors, provides a vital food source for many families, is often part of an individual, family, and cultural identity, can be a source of employment and livelihood for some, and is also used as a tool to protect the environment by controlling populations of introduced feral ungulates. Given the multifaceted nature of hunting in the islands, it is discussed separately from other nature-based recreation activities below.

Overview: Hunting

Most states in the U.S. have native wildlife species that are designated as game animals and are hunted; this is not the case in Hawaiʻi. None of the game animals hunted in Hawaiʻi are native to Hawaiʻi.[1] However, the Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW) has been delegated responsibility for managing terrestrial wildlife, including game.[2] Hawaiʻi Revised Statutes (HRS) Chapter 183D-2 mandates that DLNR shall manage and administer the wildlife and wildlife resources of the state which, by definition, include both game and nongame species. Section 183D-3 further mandates that DLNR shall adopt rules protecting, conserving, monitoring, propagating, and harvesting wildlife, and under 183D-4, DLNR is given the authority to maintain, manage, and operate game management areas (GMAs), wildlife sanctuaries, and public hunting areas for these purposes. HRS Chapter 195D provides broad authority to DLNR for the management of indigenous species and provides protection of those species by prohibiting take.[2] DLNR has a dual mandate to conserve, manage, and protect indigenous wildlife and endangered species and their ecosystems, and to preserve, protect, and promote public hunting. Maintaining a recreational public hunting program that does not threaten the persistence of native species and ecosystems in Hawaiʻi is a complex endeavor.

Hunting for Game Management and Recreation

HRS Chapter 183D is the basis of the DOFAW hunting program. The program is organized around participation in the federal Pittman-Robertson Wildlife Restoration Act, which defines activities and projects that qualify for federal funding from taxes on firearms and ammunition. Because a large percentage of Hawaiʻi's game program is funded by the federal Pittman-Robertson wildlife restoration program, game management decisions made for this federal program greatly influence management policy for public hunting areas in general. To qualify for funding, the state game management program must facilitate hunting recreation, within the constraints of other DOFAW goals and priorities. HRS Chapter 183D also created the Wildlife Revolving Fund, whereby monies collected from hunters, hunter education programs, and public shooting ranges are returned to those programs.

Since World War II, hunting has become a popular outdoor recreational activity in Hawaiʻi. Participating in game-related wildlife activities is an important recreational outlet for many of Hawaiʻi's residents and visitors. The U.S. Fish and Wildlife Service 2011 National Survey of Hunting, Fishing and Wildlife-Associated Recreation estimated that 23,000 people hunted in Hawaiʻi, spent 774,000 days hunting and spent over $50 million in the state for hunting-related recreation, up 116% from expenditures reported in 2006.[3] Hawaiʻi's game management program provides opportunities for recreational hunting of 15 species of game birds and seven species of game mammals. The game mammals in Hawaiʻi, all of which are ungulates, are pigs (*Sus scrofa*), goats (*Capra hircus*), sheep (*Ovis aries*), mouflon sheep (*Ovis musimon*), Columbian black-tailed deer (*Odocoileus hemionus columbianus*), axis deer (*Axis axis*), and, to a lesser extent, feral cattle (*Bos taurus*). Game birds include pheasant (*Phasianus* spp.), francolin (*Francolinus* spp.), quail (*Callipepla* and *Coturnix* spp.), dove (*Zanaida macroura*), chukar (*Alectoris chukar*), and wild turkey (*Meleagris gallopavo*). The game program supports and facilitates hunting on public and private lands by providing a structure that promotes and encourages participation. The program funds projects for monitoring hunter activities and game species' population status, land leases to provide additional areas for public hunting, game habitat improvement, game population management in suitable habitats through control of alien predators, facility and infrastructure development, and projects that will aid in data gathering and analysis. These and other activities are all aimed at maximizing recreational hunting opportunities and staff efficiency, within budgetary constraints, in conjunction other DOFAW mandates and in compliance with relevant state and federal laws and regulations.[2]

Whether hunting on public or private lands, hunting in Hawaiʻi requires a permit. However, commercially operated guided hunting activities are limited to private lands and are not allowed on lands designated for public hunting. There are more than 60 separate public hunting areas in the state, encompassing approximately 916,000 acres. Public hunting lands are those lands designated by the Board of Land and Natural Resources as public hunting areas where the public may hunt game birds or mammals. These lands include GMAs, Forest Reserves and surrendered lands, Natural Area Reserves, restricted watersheds, cooperative GMAs, military training areas, unencumbered state lands, and other lands designated by the board.

Hunting and Conservation

As mentioned above, game animals (ungulates) are not native to Hawai‘i. The devastating impacts of feral ungulates on Hawai‘i’s native biodiversity and ecosystems has been well documented. Feral ungulates directly and indirectly affect native ecosystems in a variety of ways. They browse and graze native plants, trample seedlings, cause soil compaction and erosion, disperse seeds of invasive plants, destroy nests of ground-nesting birds (e.g., *nene* [*Branta sandvicensis*]), and contribute to the spread of mosquito-borne avian disease (e.g., pig wallows create mosquito breeding habitat). *(See “Issue 1: Water Quality and Quantity,” and “Issue 6: Conservation of Native Biodiversity,” for additional information.)* The Island of Kaho‘olawe provides us with an example of what would happen in Hawai‘i if populations of feral ungulates were left uncontrolled *(see “The Degradation of Kaho‘olawe”).*

The Degradation of Kaho‘olawe

Non-native feral ungulates introduced in the 18th century were largely responsible for the widespread deforestation and resulting water crisis of the 1860s. Goats were introduced to Kaho‘olawe in 1793. In 1858, Hawai‘i’s government issued the first of many leases for ranching on the island. From 1858 to 1941, the uncontrolled grazing of cattle, sheep, and goats virtually denuded the island of all vegetation, leading to the complete erosion of the island’s fertile topsoil.[4] Today, the island soils are depleted of nutrients and nearly impermeable to water infiltration. The streams have been filled in with silt and no longer flow, and the reefs have been severely affected by eroded sediment.[5]

Beginning in World War II, Kaho‘olawe was used by the U.S. military as a bombing range for training purposes. After decades of protests, the Navy ended live-fire training on Kaho‘olawe in 1990, and in 1993 the last feral ungulates were removed from the island. In 1994, the island was transferred to the state of Hawai‘i. Because of decades of bombing, the island was covered with unexploded ordinance (UXO) and public access was prohibited for public safety reasons. An effort to remove all UXO from the island has not been entirely successful, but the current comprehensive program managed by the Kaho‘olawe Island Reserve Commission is aimed at re-vegetating the island. Management activities are hampered by UXO-related restricted access to large portions of the island, but progress is being made and the island is slowly coming back to life.

Protection of our remaining watersheds and conservation of our remaining native biodiversity is, in fact, dependent on our effectiveness in removing ungulates from native ecosystems. Fencing and hunting to exclude and eradicate feral ungulates has proved an effective strategy for protecting native ecosystems in Hawai‘i. DOFAW maintains trails and roads and provides hunter access to remote and pristine areas to help control feral ungulates in those areas.

Game mammals are managed not only through the hunting program, but also through endangered species projects, Natural Area Reserves projects, watershed partnership activities, and other forestry and wildlife efforts aimed at reducing or eliminating game mammal populations. Nonetheless, hunting and hunters serve as part of DOFAW’s effort to control game mammal populations in sensitive areas. This effort takes place through normal hunting activities and by granting special control permits to individual hunters to reduce game mammal numbers where necessary. Similarly, many private landowners welcome and encourage public hunting on their property to help control game animals for their watershed and native biodiversity conservation efforts. Finding ways and means to facilitate and expand those collaborative relationships on private land will contribute to overall watershed and biodiversity conservation efforts.

Balancing the dual and often conflicting mandates to conserve native wildlife and their habitats while providing for public hunting involves managing indigenous wildlife and endangered species in the areas that have the best habitat and where the species remain, controlling or eliminating ungulate populations in places necessary to sustain and conserve native wildlife, and managing game programs in appropriate areas that are not essential for sustaining native wildlife and ecosystems.

Benefits of Hunting

- Public hunting provides direct and indirect economic benefits to state agencies and the state’s economy. For example, fee hunting in appropriate places can be a source of revenue for state and private landowners. Economic benefits of hunting have been a reliable source and in 2011 provided an estimated economic benefit of over $73 million.[3]
- Hunting, used as tool in conjunction with other actions, can help manage populations of feral ungulates that may negatively affect native vegetation, watersheds, and threatened and endangered species while providing recreation and food.
- Some of the state’s game management program activities benefit and enhance endangered or threatened species. For example, predator control and water unit development for game birds also benefit the endemic Hawaiian goose *nene* in many areas. Roads, trails, and facilities developed or maintained in remote areas increase opportunities for wildlife viewing and increase hunter pressure, which helps control feral ungulate populations. Access also facilitates fire control, which benefits listed species and native species and habitats.

Threats

Loss of Areas for Game Management

Management actions for conservation of native species often involve reducing game mammal numbers, which conflicts with maintaining a sustainable game management program. In balancing native ecosystem protection and public hunting, maintaining high densities of game animals and providing sustainable hunting opportunities is feasible only in areas that are degraded and of low priority for native species restoration, and which have not been designated as critical habitat for listed species. As additional or new lands are managed for native ecosystem protection, there is a potential or perceived reduction in land area available for hunting. This conflict has led many in the hunting community to voice concerns over the loss of available land for this use. Providing a sustainable game management program is possible in appropriate areas but, is limited due to competing resource and societal needs such as management for sensitive species or incompatible recreational use, e.g. high use visitor areas. Loss of other areas for hunting and recreation is also occurring because of closure of many private lands to these activities due to private landowner concerns about liability and vandalism associated with these activities.

A continuing series of efforts has been made to resolve conflicts between hunters and conservation advocates, including state agencies. Recently, a draft game management plan was completed for the Island of Hawai‘i; the plan brought into focus some of the issues and problems and identified activities that might benefit hunting.[6] Further efforts are needed to engage recreational users and identify high-priority areas for these user groups that can be factored into forest management decisions.

Priority Issues and Areas: Hunting

Within areas managed by DOFAW, priority areas for hunting are identified in DOFAW’s Management Guidelines which are currently being update. The update process involves a mechanism for public and agency interaction that improves the understanding of our management programs by the community, other agencies, and policymakers. In identifying areas, the status (pristine to degraded) of vegetation will be considered in conjunction with public safety, public demand for specific resources, and the effect of the proposed use on conservation priorities.[2] Public lands that are prioritized for hunting are shown in Map 7.1 and described below.

Game Management Areas—In these areas, game is the primary objective. These areas are managed for public hunting on a sustained-yield basis and habitat may be manipulated for the purpose of increasing or maintaining the game carrying capacity of the habitat. Hunting seasons and bag limits are set to provide sustained public hunting opportunities and benefits.

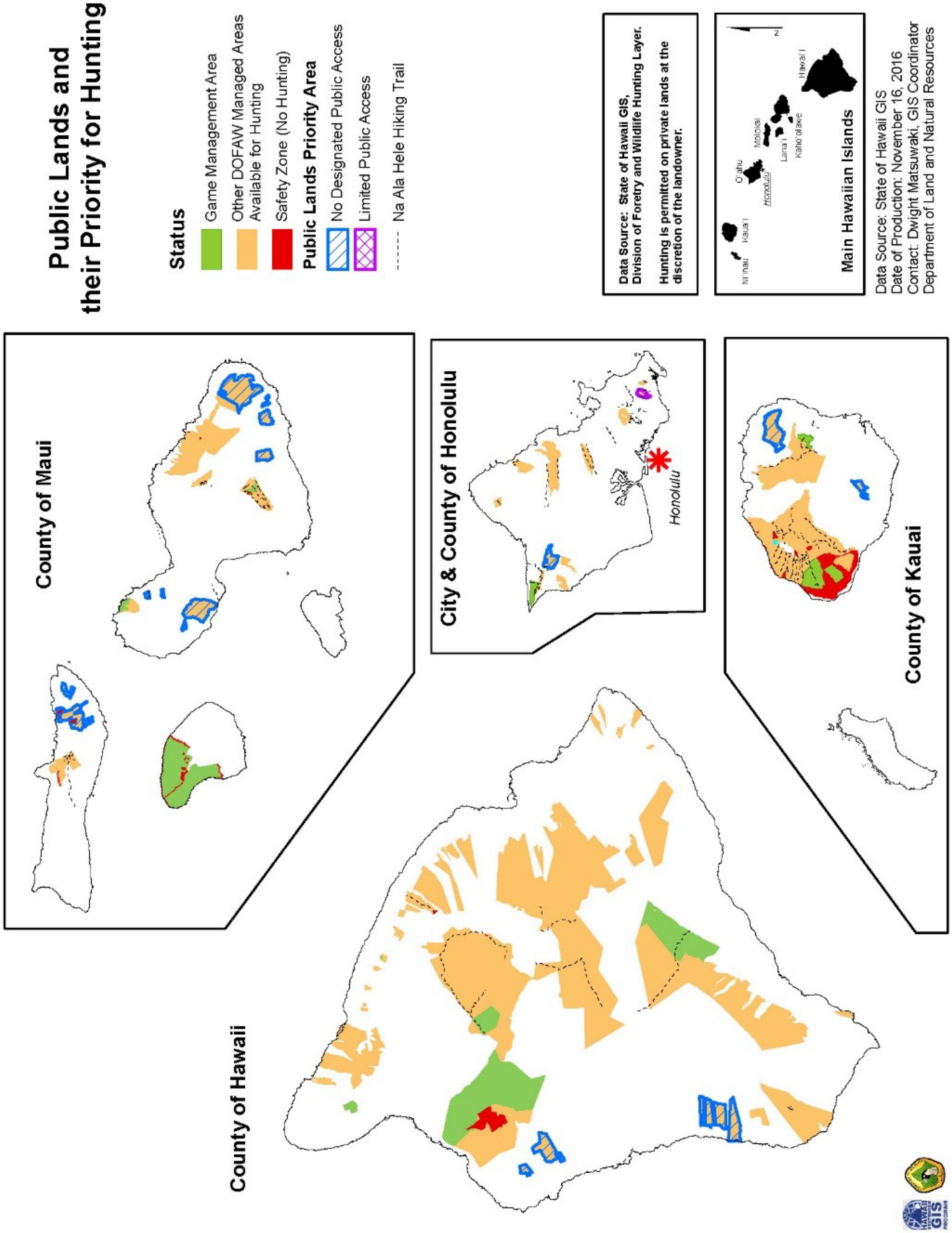
Other DOFAW Managed Areas Available for Hunting—In these areas, hunting is integrated with other uses, such as hiking, production of forest products, and protection of native resources. These areas include other lands managed by DOFAW such as the Forest Reserve lands.

Safety Zones—No hunting is allowed in safety zones which are areas within or adjacent to a public hunting area. Possession of a loaded weapon or the discharge of firearms or other weapons is also prohibited in designated safety zones to prevent hazard to people or property.

As shown in Map 7.1, some public lands either do not have direct public access or have limited public access into the public lands available for hunting. No direct public access means that the public hunting lands cannot be accessed without either crossing private lands (which requires additional Landowners Permission) or crossing other hunting units. Limited Public Access means that there is a designated public access location, however it is challenging to enter the area either due to distance or additional requirements.

Data Gaps and Opportunities: Hunting

- To a large extent, Hawai‘i’s game management program involves understanding and managing hunter access, hunter behavior, hunter pressure, hunter success, and hunter satisfaction. However, the policy and management decisions made are not based on a comprehensive understanding of the desire and needs of the hunting population. A survey project designed to ask the right questions could better inform DOFAW’s game management policy and program.
- Lack of coverage by some form of liability protection is a limitation to hunting on private lands in Hawai‘i. Providing protection against liability to landowners and hunters under state statutes, or under the state’s general coverage such as with a Cooperative Game Management Agreement (should the state be willing), should be explored as a means to support hunting as a recreational activity on private lands.



Map 7.1. Public Lands and their Priority for Hunting.

- In some land-locked public hunting sites, the buildup of game animals is a problem for controlling damage on public lands and on neighboring private lands, where game mammals migrate. Public hunting is a way to control and reduce damage; however, in such places, access for public hunting areas is often restricted. The U.S. Department of Agriculture's Voluntary Public Access and Habitat Improvement Program and the National Shooting Sports Foundation's Hunting Heritage Partnership program fund the formation of cooperative agreements with private landowners to use private trails for access to existing land-locked public hunting areas. Acquisition or lease of private trails or lands using various landowner assistance programs or through conservation easements should be explored to facilitate access for hunting and other public recreational opportunities (see map 7.1 showing lands with no public access to public hunting lands).

Overview: Nature-Based Recreation and Tourism

Hawai‘i's favorable climate and environment offer year-round opportunities for outdoor recreation for both residents and island visitors. With seven national parks/historic sites, six national wildlife refuges, 55 state parks, 55 state Forest Reserves, 31 state harbors and boating facilities, and hundreds of county parks and recreation areas,[7] the opportunities for outdoor (terrestrial and marine) experiences can accommodate both the young and old, the thrill seeker, nature lover, and the sunbather. There are growing numbers of ocean recreation sports, from windsurfing and para-surfing to paddle boarding and kayaking. Mountain and coastal trails are used not only for hiking, but have become popular venues for mountain biking, jogging, horseback riding (where permitted), and numerous extreme races. These and other outdoor recreation opportunities provide a chance for people to experience and interact with nature on lands managed by private entities and federal, state, and county agencies.

The tourism industry continues to play a significant role in Hawai‘i's economy. Hawai‘i attracts more than 6 million visitors each year, and in 2013 tourism generated $14.5 billion in visitor spending.[8] In addition, tourism generates state revenue through accommodation taxes, sales tax, and auto rental taxes. According to a 2013 Visitor Satisfaction Survey conducted by the Hawai‘i Tourism Authority (HTA), for the majority of visitors, vacation continued to be the primary purpose of their trip. While on vacation, nature-based sightseeing and outdoor recreation opportunities are two of the main visitor attractions.

Hawai‘i's recreational environment is often divided into *mauka* (upland) and *makai* (seaward). *Mauka* recreation, often in forest and park settings, includes land- and nature-based activities such as hiking, wilderness camping, picnicking, eco-tours, and hunting. State agencies most directly connected with *mauka* recreation include DLNR Division of State Parks and DOFAW.

The following sections primarily describe the benefits, threats, and impacts in *mauka* natural resources areas where recreation and tourism overlap. The *2015 State Comprehensive Outdoor Recreation Plan* and HTA's *Natural Resources Assessment* provided much of this information.[7,9]

Cultural Tourism

The fundamental idea behind cultural tourism is to create activities, events, and destinations that attract residents and visitors interested in learning about Hawai'i's rich ethnic and cultural resources. Cultural tourism fosters understanding, preservation, and appreciation for the history and heritage of the area. Many believe that cultural tourism will become a substantial part of the tourism industry.[10]

A study conducted in 2008 examined the feasibility and suitability of National Heritage Area designation for central Honolulu and documented the area's cultural and heritage resources.[10] This highly collaborative process involved the public, the support of state and city agencies, nonprofit and community organizations, educational institutions, and business owners. The study demonstrated that the proposed National Heritage Area meets all 10 of the National Park Service criteria for evaluation of candidate areas, and that there is public support for such a designation. The designated sites have yet to be approved by the U.S. Congress.

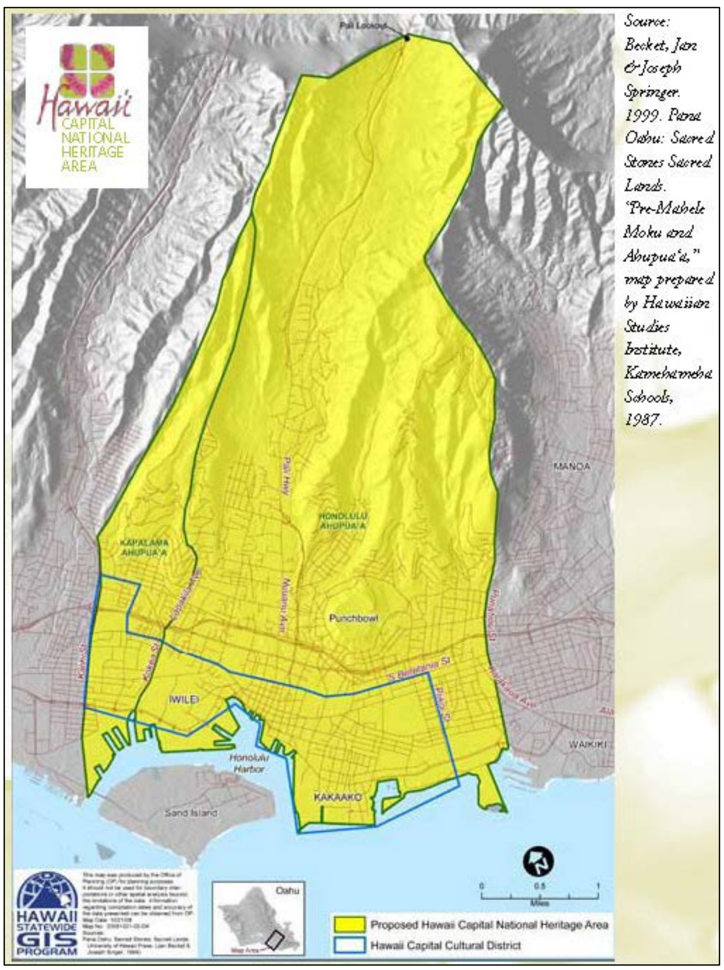


Figure 7.1. The entire *ahupua'a* of Honolulu is proposed for National Heritage Area designation.

The proposed boundaries are the ancient boundaries of the *ahupua'a* of Honolulu and Kapālama, covering the beautiful valley of Nu'uanu and adjacent coastal plains in the ancient and historical village of Kou, now the City of Honolulu, on the island of O'ahu (Figure 7.1).[10] According to the *mo'olelo*, the storytelling oral tradition of native Hawaiians, this area has been an important region for thousands of years. Its rich cultural and natural history is written in the lands that reach from the heights and mountain ridges of the majestic Ko'olau mountains to the welcoming seas of the Pacific. The example of the Hawaiʻi Capital National Heritage Area highlights the connection that can be made between tourism and Hawaiʻi's cultural and natural resources. Further development of eco-cultural tours that link traditional culture to forest resources strengthens social ties to Hawaiʻi's forests.

Nature-Based Recreation and Tourism

In 2003, HTA commissioned a study of the inter-relationships between the health of Hawaiʻi's natural resources and the health of Hawaiʻi's visitor industry. The goal of the assessment was to develop strategies to enhance this relationship for the benefit of both the visitor industry and the natural environment.[9] To accomplish this, the assessment included identification of natural resource areas most commonly frequented by visitors, and an in-depth assessment of each of the identified areas. The primary objective of this assessment, as directed by Act 250, Session Laws of Hawaiʻi 2002, was to initiate long-term planning for improving heavily visited natural resource sites. The study was also conducted to establish a baseline for the quality of natural resource sites in general throughout the state, as well as to identify specific sites in greatest need of improvements in order to prioritize future projects and initiatives.

One hundred and ten sites were selected based on a comprehensive review of travel guides and other sources of information used for vacation planning, meetings with HTA's Natural Resources Advisory Group, consultation with various agencies and organizations responsible for recreational and natural resource management, and public input. The final list of sites assessed comprised: 30 sites on Oʻahu, 19 sites on Maui, five sites on Molokaʻi, six sites on Lānaʻi, 27 sites on Kauaʻi, and 23 sites on the Island of Hawaiʻi.

It was found that, in many cases, the quality of the tourist experience may be negatively affected by aging facilities, deferred maintenance, vandalism, lack of parking, difficulty finding and accessing the site, and other issues. The assessments also revealed that, in some instances, the poor quality of facilities has a negative impact on the natural resources as well. There were, of course, places where the quality of the site and its facilities provided for an excellent visitor experience and protected the natural and/or cultural resources of the site. Sites were prioritized for improvements based on a number of indicators, including estimated volume of use, safety concerns, threats to natural resources, and economic potential. Ongoing efforts by the state are aimed at improving important natural resource areas and the visitor experience.

Hawaiʻi's Parks

Hawaiʻi's parks are situated in forested, coastal, mountainous, and urban landscapes. In 2007, it was estimated that 10.1 million people visited Hawaiʻi state parks each year. Of this total, two-thirds were out-of-state visitors and one-third were residents. [11]A large percentage of visitors engage in photography and general enjoyment of scenic views while visiting state parks. Almost three-fifths of out-of-state visitors to parks are repeat visitors.[11] Maintaining the natural beauty of the parks and the lands surrounding them increases the likelihood that visiting state and national parks will continue to be a high priority for many Hawai‘i vacationers. The benefits of Hawai‘i’s state parks are discussed below, under the general section on the benefits of nature-based recreation and tourism.

National Parks

Figure 7.2. Youth and their sponsors walking on Ala Kahakai National Historic Trail. Photo by Nany Erger. Source: https://www.nps.gov/alka/learn/news/go-digital.htm

The Hawaiian Islands are famous for their volcanoes, beautiful landscapes, and complex ecosystems, which offer unusual hiking and camping opportunities. The state of Hawai‘i contains nine national parks established to preserve native Hawaiian resources, history, and culture. The National Park Service manages two parks in forested regions: Hawai‘i Volcanoes National Park and Haleakalā National Park; two national monuments: the World War II Valor in the Pacific and the recently designated (but not yet open) Honouliuli National Monument; one Historic Trail: Ala Kahakai National Historic Trail (Figure 7.2); and four parks that preserve and interpret Hawaiian culture and history: Kalaupapa National Historical Park, Kaloko-Honokōhau National Historical Park, Pu‘uhonua O Hōnaunau National Historical Park, and Pu‘ukoholā Heiau National Historic Site. Three of the eight operational national parks in Hawai‘i charge an entrance or recreation fee, of which 80% is returned to the park and 20% is given to parks that do not charge fees.[12]

Figure 7.3. Parks and trails provide important opportunities for education and recreation.

State Parks

DLNR’s Division of State Parks is responsible for the development and management of sites that have outdoor recreation and heritage value. The objective of the state parks program is “to provide opportunities and facilities for unorganized outdoor park recreation activities and to preserve and make available for appreciation and study these places of historical, cultural, scenic and natural significance (Figure 7.3).”[6] The

Hawaiʻi State Parks system manages 55 parks on the five major islands, encompassing over 30,000 acres. Historically, many of the early state parks were carved out of state Forest Reserves to enhance and promote the recreational opportunities available to the public. The state park system includes beach parks, historical parks, state monuments, hiking trails, and mountain forest parks. Passive recreation available in state parks includes camping, picnicking, hiking, fishing, swimming, scenic viewing, and photography. Repeat out-of-state visitors report that the nature and scenery of the area is what brings them back to Hawaiʻi.[11]

Visitors and residents continue to use state parks in growing numbers every year, while the resources to manage and maintain the parks and resources in them have decreased. Many state park facilities were built between 1960 and 1980 and are now in need of major repair and renovation. Some of this renovation has been accomplished through required federal compliance with the Americans with Disabilities Act and conversion of restroom facilities to large-capacity wastewater systems.

After the economic downturn in 2008, the Division of State Parks has shifted emphasis to public health and safety and repair and maintenance, rather than development of new facilities. To generate revenues to support operation of the state park system, new fees are being implemented along with increases in the existing fee structure.

Limited state park funding is used primarily to:

- maintain existing parks;
- manage natural resources such as beaches, forests, and trails;
- manage cultural resources;
- provide adequate security—park personnel have maintenance responsibilities but are unable to enforce park rules, and there are no full-time enforcement personnel in state parks; and
- provide visitor services and interpretive programs in the parks—in several parks, non-profit organizations provide some of these services through management leases.

Forest Reserves

The Forest Reserve System (FRS) represents a public-private partnership to protect and enhance important forested *mauka* lands for their abundance of public benefits and values. DOFAW manages the FRS by protecting, restoring, and monitoring natural resources of the FRS. The FRS accounts for over 678,612 acres of state-managed land. These multi-use lands encompass a variety of public uses and benefits depending on the nature of the natural resources found within each reserve. In addition to providing watershed protection, fire protection, and habitat management for threatened and endangered native species, the FRS also provides aesthetic benefits, access to and protection of cultural resources, and recreational opportunities. Providing these benefits entails the following management responsibilities:

- Constructing, restoring, and maintaining roads and trails, arboreta, picnic and camping areas, viewpoints, and signs
- Providing public recreation and hunting opportunities
- Increasing and maintaining public access to Forest Reserves
- Enabling conservation enforcement activities

The public is generally welcome into any forest reserve provided that activities are not dangerous or detrimental to human life or the sensitive resources. Without continued management of these natural resources that provide a suite of ecosystem services to Hawaiʻi residents and visitors, the resources would fade away.

Natural Area Reserves

State lands that have been designated as part of the Hawaiʻi Natural Area Reserve System by DLNR pursuant to HRS Chapter 195-4. The system was established to preserve, in perpetuity, land and water areas that support communities of the natural flora and fauna, as well as geological sites of Hawaiʻi. The system contains 21 reserves on five islands, encompassing 123,810 acres. Many reserves are closed to recreation to preserve the flora and fauna in as unmodified a way as possible, but there are a few that provide recreation, including Kaʻena Point on Oʻahu and ʻAhihi-Kinaʻu on Maui.

City and County Parks

In addition to state parks and reserves, there are hundreds of city and county parks, botanical gardens, community gardens, and recreational sites in Hawaiʻi. For example, on the island of Kauaʻi, the County Department of Parks and Recreation manages nearly 500 acres of recreational sites, and Maui County has over 1,200 acres designated for recreational activities. Honolulu, the most populated county, has the greatest number of park facilities, including one of the largest and the busiest, Ala Moana Beach Park, and the historic Thomas Square. The Department of Parks and Recreation manages, maintains, and operates all parks and recreational facilities of the city, develops and implements programs for cultural and recreational activities, and beautifies the public streets of the city. Preservation and maintenance these city and county parks and the forest lands surrounding them needs to be a priority, because these parks are the most accessible recreational sites for the vast majority of residents and visitors.

Na Ala Hele Trails and Access Program

Na Ala Hele (NAH) (Figure 7.4) is the State of Hawaiʻi Trail and Access Program administered by DOFAW. This program was established in 1988 by HRS Chapter 198D in response to public concern about the loss of public access to trails and the threat to historical trails from development pressure. NAH plans, develops, acquires lands or rights for public use of lands, constructs, and engages in coordination activities to implement a trail and access system. It also conducts environmental risk assessment and establishes methods to improve public safety by assessing trail and ancillary natural resource conditions for specific hazards, executing mitigation actions, and applying warning signs along transit corridors.[13] NAH has become increasingly engaged in trail management and regulatory issues because of public, private, and commercial recreational activities and emerging legal issues. DOFAW lands, including the Forest Reserve and Natural Area Reserve Systems, also contain and provide recreational opportunities for residents and visitors of the Hawaiian Islands.

Figure 7.4. *Ae'o*, Hawaiian stilt (*Himantopus mexicanus knudseni*), one of six endemic waterbirds. Photo courtesy of DOFAW Archives.

Ecotourism

Ecotourism is considered a subset of nature-based tourism. The International Ecotourism Society defines ecotourism as "responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education."[14] Ecotourism is an emerging market in Hawai'i. Many activities popular among visitors, such as enjoying scenic views, visiting museums, and birdwatching and photography (Figure 7.4), are inherently ecotourism-related, whether participants choose to label themselves as "ecotourists" or not. A variety of people participate in ecotourism vacations or activities. On one end of the spectrum are environmentally aware travelers, who consciously choose to be ecotourists. They are largely motivated to participate in "eco-vacations" according to their environmental beliefs and values. These visitors are primarily concerned with wilderness, tropical forests, and wildlife. The other end of the spectrum includes travelers who visit natural places easily accessible from a car or participate in a simple nature-based activity like hiking to a waterfall while on vacation, but may not consider themselves ecotourists or realize that they are participating in ecotourism activities.[14]

The International Ecotourism Society requires that a nature-based activity meet certain criteria for it to qualify as an ecotourism activity, and also offers certification program.[15] There are several tour operators that offer ecotourism opportunities; however, the validity of their operation as ecotourism is not known. The Hawai'i Ecotourism Association, a non-profit organization run by volunteers, offers a Sustainable Tourism Certification Program with a vision "to make sustainable tourism the standard in Hawai'i."[16] Although this is ideally the way ecotourism should work, it is not clear whether people participating in ecotourism or nature-based activities recognize their potential to harm the environment and the local community.

DOFAW is working with non-profit organizations to develop state-level criteria and certification that would distinguish ecotourism activities from other nature-based activities in Hawaiʻi.

Ecotourism appeals to travelers who take special interest in local natural resources and want to be responsible and minimize their negative impact on these resources. Unlike many other nature-based activities, ecotourism in Hawaiʻi can provide a unique opportunity for residents and visitors to experience native ecosystems and wildlife. This in turn would stimulate a desire to protect Hawaiʻi's unique environment through increased conservation efforts and funding.

Benefits of Nature-Based Recreation and Tourism

The greatest benefit of tourism in Hawaiʻi is considered to be economic. The visitor population helps support maintenance of outdoor recreation programs and facilities through spending and taxes, and tourism-related employment is quite high. A study by the National Parks Service Social Science Program demonstrated that visitors to Hawaiʻi's national parks spent nearly $114 million in 2007, directly supporting 2,199 jobs.[17] The Hawaiʻi Coral Reef Initiative Research Program (HCRI-RP) has estimated that coral reefs in Hawaiʻi have an overall economic value of $363.71 million, $304.16 million of which is directly related to recreation and tourism.[4] Surveys of visitors conducted by the state Department of Business, Economic Development, and Tourism and HCRI-RP reveal that, although many factors play a role in a visitor's decision to plan a vacation to Hawaiʻi, the state's unique natural resources and the range of outdoor activities available are often the primary attraction. Therefore, continued viability and growth in the tourism industry through ecotourism or other nature-based recreation, and in turn Hawaiʻi's economic future, strongly depend on the sustainability of natural environments and resources.

Although economic gains are considered the greatest benefit, there are other environmental and community benefits specific to recreational activities. There are also many benefits to Hawaiʻi's public and private forest lands:

- By visiting Hawaiʻi's public and private forest lands, residents and tourists develop an appreciation for Hawaiʻi's natural and cultural resources, which in turn fosters respect and stewardship for these resources.
- Public access to natural areas enables passive outdoor recreation and the enjoyment of nature.
- Recreation values promote the preservation of open space and scenic view corridors.
- Residents and tourists have access to interpretation of cultural and historical sites, increasing their understanding and appreciation of Hawaiʻi's unique culture and history.
- Recreation values can be supportive of, conservation of natural areas.

Trails and unpaved access roads serve multiple functions in addition to enabling recreation. They are essential as access to recreational features and critical for resource management. Trails provide access for:

- county search and rescue efforts;
- watershed restoration;
- monitoring and removal of invasive plant and animal species;
- combating and controlling wildland fire (trails serve as both firebreaks and firefighter access routes);
- experiencing, protecting, and preserving Hawaiian culture; and
- recreating, hunting, hiking, bicycling, horseback riding, and off-highway vehicle riding.

The state operated Commercial Trail Tour Activity (CTTA) program allows commercial tour operators to use NAH trails, and is diversifying Hawai'i's economy via management and monitoring of commercial trail and access road tours. Table 7.1 lists revenues brought in by the CTTA program since its inception in 2002, totaling over $600,000 in 8 years. Private forest lands involved in commercial recreational activities also enjoy economic benefits and provide for revenue diversification along with other forest management/production activities.

Table 7.1. Revenues from Commercial Trail Tour Activity (CTTA) program.

CTTA Revenue	FY09	FY08	FY07	FY06	FY05	FY04	FY03	FY02
Kaua'i	$19,574	$41,792	$35,973	$ 37,332	$ 34,273	$11,114	$33,232	$36,145
O'ahu	$43,597	$30,622	$32,260	$ 38,356	$ 37,442	$18,884	$ 6,119	$ 2,154
Maui	$55	$1,012	$836	$1,348	$1,644	$336	$640	$ 3,436
Hawai'i	$6,967	$5,989	$22,844	$37,368	$38,723	$10,172	$25,752	$4,028
Total	$70,193	$79,415	$91,913	$114,404	$112,082	$40,506	$65,743	$45,763

Threats and Concerns

The state's largest industry depends on scenic beach parks, coral reefs, fisheries, and unique mountain and coastal forest ecosystems. While lack of funding and the subsequent inadequate maintenance of facilities are considered primary concerns, other issues, such as invasive species, have proven to be a serious threat to tourism and recreation. Certain species, such as the little fire ant (*Wasmannia auropunctata)* and the red imported fire ant (*Solenopsis invicta*), have the potential to limit the outdoor recreational experience in Hawai'i and cause extensive economic and environmental harm in Hawai'i.[18, 19] (*See "Issue 2: Forest Health: Invasive Species, Insects, and Disease," for additional information.*) Projected impacts are also expected to result from climate change and its associated higher sea levels, accelerated beach erosion, damage from sea surges and storms, and reduced freshwater supply. *(See "Issue 5: Climate Change and Sea Level Rise," for additional information.)* All of these could negatively affect tourism, a mainstay of

Hawai'i's economy. Table 7.2 provides an overview of threats and concerns to recreation and tourism in Hawai'i and the associated national objectives.

Table 7.2. Threats and concerns for recreation and tourism.

Threats and Concerns	National Themes and Objectives*
Introduction of Invasive Species	
Recreational hikers can unintentionally be vectors for invasive species.	2.2, 3.5
Overuse of trails and subsequent erosion open up habitat for invasive species and landslide events.	1.2, 2.2, 3.5
Invasive species such as the red fire ant have the potential to cause extensive environmental and economic harm.	2.2, 3.5
Release of pets and animals in parks and Forest Reserves is a threat to native species.	2.2, 3.5
Inadequate Funding	
Inadequate funding and subsequent lack of proper maintenance of lands and facilities will cause a reduction in health of natural resources and subsequent reduction in use by residents and visitors.	1.1, 1.2, 2.2
User Conflicts	
User conflicts can occur with over-crowding, poor regulations, and conflicting uses (e.g., hunting and hiking).	1.2
Game animals can harm threatened and endangered species and/or habitat.	1.2, 2.2
Beach and Coastal Erosion	
Over the last half-century, nearly one-quarter of Hawai'i's beaches have been significantly degraded. Typical erosion rates throughout the state range between 0.5 and 1.0 foot per year.	1.1, 1.2, 2.2, 3.7
There are considerable concerns about the future condition of Hawai'i's coastal ecosystems, particularly erosion and the health of coral reefs. Loss or damage of reefs and beaches is detrimental to overall coastal health, as well as recreational activities.	1.1, 1.2, 2.2, 3.1, 3.5, 3.7
Pollution	
Visible pollution significantly damages the image of Hawai'i as an unspoiled tropical destination.	1.1, 1.2, 2.2
Concentrated pollution in all forms—air, water, and solid waste—from urbanization, particularly when the infrastructure necessary to accommodate growth is not in place, is damaging to Hawai'i's resources and recreation appeal.	1.1, 1.2, 2.2, 3.1, 3.2
Overcrowding and Population Growth	

Threats and Concerns	National Themes and Objectives*
Overuse threatens resources. Projected growth in both resident and visitor populations has the potential to negatively affect the health of the environment, as well as its accompanying attractiveness to visitors.	1.2, 2.2, 3.6
An increase in the number and size of urban areas will result in further encroachment into natural areas.	1.2, 2.2
An increase in the number of residents and visitors, combined with a decrease in the size of accessible natural resource areas, may result in overcrowding at remaining resource-based sites.	1.2, 2.2
Aquatic Resources and Marine Life	
Numerous factors have the potential to negatively affect the quality of streams and estuaries that drain into the ocean and near-shore ocean waters. The most significant impacts on marine waters are caused by siltation, turbidity, nutrients, organic enrichment, and pathogens from non-point sources, including agricultural and urban runoff.	1.1, 2.2, 3.1
Point-source discharge into coastal waters by industrial facilities and wastewater treatment plants is also a serious concern.	1.1, 2.2, 3.1
Leptospirosis is a threat to water-based activities.	1.1, 2.2, 3.1
Climate Change	
Increases in air temperatures and changes in rainfall regimes could lead to losses in landscape amenities for land-based activities and changes in the competitive advantage of the local tourism sector.	3.7
Impacts of sea level rise will lead to deterioration of coastal recreational facilities, inundation of critical infrastructure, and a decrease in beach and shorelines areas.	3.7
Increases in storm frequency and intensity could lead to a decrease in tourist numbers as visitors react to the greater uncertainty of storm events.	3.7

*The national themes and objectives are discussed in "*Background*" section on page 14.

Trends

In Hawaiʻi, as well as nationally, the proportion of the population age 65 and older rose by 21% between 2000 and 2010.[7] The aging of the population is attributed to declining birth rates and longer life expectancies, which in turn affect the population's preferences for recreational opportunities. For example, an aging population is less likely to demand youth-oriented facilities such as little league ball fields or skate parks. Rather, they demand facilities that provide less strenuous activities such as walking, golfing, and fishing. Other trends point toward population growth contributing to overuse and overcrowding of recreational and nature areas, and an increase in sports tourism, cultural tourism, and ecotourism.

Trails and recreation sites that were previously less known to out-of-state visitors have, in the recent years, been popularized via the internet (e.g., TripAdvisor and Yelp), including social media. This has led to higher use of such places, which are not yet equipped to meet the demand and pressure of increased use. For example, according to DOFAW NAH staff, over the last 20 years, the number of people hiking the Mānoa Falls trail in Honolulu has increased from about 30 to 500 people daily. In a survey sponsored by NAH of hikers on Mānoa Falls trail, an overwhelming 82% responded “yes” to the question, “Did you have to wait while hiking for other hikers to pass by?” Such a level of use is affecting the natural resources as well as the visitor experience of the site. Furthermore, the lack of site-specific safety precautions on many nongovernmental internet travel sites, as well as the greater number of ill-informed visitors and the sheer increase in visitation, has resulted in an increase in search and rescue operations responding to lost or stranded hikers in remote forested areas. Although guided tours can offer safer alternatives, there will always be a demand from independent travelers to enjoy remote natural areas.

There also is an increasing demand among residents and out-of-state visitors to engage in outdoor conservation activities in natural areas that are otherwise closed for recreational purposes. For example, people are willing to pay to contribute labor for a chance to access and enjoy the island of Kaho’olawe, plant trees at Hawaiian Legacy Hardwoods forest restoration area, or visit the Hakalau National Wildlife Refuge on the Island of Hawai‘i.

Figure 7.5. Visitors come to experience Hawai‘i's unique fauna and flora, such as this rainforest on the Big Island.

Present Conditions

Much of Hawai‘i’s popularity as a visitor destination is based on the range and extent of outdoor activities and natural resources (Figure 7.5). Tourism is the biggest generator of jobs among the major economic sectors, it is the largest single source of private capital in Hawai‘i, and it contributes billions of dollars to total state tax revenue. It is for this reason that so many of the state’s resources and planning efforts are directed toward sustaining and promoting the tourism industry. In contrast, funding for natural resource protection and management at all levels of government has been drastically reduced during the past decade. For example, the 2015 budget for DLNR, the agency primarily in charge of statewide natural resource protection and management, accounted for only 1.14% of the state’s total budget, despite the fact that DLNR manages more than a quarter of the total land mass, as well as many coastal areas.

Priority Issues and Areas: Nature-Based Recreation

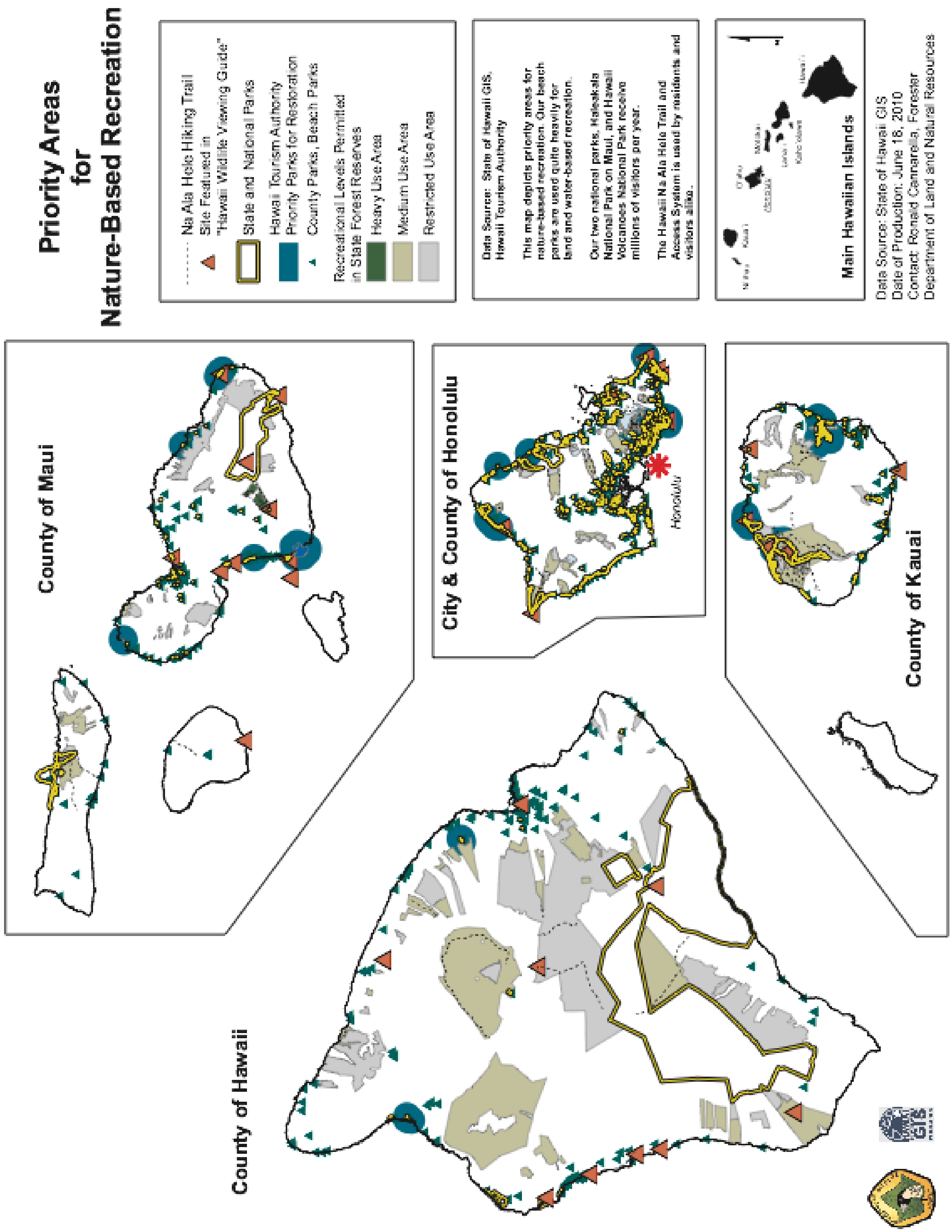
In addition to DOFAW, the Division of State Parks and the HTA have identified priority landscapes, issues, and goals relating to nature-based recreation and tourism in Hawai‘i. Documents referenced include the 2015 *Statewide Comprehensive Outdoor Recreation Plan*, DLNR's *Recreational Renaissance Plan B*,[20] the HTA's *Natural Resources Assessment*,[9] and DOFAW's Management Guidelines. In addition, 10 areas were highlighted in the *Hawai‘i Wildlife Viewing Guide*,[21] carefully selected to direct anyone interested in watching wildlife to accessible locations for viewing wildlife.

Our priority areas for nature-based recreation and tourism (Map 7.2) consist of all state and national parks, DOFAW's Forest and Natural Area Reserves, priority areas identified by the four agencies, and the locations suggested in the *Hawai‘i Wildlife Viewing Guide*, plus the lands surrounding these areas that add to the scenic qualities of the sites. Further, private forest lands that provide for public recreation are considered a priority for technical and financial assistance programs. Map 7.2 shows Hawai‘i's priority areas for nature-based recreation.

The 2015 *Statewide Comprehensive Outdoor Recreation Plan* identified the following priority issues:

- Quality and condition of facilities
- Hiking trail demand and use
- Liability concerns
- Enforcement
- Accessibility
- Physical fitness
- Communication
- Fragility of the natural environment
- Protection of cultural resources
- Effects of climate change

DOFAW's Management Guidelines identified priority areas for non-hunting recreational use in the state Forest Reserves, and also identified priority areas for hunting in state Forest Reserves and GMAs.



Map 7.2. Priority areas for nature-based recreation.

DLNR's *Recreational Renaissance Plan B*[20] focuses on two goals:

- Increase routine repair, maintenance and improved operations
- Start the longer-term process of raising new revenues from vacant urban lands

HTA identified 110 sites across the state in which visitor usage was high or growing. From the evaluation, a list of 23 key sites was identified for more intensive study. The key sites list represents sites with high visitor use that have critical needs and could generate economic benefits if the needs were addressed. The 23 sites are as follows:

Figure 7.6. Kalalau lookout, Kaua'i.

Kaua'i County

- Hā'ena Beach County Park (and Maniniholo Dry Cave)
- Hā'ena State Park
- Kalalau Lookout (Kōke'e State Park) (Figure 7.6)
- Ōpaeka'a Falls (Wailua River State Park)
- Pu'uhinahina Lookout (Waimea Canyon State Park)

O'ahu

- Diamond Head Lighthouse Overlook
- Diamond Head State Monument
- Lā'ie Point State Wayside
- Makapu'u Point State Wayside
- Mānoa Falls
- Pūpūkea Beach Park

Maui County

- Pālā'au State Park Lookout, Moloka'i
- Luahiwa Petroglyphs, Lāna'i
- 'Ahihi-Kina'u Natural Area Reserve, Maui
- Honolua Bay and Mokulē'ia Bay (Marine Life Conservation District)
- Kama'ole III Beach Park
- Kaumahina State Wayside

Hawai'i County

- Wai'anapanapa State Park
- 'Akaka Falls State Park
- Hāpuna Beach State Recreation Area
- Kealakekua Bay State Historical Park
- Punalu'u Beach Park
- Waipi'o Lookout

Data Gaps and Opportunities: Nature-Based Recreation

- Compared to other nature-based activities, ecotourism activities are supposed to have minimal impact on the natural environment. However, it is unclear whether this is the case in Hawai'i. There needs to be more research to identify the impacts of ecotourism and determine whether a certification program by the state would provide authentic ecotourism opportunities to visitors while also providing for enhanced protection of resources.
- For high-use recreational sites, research needs to be done to determine the number of people that should be allowed at each site or on a trail at any given time, such that recreation does not have an adverse impact on the natural or cultural resource, and the visitor experience and safety is enhanced.
- Outside O'ahu, the hiking trail system is limited and should be developed to increase hiking opportunities. Wilderness camping sites that are well connected by the trail system, and to which people can hike without having to drive, should also be developed statewide.
- Partnerships or agreements should be developed with the local community or with hiking clubs such as the Sierra Club to assist with maintenance of trails statewide.
- Historical trails require research, mapping, and documentation.
- Using the Hakalau National Wildlife Refuge, Hawaiian Legacy Hardwoods ecotours, and the Island of Kaho'olawe as a model system, more opportunities should be provided for residents and visitors to pay to contribute labor toward conservation work in exchange for an opportunity to enjoy the outdoors in forested areas that are otherwise closed to recreation. Similarly, more opportunities should be provided for organized groups to volunteer their labor and expertise for conservation work in protected forest habitats.
- Overall, there is a need to create more nature-based recreational opportunities on state and private lands. Working with private landowners through land acquisition, conservation easements, Memoranda of Understanding (MOUs), access agreements, or cooperative agreements is essential to ensuring public access to recreational resources across landowner boundaries. Private lands could then be used to develop new trails and

recreational opportunities. Lack of coverage by some form of liability protection is a limitation to organizing recreational activities on private lands in Hawaiʻi. Providing protection against liability to landowners and visitors under state statutes, or under the state's general coverage such as with a Cooperative Game Management Agreement (for hunting, should the state be willing), should be explored as a means to support recreational activities on private lands.

- Many trails are closing because of vandalism and theft. There needs to be education and outreach about respecting access, property, and natural and cultural resources.
- Over the past few years, multiple mandates of the NAH have become particularly challenging because of the increase in development actions affecting ancient and historical trails and the need to respond at a rapid pace to development pressure, while also managing heightened demand for recreational trail opportunities such as off-highway vehicle riding. Such challenges require continuous evaluation and assessment.

Summary

Tourism continues to play a significant role in Hawaiʻi's economy, generating billions of dollars in visitor spending (Figure 7.7). The majority of visitors choose Hawaiʻi as a vacation destination based on the unique natural resources found here. While economic gains are considered to be the greatest benefit, tourism also has other environmental and community benefits. For example, hunting can be used as a tool for managing feral ungulates in protected watersheds. Trails that are used for recreational hiking also serve as access routes for firefighting and conservation work.

In spite of these benefits, funding for the departments that are mandated to protect natural resources and manage nature-based recreational activities has remained drastically low for decades. As departments struggle to maintain services and recreation programs in spite of limited funds, natural resources will ultimately be negatively affected. Potential problems include failure to meet the public's recreational needs, increased liability exposure if recreation areas are not maintained to ensure public safety, park and trail closures, and resource degradation, all of which will harm Hawaiʻi's visitor industry. The impact of a degraded environment in general would not only diminish Hawaiʻi's attractiveness to visitors but also affect the lives of our residents, whose recreation, culture, subsistence, and physical health are closely linked with the health of the land. Other threats to tourism and recreation include invasive species, pollution, overcrowding and population growth, and climate change.

There is a demand for ecotourism; however, more research needs to be conducted to identify the impact of ecotourism in Hawaiʻi and determine whether a certification program is needed. Many recreational sites and trails are experiencing heavy use, which is affecting not only natural and cultural resources but also visitor experience and safety. Additional recreational sites are needed on public and private lands to provide more opportunities. Also, more opportunities need to be created for visitors to be able to pay to engage in conservation in exchange for enjoying protected areas that are otherwise closed to recreational use. Lastly, there needs to be an increase in awareness among visitors regarding safety and respect for access, resources, and culture.

Figure 7.7. President Obama with his daughters. Visitors and residents alike enjoy Hawai'i for its natural beauty, recreational opportunities, perfect weather, and the Aloha spirit of our people. Photo courtesy of Associated Press.

Strategies for Issue 7: Hunting, Nature-Based Recreation, and Tourism

Recreation and Tourism: Provide Public Access to Natural Areas								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Enhance, preserve, and protect areas for nature-based recreation.	Officially designated hiking trails; federal, state, and county parks; Forest Reserve Areas designated for recreation in DOFAW Management Guidelines; areas identified in *Hawai'i Wildlife Viewing Guide*; HTA priority parks for restoration; public access easements through applicable private lands.	Reduce negative impact on sensitive resource areas, improve quality of life for residents, improve visitor experience.	NAH, NARS, FRS, state and county parks, DAR, NPS, FSP, FLP, LLCP, UCF, HTA, env. ed. orgs. (e.g., Hawai'i Nature Center).	All private residents, landowners, and visitors, conservation orgs, advocates for nature-based recreation, visitor industry, env. ed. orgs, cultural groups.	NARF, various federal grants, TAT and HTA Natural Resources Grant Program, TNC, TPL, Land Trusts, HCA.	Increase in number of people responsibly using recreation areas annually; reduced user conflicts; increased level of satisfaction in opinion surveys of residents and visitors.	3.6	1.2 2.2.b, c 2.3
2. Preserve open space, natural settings, and recreational opportunities through public and private acquisitions, conservation easements, MOUs, access agreements, and cooperative agreements.	Public recreation areas, targeted private lands.	Create management buffers and new conservation lands, sequester carbon, support multi-state involvement.	State and county planning offices, LWCF, CELCP, FLP, LLCP, RLA, FRPP, UCF, FSCG.	All private residents, landowners, and visitors, env. ed. orgs., cultural groups.	Land Trusts, TPL, TNC, County "open space" funds, private donations, HCA, NOAA.	Increased acreage under public ownership or control and managed for recreation; expansion of park systems.	3.3 3.6 2.2	1.2 2.2 2.3
3. Promote responsible behavior and preservation of natural and cultural resources through understanding and stewardship of these resources.	Public and private recreation areas, coastal areas, upland forest areas.	Promote awareness of invasive species impacts on natural areas, promote public awareness of conservation and biodiversity issues.	Government and community partnerships, volunteer programs, eco-tourism companies, various park rangers, UCF, env. ed. orgs., schools.	All private residents, landowners, and visitors, env. ed. orgs., cultural groups, schools.	TAT, HTA, state special funds, HISC, HCA, NOAA, env. ed. orgs., schools.	Increase in interpretive materials available to visitors, increase in public support for stewardship projects, more environmental ed. opportunities for schools, community and cultural groups.	3.6	1.2 1.5 3.1 3.3 5.1

Strategies for Issue 7: Hunting, Nature-Based Recreation, and Tourism

Recreation and Tourism: Priority – Provide Recreational Opportunities and Manage Game Mammals

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Continue to comply with relevant state statutes (HRS 183D and 195D) and federal laws (PR and ESA Section 7).	Forest Reserves, private lands, land-locked state lands.	Identify and control incipient invasive species.	NAH, conservation education, forest stewardship, FSP, CREP, UCF, FLP.	Recreationists, hunters, rural communities, private landowners.	Hunting fees, PR, appropriate land parcels engaged, FSCG.	Hunting licenses sold; hunter days in the field; game mammals harvested; new acres added/removed for hunting.	3.4 3.6	
2. Increase capacity to effectively manage game mammals through better research and monitoring.	Public hunting areas, private hunting lands, state leased lands.	Same as above.	Wildlife program, USGS-BRD UH-Manoa Dept. of Nat. Res. and Env. Mgmt., FLP, FSP, UCF, FSCG.	Hunters, rural communities, UH, watershed partnerships, private landowners.	Hunting fees, PR, research capacity of state and federal institutions, HCA.	Number of areas and game spp. with population estimates; number of plans and estimates of desirable game population numbers.	2.2 3.4 3.6	
3. Increase effective communication between programs and the public, and among programs, regarding resource problems and management and protection issues.	Urban and rural communities and institutions statewide.	Enhance env. ed., identify and control incipient invasive species.	HISC, invasive species program (wildlife), forest health, watershed partnerships, FRS, NARS, FSP, CREP, UCF.	Public and private landowners, resource management agencies.	HCA, Forestry and Wildlife Education and Outreach, HISC and CGAPS outreach staff, NOAA.	Reduced conflict and increased cooperation in natural resource management; public support and participation in management and protection initiatives.	2.2 3.4 3.6	1.2 1.5 3.1 3.3 5.1

Recreation and Tourism: Outreach and Education

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Establish a Children's Forest Program to provide educational and recreational opportunities in forests for K–12 students across the state.	State forests, Hawai'i Tropical Experimental Forest.	Support multi-state and multi-island participation.	Conservation education, FSP, FRS, NAPP, UCF, FSCG.	All private residents, landowners, and visitors, schools, env. ed. orgs.	HCA, TPL, TNC, IPIF, Dryland Forest Alliance, Outdoor Circle, Parks.	Number of children engaged; broad Pacific Island involvement; Demonstration Sites.	3.6	1.2 1.4 1.5 2.2 3.1

Strategies for Issue 7: Hunting, Nature-Based Recreation, and Tourism

2. Enhance education and outreach to increase public awareness and engagement in safety measures related to nature-based tourism and to increase respect for public and private access, property, and natural and cultural resources.	Statewide.	Promote public awareness of conservation and biodiversity issues, invasive species movement and concerns, and Hawaiian cultural practices.	Conservation education, UCF, FSP, FSCG, state and county parks.	Public and private landowners, resource management agencies, schools, env. ed. orgs.	TNC, TPL, NOAA, NPS, UH, Schools, env. ed. orgs., HELP.	Decrease in search and rescue events and vandalism at recreation sites statewide.	2.2 3.4 3.5 3.6	3.1
3. Maintain a relationship with HEEA and help implement the Hawai'i Env. Literacy Plan.	Statewide.	Promote public understanding of invasive species issues, coastal area protection, climate change, water quality and quantity.	Conservation education, UCF, FSP, FSCG, state and county parks.	Public and private landowners, resource management agencies, schools, env. ed. orgs.	TNC, TPL, NOAA, NPS, UH, schools, env. ed. orgs, HELP.	More Cooperative Agreements and MOUs; increased partnerships with communities; number of schools, educators, and env. ed. orgs. benefiting from HEEA.	3.3 3.6 3.1	All HELP goals

Key:
CELCP = Coastal Estuarine Land Conservation Program
CGAPS = Coordinating Group on Alien Pest Species
CREP = Conservation Reserve Enhancement Program
DAR = Division of Aquatic Resources
DOFAW = Division of Forestry and Wildlife
env. ed. orgs. = environmental education organizations
ESA = Endangered Species Act
FLP = Forest Legacy Program
FRPP = Farm and Ranchland Protection Program
FRS = Forest Reserve System
FSCG = U.S. Forest Service Competitive Grants
FSP = Forest Stewardship Program
HCA = Hawai'i Conservation Alliance
HEEA = Hawai'i Environmental Education Alliance
HELP = Hawai'i Environmental Literacy Plan
HISC = Hawai'i Invasive Species Council
HRS = Hawaii Revised Statutes
HTA = Hawai'i Tourism Authority
IPIF = Institute of Pacific Islands Forestry
LLCP = Legacy Land Conservation Program
LWCF = Land and Water Conservation Fund
MOU = memorandum of understanding
NAH = Na Ala Hele trail and access program
NAPP = Natural Area Partnership Program
NARF = Natural Area Reserve Fund
NARS = Natural Area Reserve System
NOAA = National Oceanic and Atmospheric Administration
NPS = National Park Service
PR = Pittman-Robertson Funds
RLA = Recovery Land Acquisition Program
TAT = Transient Accommodation Tax administered by HTA
TNC = The Nature Conservancy
TPL = Trust for Public Lands
UCF = Urban and Community Forestry (Kaulunani)
UH = University of Hawai'i
USGS = U.S. Geological Survey

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Issue 8: Forest Products and Carbon Sequestration

Overview

The history of forest product use in Hawai‘i is both diverse and unique. The forests of Hawai‘i have changed dramatically from the time the first Polynesians migrated to these islands in AD 400. The Hawaiians modified much of the lower-elevation forest as they developed their communities in the islands. Their activities included using the native forest resources they encountered, supplementing the forest with plants they had brought with them, introducing new animals to the islands, and clearing areas for settlement and agricultural production. In some cases these modifications to the forest resulted in unintended consequences for native species. The native palm, or *loulu* (*Pritchardia* spp.), was once a dominant overstory tree species in the dry and lower-elevation forests of Hawai‘i, forming a unique forest ecosystem. Native Hawaiians inadvertently introduced the Polynesian rat (*Rattus exulans*), which has often been posited to have caused the dramatic decline in *loulu* populations and the near-extinction of many other native species.

When Europeans first encountered Hawai‘i, they noted that lowland forests had been mostly converted to grasslands that were periodically burned to stimulate the growth of *pili* (*Heteropogon contortus*), which was the primary thatching material for house structures. Although Hawaiian civilization altered the forests of Hawai‘i, development of the *ahupua‘a* system allowed sustainable living in harmony with the natural resource base and unique geography of these high islands.

For the most part, native Hawaiians did not use timber-producing species from the forested uplands in significant quantities, with the exception of the endemic tree *koa* (*Acacia koa*). *Koa* is a dominant species in wet and mesic forests. A mature *koa* tree can reach 120 feet in height, and is capable of producing a straight trunk with no wood defects, which native Hawaiians found ideal for producing ocean-voyaging canoes. A mature *koa* also produces beautiful wood with a “curl” that rivals any fine craft wood in the world. Today, a *koa* rocking chair retails for $3,000 to $5,000 depending on the curl and the skill of the craftsman. Thus, *koa* is highly prized for its ecological, cultural, and economic values.[1] Much of the original *koa*-dominated forests have already been harvested or cleared for other agricultural production, namely cattle ranching, and remaining stands are subject to theft, which has increased in the last several decades owing to high demand for the valuable heartwood. Other native tree species in Hawai‘i for the most part are not used to the same commercial and personal use scale as *koa*; nevertheless, early Hawaiian society made use of a variety of other forest products to supply building materials, tools, clothing, medicine, and food, among many other uses.

The first internationally traded, commercial forest product exported from Hawaiʻi was the endemic species of *ʻiliahi*, or Hawaiian sandalwood (*Santalum* spp.). Sandalwood is so highly prized for its fragrant wood and valuable essential oil that, for the Hawaiian Kingdom, its trade developed into a lucrative and internationally recognized industry in the islands. The trade of sandalwood in Hawaiʻi and other Pacific islands took hold in the late 1700s to early 1800s as the demand in Asia for the fragrant wood grew and as shipping activities increased throughout the Pacific Ocean. The six different species of sandalwood, distributed throughout the Main Hawaiian Islands, were all used to some extent during the sandalwood era. The growing demand, high price, and unsustainable harvesting eventually lead to a market crash for Hawaiʻi when all of the accessible sandalwood had been harvested a short 40 years after trade began. Hawaiian sandalwood is still considered the most profitable natural resource to have been exported from the islands under the Hawaiian Kingdom. However, the exploitation of the trees led to a significant decline in the resource, subjected harvesters to hazardous working conditions, and ultimately removed a major component of Hawaiʻi's forests.[2] Since the collapse of the industry in the late 1800s, Hawaiian sandalwood has not been a significant trade item, with only a few small-scale sales of *ʻiliahi* every few decades. Internationally, sandalwood is still one of the most valuable woods in the world.[2, 3]

Since the decline of the sandalwood trade, a sustainable forest product export market of any scale has not developed, largely because less-expensive wood-based building materials are available from overseas sources such as the Pacific Northwest and Southeast Asia. Large-scale timber trials of introduced commercial species were undertaken by the Territory of Hawaiʻi Board of Forestry and Agriculture, the Hawaiʻi Sugar Cane Growers' Association, and the U.S. Forest Service (FS) in the 1900s. Despite the fact that several Hawaiian-grown non-native commercial species have some of the highest growth rates in the world, a viable and sustainable commercial timber industry has yet to develop.

There are a number of mid- to large-scale timber plantations on both public and private lands throughout the state. Many of these stands are mature or even senescing, and should be harvested, but without a large scale market, this has not happened. It was hoped that the establishment of a medium-sized veneer plant and cogeneration facility on the Hāmākua coast of the Island of Hawaiʻi would stimulate a commercial timber industry, but that venture did not prove to be successful, owing to a number of factors. There are, however, *Eucalyptus* stands on Kamehameha Schools land on the Hāmākua coast that are being harvested, with most of the wood going to foreign markets.

In recent years, the use of biomass for energy production has emerged as a viable way to use existing plantation forests and for the state of Hawaiʻi to reach its renewable energy goals. There is currently a biomass power plant in operation on Kauaʻi—a 7-megawatt (MW) plant in the Kōloa area[4]—that uses various types of biomass stock. Much of the initial wood supply is coming from clearing state and private lands overgrown with invasive albizia (*Falcataria moluccana*) trees, which once removed, will be replaced by a non-invasive *Eucalyptus* hardwood hybrids to provide a long-term supply of wood. The biomass operation has also used salvaged trees burned in wildfires at Kōkeʻe in 2012.[5] Another 22-MW biomass plant is under construction on the Hāmākua coast on the Island of Hawaiʻi and 50% completed, that when operational would harvest approximately 2,000 acres of *Eucalyptus* trees per year, mainly from the Hāmākua and Pahala areas. As of May 2016, company officials were working on obtaining a power purchase agreement and proceeding with the remainder of facility construction.[6] The success of these projects may lead to an increase in wood product use and commercialization of the wood products industry in Hawaiʻi.

Forest Products of Hawaiʻi

Increasing timber production and developing markets to support those products is highly desirable in Hawaiʻi,[1] but timber is not the only product derived from Hawaiian forests. For the purposes of this assessment, *forest products* are defined as a suite of products and services, including, but not limited to, those described below.

Timber and Other Commercial Products

- <u>Timber, wood chips, craft wood, and other solid wood products:</u> Non-native planted commercial forests, new native forest plantations (mostly *koa*, but also milo [*Thespesia populnea*] and kou [*Cordia subcordata*]) for timber production, management of natural forests for sustainable production, and salvage operations
- <u>Biomass and/or biofuel production:</u> Non-native plantations, invasive plant species control and use, commercial forestry byproducts, biomass fuel management, and salvage operations
- <u>Non-timber forest products:</u> Gathering and use of non-timber forest products for personal, commercial, medicinal, and cultural purposes

Ecosystem Services

- <u>Watershed protection and production of water:</u> Water capture, percolation, recharge, and supply (*see "Issue 1: Water Quality and Quantity," for additional information*)
- <u>Carbon sequestration:</u> Native or non-native plantations, reforestation or restoration projects for both non-commercial and commercial purposes, and improved forest stand management (*see "Present Conditions and Trends" section for more detail*)

- Native ecosystem protection: Preservation of the unique flora and fauna of Hawaiʻi (*see "Issue 6: Conservation of Native Biodiversity," for additional information*)

Social, Cultural, and Non-Traditional Forest Products and Services

- Benefits to human health: Open space, improved air and water quality, and exercise opportunities
- Cultural: Sacred site protection; resource gathering for medicinal, ceremonial, or traditional uses; access for cultural practices; and spiritual inspiration
- Recreational opportunities: Hunting, hiking, and camping, among many others (*see "Issue 7: Hunting, Nature-Based Recreation, and Tourism," for additional information*)

Benefits

A well-managed forest products industry would not only provide needed products in and outside of Hawaiʻi, but also would provide jobs and landscape-level ecosystem services. Other important benefits from such an industry are those associated with biomass production for fuels (possibly reducing dependency on the mainland and foreign countries), carbon storage and sequestration, and positively addressing climate change issues and related management needs.

Due to the Forest Reserve tax deferment policy of 1957, forest land greatly increased between 1961 and 1970, as did logging; total board-foot production for forest products throughout the state rose from 915,000 board feet in 1958 to 4,121,000 board feet in 1967. After the passage of the Endangered Species Act in 1973, commercial tree planting dropped from an average of 580 acres per year between 1956 and 1965 to only 82 acres in 1985. However, the 2004 survey "Economic Value of Hawaiʻi's Forest Industry in 2001" revealed that over 900 workers were employed in the Hawaiʻi forest industry, with a corresponding payroll of $30.7 million.[7] This "placed the average wage rate for forest industry employees at over 50% higher than the average for farm labor."

Valuation of forest products can be difficult if all products and services are considered. Measuring the value of water, medicinal plants, wildlife habitat, recreation, and other benefits is not an exact science; rather, it is inherently subjective. In Hawaiʻi and much of the Pacific, these types of forest products and services are very important and are often managed specifically to perpetuate their long-term sustainability.

We know that a multitude of benefits are derived from or positively influenced in some way by forests. Because an island functions as an integrated system rather than as a grouping of independent systems, it is important to understand that forest products need to be valued by their roles in the larger system, rather than by the value of the individual product in isolation.[14]

Threats

A principal threat to the forest products industry in Hawaiʻi is the conversion of forest to non-forest uses. Labor and land costs are high in Hawaiʻi, and many landowners who have land suitable to support the production of forest products often choose or are forced to sell their property instead. Keeping forests from being converted to non-forest uses is an ever-present challenge in Hawaiʻi. As an isolated island state, concerns about food, construction material, and energy security should be included in discussions about urban development on productive lands and the associated debate about expanding agricultural areas for food and/or forest products.

People living in Hawaiʻi are dependent on imported resources for a large percentage of life-sustaining products, such as food, fuel, equipment, and many wood products and supplies. On the island of Oʻahu, an estimated two weeks of food, water, and supplies are available to support a population of more than 998,000[8] people if the air and sea ports are rendered non-operational. It is very important that Hawaiʻi address self-sustainability issues, including the importation of food, fuel, and forest products. The role of forest management and forest products should be central in discussions and decisions regarding how our society addresses crucial resource allocation decisions.

Lack of proper infrastructure to support the development and maintenance of an operational timber industry in Hawaiʻi is another limiting factor. For example, existing ports and facilities may not have the proper size, configuration, or accessibility to handle large volumes of primary or processed timber products. If the export of Hawaiʻi-grown timber or wood products increases, some expansion or further development of port facilities may be necessary.

Lack of access to federal or state programs for private landowner loans, land management planning assistance, and marketing assistance also has affected the development of forest product industries. Because of factors such as scale, geographic location, and local economic conditions, entities seeking to develop forest industry infrastructure in Hawaiʻi commonly encounter challenges in obtaining capital, necessary permits, and loans, yet their success in this regard is critical for the forest industry to grow in Hawaiʻi.

Invasive species are a major threat to the forests of Hawaiʻi (*see "Issue 2: Forest Health: Invasive Species, Insects, and Disease*). The introduction of invasive species, insects, or diseases that would affect the vitality of the major native forest product species, such as *koa* or ʻ*iliahi*, or non-native commercial production species such as *Eucalyptus,* would impede or slow the development of the forest products industry in the state. Already, the statewide occurrence of *koa* wilt in native forests, plantations, and nurseries limits the use of this ecologically and economically important species for ecosystem restoration and commercial reforestation efforts. Introduction of other new diseases and pests could have similar effects on native and introduced commercially important species. Consequently, the invasiveness of any proposed new introduction or currently occurring commercial forest products species should be evaluated and considered when developing it for the industry. If non-native species are being introduced for commercial purposes, they should be screened using the Hawai‘i Pacific Weed Risk Assessment or similar tool, and only introduced if found to have a low probability of becoming invasive. The suitability of native species should be investigated, and native species should be invested in as alternatives to the introduction of new commercial species.

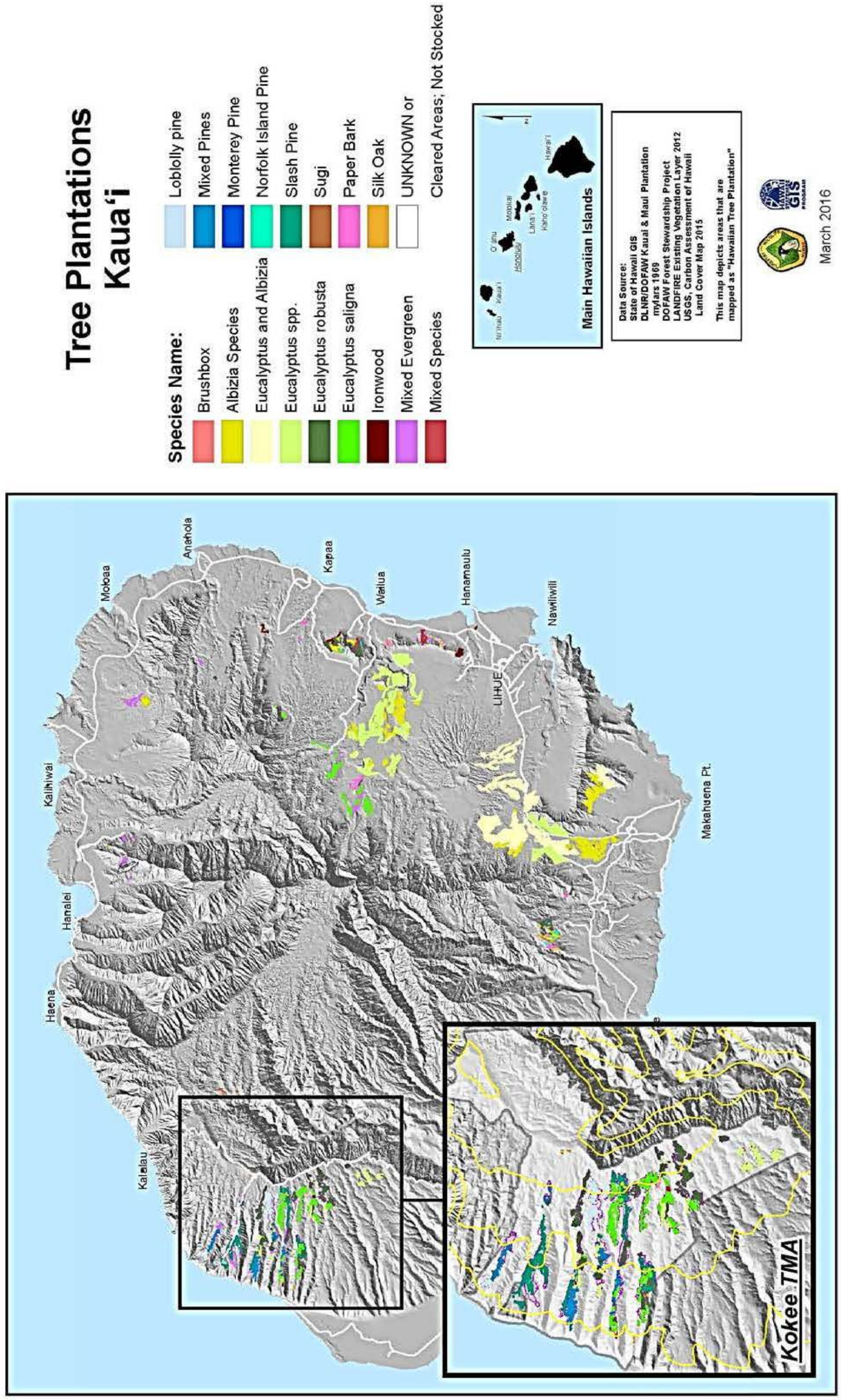
Developing any new industry is challenging, especially in Hawai‘i, which has limited land and resources. Hawai‘i also has some of the rarest species and natural habitats in the world, including 434 plants and animals that are federally and state-listed as threatened and endangered,[9] necessitating extra care and precaution in the implementation of projects and programs. Regulatory restrictions to avoid impacts on sensitive species and habitats may limit the location, timing, and scale of commercial operations.

One current example of this is the operational restrictions imposed to protect the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*). This species is widely distributed and can be found in many habitats.[10] Commercial timber harvesting may inadvertently harm individual bats, particularly juvenile bats that are unable to fly, which could result in “take” under the state and federal Endangered Species Acts. To mitigate this impact, harvesting operations are restricted during the bat pupping season (June 1–September 15). The industry is trying to develop an acceptable way to conduct harvest operations during the pupping season that will avoid harming Hawaiian hoary bats. Similar concerns and restrictions apply for many of the other protected species, including numerous endangered forest birds. Finding workable solutions to this and other regulatory requirements is essential for an industry that must operate year-round to be competitive and meet industry standards for biomass or solid wood production.

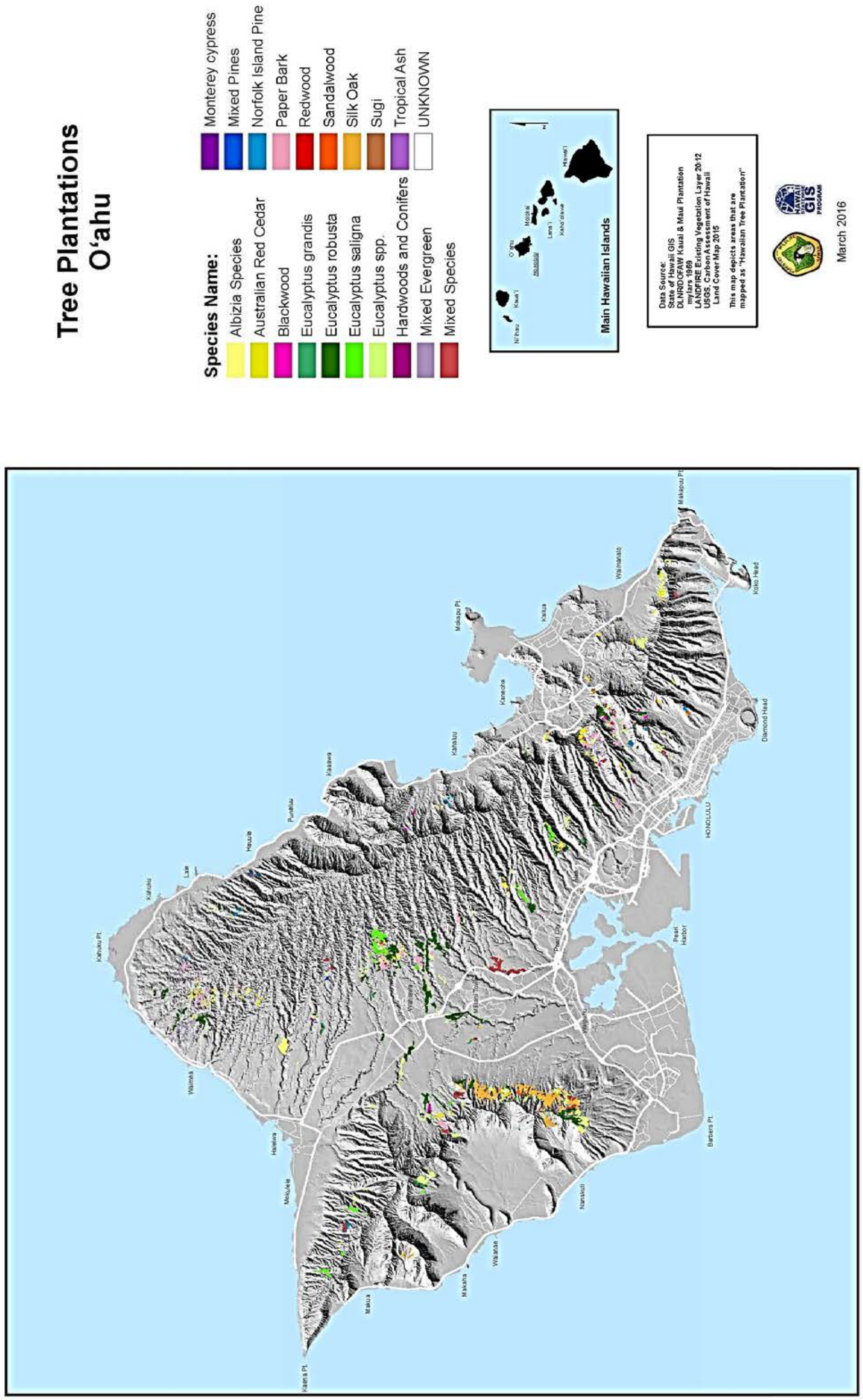
Present Conditions and Trends

Forest Products

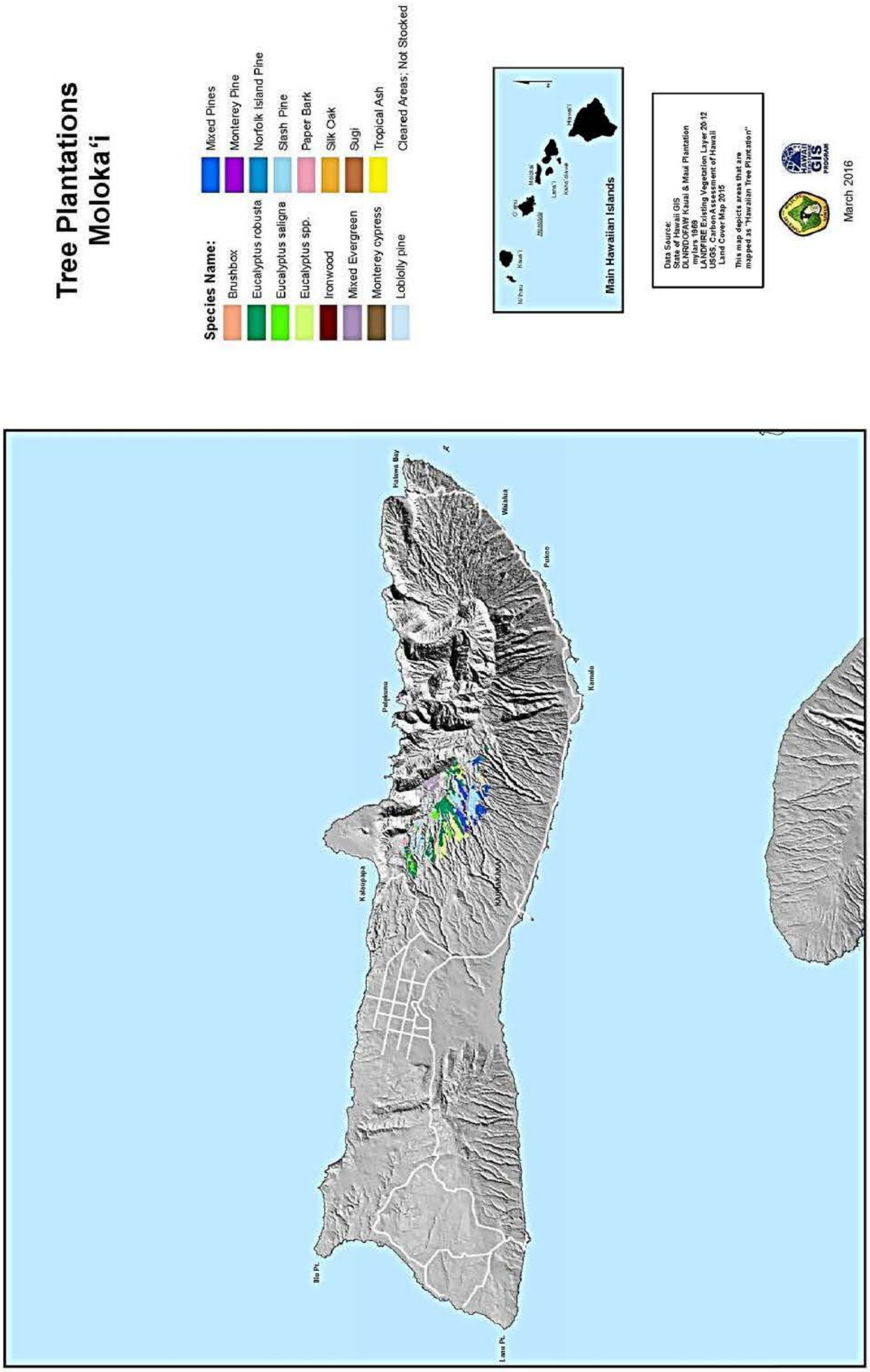
Any large-scale commercial timber industry in Hawai‘i is in a nascent stage of development despite decades of efforts to generate commercial ventures. A thriving forest products industry has many components that need to be operational in order for it to fully function at capacity, including both native and non-native forest products. The first requirement is having the land and supply of trees to support a commercial industry. The Division of Forestry and Wildlife (DOFAW) forest records indicate that there are 385 major landowners with 76,500 acres of potential commercial tree plantations in the state. Maps 8.1 to 8.5 show the locations and species compositions of tree plantations across the state of Hawai‘i.



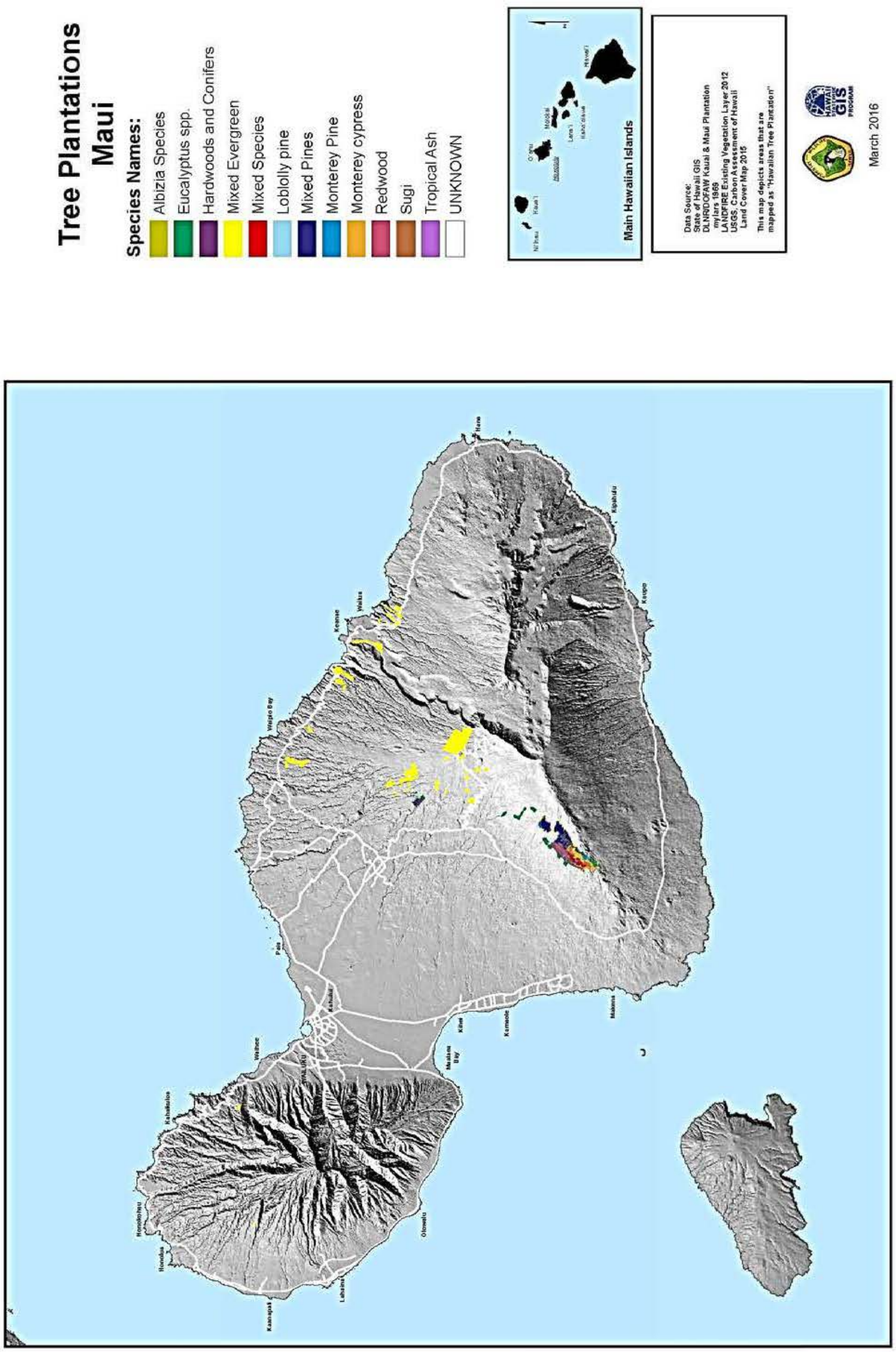
Map 8.1. Locations and species composition of tree plantations on Kauaʻi.



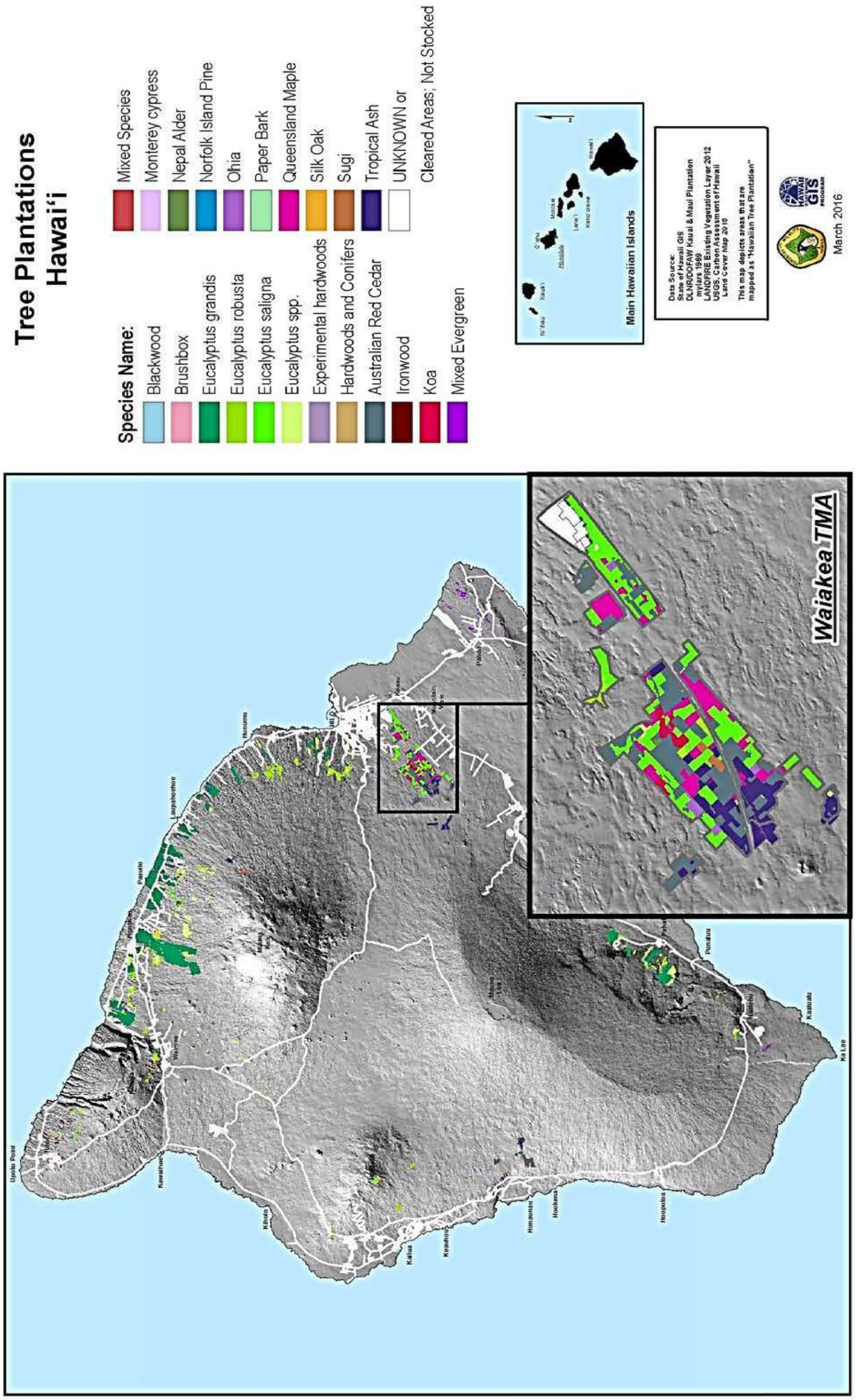
Map 8.2. Locations and species composition of tree plantations on O‘ahu.



Map 8.3. Locations and species composition of tree plantations on Moloka'i.



Map 8.4. Locations and species composition of tree plantations on Maui.



Map 8.5. Locations and species composition of tree plantations on Hawai'i.

Once components are fully developed and implemented, the industry in Hawai'i likely will include timber for craft woods, lumber, veneer, wood biomass and biofuels, export wood chips, and more.[11, 12] Hawai'i has several wood product companies, operators, and primary log processors who use small portable mills to process timber resources. Demand already exists for solid wood products in local, mainland, and foreign markets, especially in the case of *koa*.[7, 8, 13] Hawai'i forest-grown non-native products such as *Eucalyptus robusta* (Robusta) and *Eucalyptus saligna* (Saligna) make beautiful hardwood flooring, furniture, cabinetry, and other fixtures, including doors, windows, and moldings. Plantations stands of these species are ready for harvest.

Development of a mid-size wood mill on the Island of Hawai'i remains a worthy goal and could be attainable. Some of the critical pieces needed for a wood mill may be coalescing, with an increase in wood supply coming from release of new acreage to lease on state lands in the Waiākea Timber Management Area.[14] A mid-sized mill would have access to wood supply from both public and private lands. There is potential for the mill to run its own biomass operation, using waste material for heat or electricity to dry lumber; it also could team up with another biomass operation under construction to provide affordable services.

Finally, there is market demand for high-quality Hawaiian hardwoods in domestic and foreign markets. At present, 160,000 tons of *Eucalyptus* logs from the Hāmākua coast are being shipped to foreign markets, and market studies identify consistent domestic demand.[7, 8, 9] *Koa* has continued to increase in value as new mainland markets are developed, and other native and Polynesian hardwoods are being highlighted by local and international woodworkers. While there are several non-native tree species that are used in the forest industry for timber and other forest products, there continues to be a strong trend to develop a wood products industry based on endemic tree species such as *koa* and *'iliahi* (Figure 8.1). Planting and management of such endemic tree species could potentially be a win-win situation for conservation and the forest products industry. The commercial production of an endemic species would provide a financial incentive to convert marginal pasturelands and degraded croplands to native forests and thereby support the development of a high-value forest industry. In particular, planting and management of *'iliahi* would help restore this endemic species and associated native plants and wildlife. This in turn would support continued traditional and cultural uses of *'iliahi* and encourage landowners to value, manage, and retain native forest.

Figure 8.1. ‘*Iliahi*, or Hawaiian sandalwood (*Santalum* spp.), seedlings, essential oil, and adult tree. ‘*Iliahi* is an endemic species that was the foundation of the forest products industry in Hawai‘i during the 1800s, and today has the potential to once again become a major contributor to the industry.

Much of the historical harvest of the endemic forest, which still continues in some places today, has been a series of high-grading, unsustainable extractions, ultimately resulting in conversion of the forest to pasturelands. Improved silvicultural practices for native forest production are needed, in addition to implementation of sustainable forest management guidelines. Some plantations, primarily of *koa*, have begun to be established on private lands, but degraded site conditions, pests, and diseases remain concerns at most sites. Many native species are not as fast-growing as some non-native timber species, but the overall positive environmental impacts and high economic value of using endemic species for forest products, especially *koa*, *‘iliahi*, *milo*, *kamani* (*Calophyllum inophyllum*), and *kou*, clearly provide far more benefits and services than using non-natives alone. DOFAW, through a variety of private landowner assistance programs, offers technical assistance and cost-share incentives for the development and improved management of sustainable forest production.

The state, along with a number of key partners, is developing a Koa Action Plan. This plan will include short- and long-term goals to prioritize and promote research on *koa* resilience to disease and insect damage, market development and commercial use, demonstration trials, and conservation planning. With such a plan in place, funds and resources can be leveraged from a number of *koa* interest groups to support a sustainable *koa* forest industry that may include large-scale timber production, genetic improvement of commercial and conservation stock, carbon sequestration, and a market for carbon credits (discussed further below). *Koa* forests will also provide vital ecosystem services, including provision for cultural and societial uses, conservation of wildlife habitat, and a plethora of other uses that *koa* supports in Hawai‘i. Similar action plans may also be developed for other native tree species, such as *‘iliahi*.

The FS Institute of Pacific Islands Forestry, University of Hawai‘i, Hawai‘i Agricultural Research Center, and state, federal, industry, and private organizations partnered with Purdue University to establish a Tropical Hardwood Tree Improvement and Regeneration Center (THTIRC) in 2010 for Hawai‘i and other Pacific islands. The focus of THTIRC is to provide additional resources to advance the science of Pacific island hardwood tree breeding, conservation, genetics, and silviculture for sustainable production of forest products, improved ecosystem services from native forests, economic development of local communities, and cultural enhancement for indigenous cultures, local communities, and visitors. A major focus of THTIRC is to expand upon existing efforts to improve *koa* for traits such as better growth, form, wood quality, pest/disease resistance, and abiotic stress resistance for restoration and forestry applications. The program adds needed research, but also transfers information and technical expertise on breeding, silviculture, and nursery management among stakeholders. The services of THTIRC are available for *koa* and other native tropical hardwood species. The successful program of tree improvement through breeding and genetic research can also be applied to other important production species, such as *‘iliahi* and *milo*, and *‘ōhi‘a* (*Metrosideros polymorpha*) for its ecosystem services.

Hawai‘i’s Clean Energy Initiative, Biomass, and Development of the Forest Products Industry

There is an increased focus in Hawai‘i on reducing reliance on fossil fuels and improving renewable energy self-sufficiency. In 2015, the governor signed legislation adopting the most aggressive clean energy goals in the nation, to achieve 100% clean energy production by 2045.[15] This ongoing long-term commitment to clean energy production has encouraged interest in development of wood biomass for electrical generation and/or biofuel production in Hawai‘i. A primary objective of the Hawai‘i Clean Energy Initiative (HCEI) is to wisely use the energy resources we currently have. One of the identified strategies under this objective is to harness energy from biomass resources.

The HCEI discusses a wide variety of products suitable for biomass energy production, including conventional sources such as trees, but also agricultural residues like sugarcane bagasse and macadamia nut shells, dedicated energy crops such as hemp (*Cannabis sativa*) and bana grass (*Pennisetum purpureum*), and even urban wastes. The nascent forest industry in Hawai‘i is recognized as a potential source of biomass feedstock,[16] including biomass produced through wood residues generated as a byproduct of timber harvesting and wood processing, or potentially through the development and production of dedicated forest biomass crops. The HCEI also envisions the development of biorefineries that will convert biomass into biodiesel to provide a renewable source of fuel for land, sea, and air transportation.

The State of Hawaiʻi's clean energy goal of using 100% renewable energy for electric power generation by 2045, presents some unique opportunities for win-win solutions in forest management. Use of biomass helps the state meet its renewable energy goal, and it may help yield a viable economic return from the use of lower-elevation croplands that otherwise would sit fallow, facilitating the spread of weeds. Additionally, biomass energy projects can support the development of a solid-wood forest products industry by providing an economic use for the waste stream from harvest and milling processes. Also, biomass operations can further contribute to forest management by making use of invasive trees such as albizia. Biomass use not only would help control this pest, but may even contribute economic incentives to support the control of invasive species and/or fund reforestation of cleared areas with economically valuable forest products such as *koa* or a non-invasive commercial species like *Eucalyptus*.

Another forest management benefit that would occur with the development of biomass facilities is the opportunity to use salvaged materials following natural disasters, pest or disease outbreaks, or natural mortality events. Damaged wood products could thus be incorporated into energy generation. For instance, a portion of the 3,000 acres of trees that were killed or damaged during the 2012 fire season in Kōkeʻe, Kauaʻi, have been salvaged and hauled to the biomass plant on Kauaʻi.[4, 5] The fees paid for the salvaged trees are being used to help reforest the burned area using native and non-invasive commercial species. This biomass facility is also helping to clear thousands of acres of forest land infested with albizia to support its electricity production.

Many of the foundational policies and principles being followed in the development and implementation of the HCEI[15] mesh closely with, and support the development of, a sustainable forest products industry in Hawaiʻi.[17] Both initiatives aim to maximize the diversity and use of natural resources in the state; strive to create substantial economic benefits in employment and diversified economic activity; aim to be technologically advanced; and are largely privately funded and market driven.[15, 17] The integration and codevelopment of renewable energy and a local forest products industry is achievable, as we have seen on Kauaʻi.[4] Through implementation of forward-looking renewable energy policies, such as those outlined in the HCEI, combined with a variety of forestry incentive programs, it is hoped that the forest products industry can participate in and make a positive contribution to the future of clean energy in Hawaiʻi at a meaningful scale.

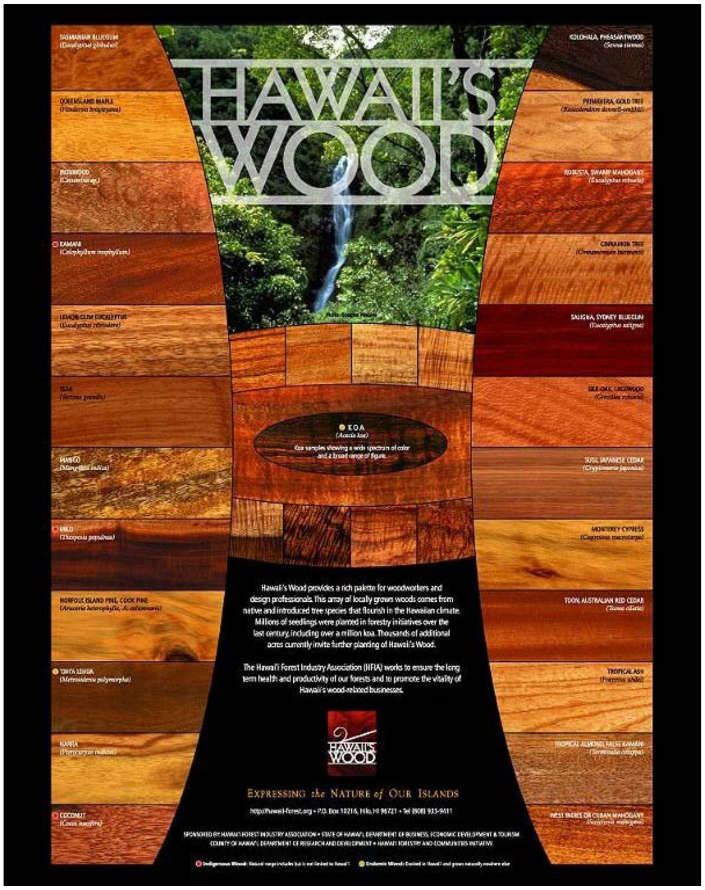


Figure 8.2. Poster advertising the 2002 Hawaii's Woodshow. Image courtesy of Hawaiʻi Forest Industry Association. Photo courtesy of Hal Lum, photographer.

Although Hawaiʻi does not yet have a large-scale timber industry, the craft wood industry is thriving. Local artisans produce an astonishing number of objects crafted from native woods, notably *koa*, but also from a variety of other native and introduced wood species such as mango (*Mangifera indica*), *milo*, and *kamani*. The Hawaiʻi Forest Industry Association (HFIA) has been instrumental in helping this industry to grow and gain exposure locally and abroad.[18] The HFIA has been sponsoring Hawaii's Woodshow every year since 1993. Only Hawaiian-grown wood works are displayed in Hawaii's Woodshow. The show is designed to strengthen appreciation for locally grown woods and artists' work, as well as encourage sustainable forestry through the planting of native and introduced but non-invasive trees (see Figure 8.2).

Non-Timber Forest Products

Although not as well described or studied, the use of non-timber forest products (NTFPs) is likely the most significant use of Hawaiʻi's forests. NTFPs are substances, materials, or commodities that are obtained from forests, but their collection does not require harvesting of trees.[19] They include animal products, edible and medicinal plants, berries, seeds, oils, sap and syrup, foliage, fuel wood, forage, and building materials, as well as one of the most important products in Hawaiʻi as on all islands, water. The harvest of NTFPs remains widespread throughout the world, and is often important to rural communities, including those in Hawaiʻi, for household subsistence, maintenance of cultural and familial traditions, and spiritual fulfillment, as well as house heating and cooking, animal feeding, medicine and healing, and a source of income. In Hawaiʻi, common NTFPs include flowers and foliage collected from the forest for making *lei* and handicrafts, wild fruits and edible plants, bamboo (*Bambusa vulgaris*), game animals, and water that is collected or diverted. Common fruits trees that can be found growing wild in the forest include mango, mountain apple (*Syzygium malaccense*), banana (*Musa* spp.), coconut (*Cocos nucifera*), noni (*Morinda citrifolia*), and many other domestic fruits planted intentionally or escaped from backyards. For hunting game, Hawaiʻi provides opportunities to hunt for 15 species of game birds and six species of game mammals. In 2015, forests and game management areas provided over 33,000 game mammal and bird hunting trips, with the harvest of 13,300 game birds and 4,883 game mammals.[20] *(See "Issue 1: Water Quality and Quantity," for additional information on watersheds, and "Issue 7: Hunting, Nature-Based Recreation, and Tourism," for additional information on hunting and recreational uses of forest.)*

Carbon Sequestration

Carbon sequestration is the capture of carbon dioxide (CO_2) from the atmosphere. Forests play an important role in light of climate change by sequestering CO_2 via photosynthesis.[21, 22, 23, 24, 25, 26, 27] Sequestration can be improved by protecting forests from conversion, by improving management to retain carbon in the forest for longer periods, and by planting trees, reforesting, and afforesting (establishing new forests). International, national, and regional efforts to mitigate increasing atmospheric concentrations of greenhouse gases (GHGs) have led to the formation of carbon markets. Both mandatory-compliance markets and voluntary carbon markets are now recognized as cost-efficient ways to reduce net global CO_2 emissions. These programs allow entities to meet CO_2 emission reduction obligations by investing in projects globally that can capture and store carbon.

Globally, the forestry industry has been engaged in the carbon market through the sale of carbon credits to emitters. Eligible forestry carbon credits are derived from avoided conversion, reforestation or afforestation, and forest stand improvement projects. Although carbon markets have been around for a number of years, successful participation has a steep learning curve. Mathew Smith of the Society of American Foresters said, "Carbon markets are more of a riddle to be solved than an easily defined path to a new payday for forestry."[28] This outlook may well apply to a small state with a young forest products industry such as Hawaiʻi; however, there is significant opportunity and interest among state, federal, and private landowners in Hawaiʻi to investigate the voluntary and developing mandatory carbon markets.

There are no mandatory GHG emission trading schemes (ETS) regulated by the U.S. government, but some states and state cooperatives have implemented mandatory carbon markets in their regions, including the California compliance market (approved by the California State Legislature in 2006) and the Regional Greenhouse Gas Initiative begun in nine northeast and mid-Atlantic states in 2012.[21] Hawaiʻi does not have a locally mandated GHG ETS, but with the aggressive renewable energy goals[15] carbon market opportunities may soon be developed. From a forestry perspective, DOFAW has been investigating participation in either out-of-state mandatory carbon markets such as the cap-and-trade market of California or a voluntary carbon market to generate revenue for maintenance of underfunded state forestry lands.

In a report produced jointly with the University of Hawaiʻi, DOFAW explored three voluntary carbon market standards, the American Carbon Registry, the Climate Action Reserve, and the Verified Carbon Standard, as well as one mandatory standard, the California compliance market. The purpose of the report was to explore opportunities for state and private landowners in Hawaiʻi to contribute positively to climate change action while using the carbon market as a revenue-generating tool. The report highlights the variety of considerations, components, and financial investments associated with these carbon markets, and identifies the most attractive options for participation by Hawaiʻi landowners. One notable outcome of this report is the interest, demand, and in some cases requirement that carbon projects focus on carbon sequestered by native tree species.

Voluntary carbon markets in Hawaiʻi have the potential to incorporate value-added qualities to our forest resources. Such projects are akin to sustainable-harvest forest certifications, such as those awarded by the Forest Stewardship Council, American Forest Foundation, and other such entities. Like certifications, carbon market projects could contribute to sequestration but also would provide the equally important services of conserving native habitat for endangered species, contributing to cleaner water, and increasing water supplies, among other benefits. Thus, multi-faceted carbon projects that provide multiple benefits in addition to sequestering tons of carbon can complement existing forest management goals in Hawaiʻi.

DOFAW is continuing to explore carbon market opportunities for public lands, as well as encouraging private landowners and managers to consider carbon sequestration as part of their overall forest management. While the state is still working on policy and procedures regarding the use of state forests to generate revenue through the carbon market, forestry companies on Kauaʻi and the Big Island are moving ahead with selling carbon under the voluntary carbon market, which involves planting and managing non-native trees and native *koa* plantations. To date, there is one reforestation project (in the Hāmākua District of the Big Island) actively selling voluntary carbon credits in Hawaiʻi, and two other landowners have expressed intent to do so. The various landowner assistance programs (see below and *Appendix C*) offered by DOFAW can be used to support private landowners to maintain forests or plant forests that can generate revenue, not only by providing various forest products but by facilitating the sale of carbon credits.

Community-Based Forest Management Projects

In Hawaiʻi, there are a number of community-based forest management projects that focus on socially and culturally important forest resources. These projects are public-private partnerships that have formed to protect native dry forests, which are one of the most threatened ecosystems in Hawaiʻi. These partnerships increase the chances of survival of two endemic dry forest dominant tree species: *wiliwili* (*Erythrina sandwichensis*) and *uhi uhi* (*Caesalpinia kavaiensis*). These species are very culturally important, but also at a high risk from wildfire (*see "Issue 3:*

Wildfire") and infestation by the *Erythrina* gall wasp (*see "Issue 2: Forest Health: Invasive Species, Insects, and Disease"*). The Hawai'i Forest Stewardship Program and Watershed Partnerships are particularly important to the development and support of community forest projects.

Programs

There are a number of programs that support the development of forest products and services on state and private lands in Hawai'i by providing educational and technical assistance, as well as financial support through cost-share grants, conservation easements, and land acquisition.

The Forest Reserve System was established by the Territorial Government of Hawai'i through Act 44 in 1903. Its primary purpose is to protect *mauka* forests, enabling them to provide forest products and services for *makai* communities and agricultural demands—sustainable water supply was the principal underlying consideration. Today, the Forest Reserve System includes approximately 678,000 acres across the state and is managed to provide a suite of services for the public[29]:

- Protect and manage forested watersheds for production of freshwater supply for public uses now and into the future
- Maintain biological integrity of native ecosystems
- Provide public recreational opportunities
- Strengthen the economy by assisting in the production of high-quality forest products in support of a sustainable forest industry

Timber management areas can be found in a number of the Forest Reserves and contain economic opportunities supporting local timber and wood product industries. These timber management areas contain a variety of primarily non-native species and non-timber forest products that can be harvested for commercial purposes or small-scale salvage uses.[14]

The Forest Legacy Program is a federal grant program administered through DOFAW. As stated in the Forest Legacy Program Assessment of Needs, this program identifies important private forest lands that are threatened by development or fragmentation and contributes to the following overall program goals:

- Protect unique and fragile environmental resources of Hawai'i
- Encourage the protection of rare and/or endangered species
- Promote the preservation of aesthetic beauty in Hawai'i
- Preserve watershed health and protect the sustainable yield of fresh water
- Protect working forests as economic assets for the state and counties of Hawai'i
- Protect traditional and cultural forest practices and resources

- Protect recreational forest practices

Through this program, private landowners have an option to preserve forests on their property by either entering into a conservation easement or by selling their land to a government agency for conservation purposes.

The Legacy Land Conservation Program is a state grant program administered through DOFAW that provides funds for the acquisition and protection of threatened resources. Many of the cultural, natural, agricultural, historical, and recreational resources of Hawai'i are lost when private lands possessing these resources are sold and developed. The Legacy Land Conservation Program provides grants to local organizations and agencies seeking to purchase and protect lands with unique, rare, and valuable resources.

Other state and federal programs that support forest product capacity, forest restoration, or conservation needs on public and private lands are the Forest Stewardship Program, Kaulunani Urban and Community Forestry Program (*see "Issue 4: Urban and Community Forestry"*), Tree Farm Program, Native Forest Dedication, Watershed Partnership Program, Conservation Reserve Enhancement Program, Environmental Quality Incentives Program, and others. (See "Appendix C: Forestry-Related Assistance Programs.")

Participants

Development of a sustainable forest products industry, resource restoration and conservation, watershed protection, and outreach and education are all important goals in Hawai'i. Achieving these goals can be accomplished only through a wide variety of partnerships and with expertise focusing on creative solutions to challenging endeavors. There are a number of organizations and private landowners that are engaged in forest product development and which contribute to such achievements in Hawai'i.

Hawai'i Forest Industry Association (HFIA) (http://www.hawaiiforest.org/) is dedicated to responsible forest management. HFIA produces the annual Hawaii's Woodshow, sponsors the Hawaii's Wood trademark, and advocates for the diverse forest industry in Hawai'i, from the planting and harvesting of trees to the creation and sale of wood products.

Private timber plantation owners, land lessees, and green energy companies, such as Kamehameha Schools, Parker Ranch, and other large landholders, have large amounts of standing timber that will play an important role in a forest products industry in Hawai'i. Several private companies operate mature tree farms that produce a variety of forest products, including animal feed, lumber, biochar and soil blends, and carbon credits.[30] A utility-scale biomass electrical energy production plant has been built and is operational on Kaua'i,[4] and a second plant is under construction on Hawai'i.[6] A few other green energy companies are developing biomass-to-energy facilities for the production of biodiesel or biofuel to power electrical generation plants.[31]

Federal and nonprofit landowners, such as The Nature Conservancy, National Park Service, U.S. Fish and Wildlife Service Refuge System, and the Office of Hawaiian Affairs, have large expanses of mostly native forests that are actively managed for a variety of ecosystem services.

The Hawaii Agriculture Research Center (http://www.harc-hspa.com/) is actively engaged in management of Acacia *koa* and supports other research on hardwood tree species. One project in particular works to identify fusarium-resistant *koa*, as well as *koa* stock that exhibits a straight tree growth form *(see "Issue 2: Forest Health: Invasive Species, Insects, and Disease").*

The FS Institute of Pacific Islands Forestry (IPIF) (http://www.fs.fed.us/psw/programs/ipif/) provides research, education, demonstration projects, and scientific and technical information for state, federal, industry, and private partners to restore, conserve, and sustain tropical forests and wetlands of the Pacific. IPIF provides research and information on climate change, carbon, water, silviculture, tree improvement, sustainable agro-forestry and bio-energy production, and best practices for forest management.

The Tropical Hardwood Tree Improvement and Regeneration Center (THTIRC) (http://www.trophtirc.org/) is a partnership between Purdue University's Hardwood Tree Improvement and Regeneration Center, FS, University of Hawai'i, and state, federal, industry, and private organizations to establish a tropical hardwood tree improvement research center in Hawai'i. THTIRC's mission is to advance the science of Pacific island hardwood tree breeding, conservation, genetics, and silviculture for sustainable production of forest products, improved ecosystem services from native forests, economic development of local communities, and cultural enhancement for indigenous cultures, local communities, and visitors. A major focus of THTIRC is improvement of *koa* for traits such as growth, form, wood quality, pest and disease resistance, and abiotic stress resistance for restoration and forestry applications. The major focus is on *koa*, but tree improvement also can be applied to other important production species such as *'iliahi*.

The Hawaii Experimental Tropical Forest (HETF) (http://www.fs.fed.us/psw/ef/hawaii/) is located in two units on the Island of Hawai'i, at Laupāhoehoe and Pu'u Wa'awa'a. HETF was established to address the critical natural resource and conservation questions that must be answered to properly manage tropical forests and watersheds for a variety of objectives, including restoration, preservation, and use. The experimental forest provides a land base for conducting relevant natural resource related research—both biological and physical in nature—and has a major emphasis on climate change monitoring, invasive species control, and documentation of forest carbon storage and watershed function.

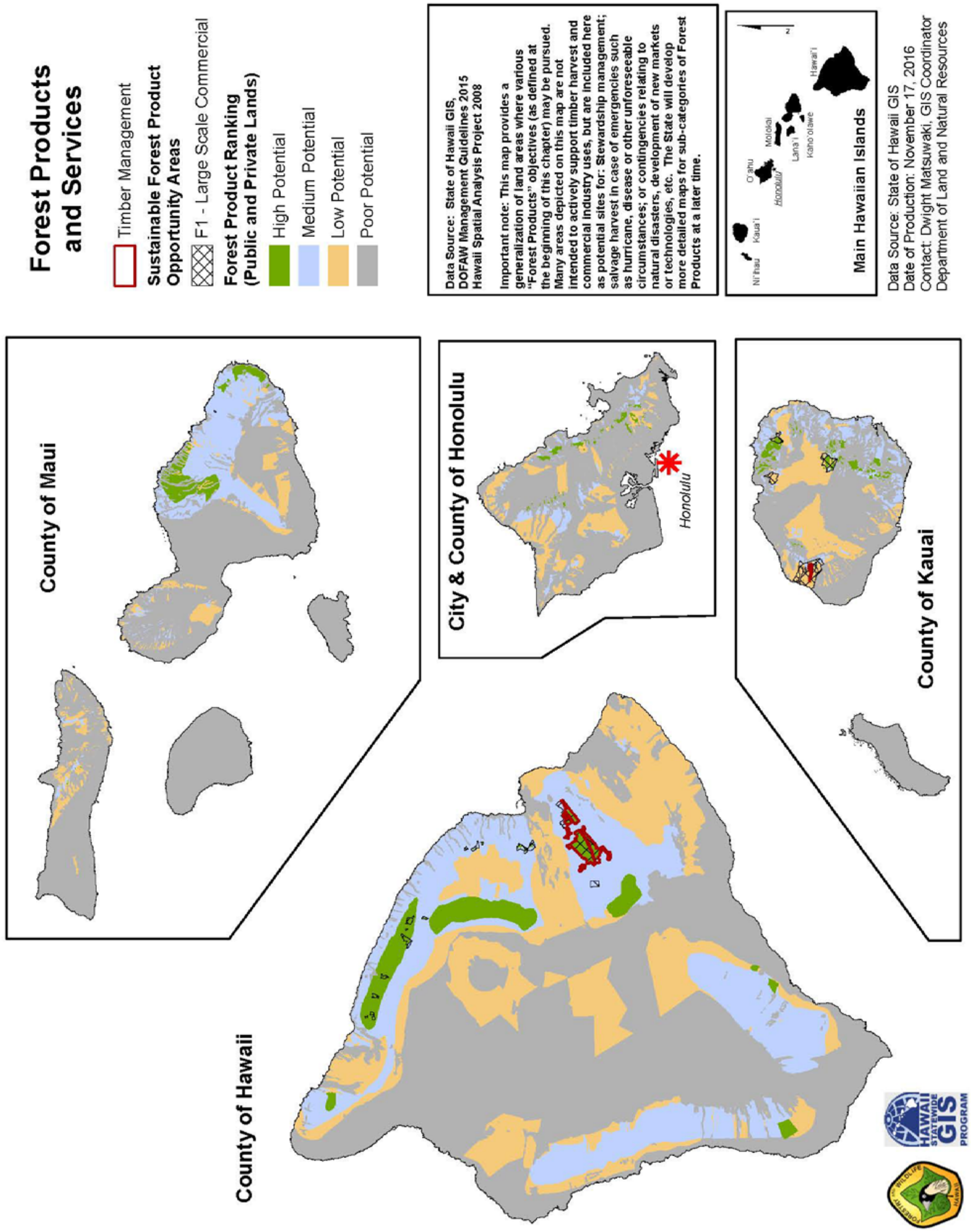
Priority Areas for Forest Products and Carbon Sequestration

Forests cover roughly 1.7 million acres (41%) of the state's total land area, and approximately 60% of this area is considered productive, healthy forest—mostly covered by *‘ōhi‘a*, *‘ōhi‘a-koa* mix and relatively pure *koa*. About 700,000 acres (50%) of the relatively productive forest land is considered to be timberland, capable of producing timber and wood products on a sustainable basis.[32] Of that, roughly 76,000 acres are tree plantations (Maps 8.1–8.5).

Areas that have potential for providing forest products and services have been mapped (Map 8.6) based on distribution and forest type, or potential to support forest vegetation, and by analyzing environmental factors such as rainfall, elevation, and soils. These forest areas are mapped for the entire state, including private and public lands, and are further categorized as having high, medium, low, or poor potential for forest products. [33] This map provides a generalization of land areas where various "Forest Products" objectives may be pursued. Many areas depicted on this map are not intended to actively support timber harvest and commercial industry uses; but are included here as potential sites for activities such as stewardship management; salvage harvest in case of emergencies such as hurricane, disease or other unforeseeable circumstances; or contingencies relating to natural disasters, development of new markets, or technologies. More detailed maps for sub-categories of forest products will be developed at a later time.

An area with high potential has soil capable of growing wood at a rate of 85 cubic feet or more per acre per year. Most of the high-potential timber-producing land, approximately 470,000 acres, is on the island of Hawai‘i. Non-native commercial timber plantation areas managed by DOFAW, roughly 48,000 acres, were automatically ranked as having high potential. An area with medium potential has soil capable of growing wood at a rate less than 85 cubic feet per acre per year, but can grow a high-value species, maintain soil productivity and protect water quality. An area with low potential has value and opportunities to be managed for ecosystem services, salvage of resources after natural disasters, invasive species control, and native species restoration. Other non-forested areas, such as pasture, croplands, and urban areas, are designated as having poor potential for forest products.

The Forest Products and Services Map also identifies the location of DOFAW-managed lands (cross hatching) identified for large scale commercial production. The policy guidance on how these lands are going to be managed to provide large scale commercial forest product is provided under DOFAW's Management Guidelines. The management of sustainable forest product opportunities is categorized into four classes: large scale commercial (F1), small scale commercial (F2), personal use (F3), and restricted (F4). Table 8.1 defines these classes and the management strategies that guide these classes. The lands classified as F1 are depicted on Map 8.6.



Map 8.6. Priority area for forest products and services in the State of Hawaiʻi.

Table 8.1. Draft Management Plan Guidelines (2015).

Forest Product Management		
Management of Sustainable Forest Product Opportunities		
Class Name	**Class Definition**	**Management Strategies**
F1 Large Scale Commercial	Forest products are a primary objective and large scale commercial timber harvesting or salvage is allowed. Permits and/or licenses are required with appropriate restrictions. Harvesting of non-timber forest products is allowed. All Timber Management Areas are designated as F1 areas.	To produce timber while allowing other uses such as recreation, hunting and gathering. Activities may include, but are not limited to, pre-commercial thinning, commercial thinning, and forest stand improvement. Harvesting activities should follow best management practices for maintaining water quality. Sustained yield management is encouraged and planting or revegetation must follow harvesting to ensure sustainability.
F2 Small Scale Commercial	Areas where limited small-scale (no more than 1% of the total acreage of a forest reserve annually) commercial timber harvesting or salvage is allowed. Harvesting of non-timber forest products is allowed. Permits and/or licenses are required with appropriate restrictions.	To ensure sustainability of forest product resources while minimizing impacts to non-target native species. Activities may include, but are not limited to pre-commercial thinning and forest stand improvement thinning. To distribute impacts of harvesting over the resource area through controlled seasons and harvest. Depending on the scale and impact of harvesting, planting or revegetation may be required, if deemed necessary by land managers. To encourage active management of culturally and economically significant forest products.
F3 Personal Use	Areas where limited non-commercial timber harvesting and commercial timber salvage is allowed. Harvesting of non-timber products will be considered on a case by case basis. Permits are required with appropriate restrictions.	To minimize human impacts to native species and native ecosystems. To encourage active management of culturally and economically significant forest products for sustainable personal use.

Forest Product Management		
Management of Sustainable Forest Product Opportunities		
Class Name	**Class Definition**	**Management Strategies**
F4 Restricted	Forest products are not a primary objective. Harvesting of timber products is not allowed. Harvesting of non-timber forest products is generally not allowed and will be considered on a case by case basis for improving forest health, watershed protection, cultural uses, and conservation efforts. Permits are required with appropriate restrictions.	To ensure protection of native species and native ecosystems. Permitted activities in these areas are minimally disruptive, and would be focused on improving forest health, watershed protection, and conservation efforts.

Data Gaps and Opportunities

1. Manage native forests for social and cultural objectives. For example, the state seeks to develop an *Acacia koa* canoe log production forest at Kapāpala on the Island of Hawaiʻi.
2. Take necessary administrative steps that would allow the state's forestry program to participate in the California compliance market or the voluntary carbon market to help generate revenue for state forestry lands and programs that are currently underfunded.
3. Investigate requirements and benefits for obtaining national and international certification of sustainable production and harvest practices for common market species such as *koa*, sandalwood, and *Eucalyptus*.
4. Develop a chain-of-custody certification program for sustainably harvested Hawaiʻi forest products that will allow the users in the market to distinguish between products obtained from forests that are sustainably managed and those that are not.
5. Pursue certification of Hawaiʻi-grown and -processed solid wood *Eucalyptus* products to meet local and national building code standards, for use in local construction.
6. Analyze the potential and opportunities to develop Christmas tree plantations on state lands as well as support such an industry on private lands. This would minimize the quantities of trees imported to Hawaiʻi each year and also help mitigate the risk of introducing new invasive species that hitchhike on those trees.
7. Support establishment of mid-sized sawmill, biomass/biofuel, and veneer mill facilities. Identify loan programs to help private businesses obtain capital for field equipment, processing facilities, infrastructure development, and product marketing to develop the forest industry in Hawaiʻi.
8. Develop genetically improved and/or disease-resistant seedling stock for non-native and native species, including *koa*, *ʻōhiʻa*, and *ʻiliahi*.

9. Use commercial forestry as a way to convert lands dominated by weedy, invasive species to productive forests and native forests.
10. Develop new markets, both domestic and international, for common Hawai‘i commercial species. Near-term market opportunities appear to exist for export of sandalwood to U.S. essential oil markets as well as to China, *Eucalyptus* sawn lumber to Indonesia and the mainland Northwest, and *koa* to the U.S. mainland.
11. Complete comprehensive management plans for all State Forest Reserves (hawaii.gov/dlnr/dofaw/forestry/FRS/frplans). Investigate opportunities to develop additional forest product or timber management areas on state lands. Identify areas that have soils with high-enough productivity to produce wood products, have adequate accessibility for forest management and commercial harvest activities, and are not already committed for other high-priority purposes such as native species’ critical habitat.
12. Develop survey and monitoring techniques, best management practices, and harvest protocols to avoid take of endangered Hawaiian hoary bats and other listed species that may be at risk during commercial forest management and timber harvest operations. Develop regulatory tools, approaches, agreements, and/or permits to enable the forest products industry to operate compatibly with management and conservation needs of protected species.
13. Implement studies or research to answer the following questions:
    a. How much forested and agricultural land is needed to produce adequate quantities of products to support processing plants for solid wood products, for electricity, or for biomass conversion to diesel or other fuels.
    b. How do existing stands of mature commercial forest on state lands fit into the long-term goal of a viable forest products industry?
    c. Where are timber resources located relative to potential markets, and what are the best ways to connect them?
    d. What are the characteristics of the existing industry, including logging infrastructure?
    e. What are the markets (expected price and depth) for various products, including high-, medium-, and low-grade hardwood lumber and other products?
    f. What opportunities exist to use or sell manufacturing and forest residue? How sustainable are the various components of the timber resource?
    g. What new products or services are suitable for Hawai‘i?
    h. What are the best restoration and silvicultural methods and practices for production of sandalwood for conservation and commercial purposes?
14. Implement studies or research recommended by the Koa Action Plan, such as:
    a. Investigate the potential to create silvi-pastoral systems that successfully integrate grazing animals with *koa* forestry.

b. Conduct replicated trials across a variety of environments to evaluate genetic variability and to identify superior families for continued selection and as seed sources for planting.
c. Expand field trials to test the durability of wilt resistance, as identified by seedling screening, and to develop resistant varieties for all affected ecotypes.
d. Quantify the current and future market value of *koa* products and the number of jobs created by *koa* forestry.
e. Quantify value of ecosystem services for *koa* forest restoration.
f. Quantify the supply of wood from old-growth trees that are available for harvest, and determine whether continued harvests are appropriate.
g. Conduct market research to investigate how to expand markets for plantation *koa* while maintaining prices.
h. Conduct research on *koa* wood quality from planted stands.
i. Develop grading system for *koa* wood quality.

Summary

The forests of Hawai‘i will continue to be critically important to the state’s water supply, unique plants and animals, the economy, clean energy supply, people, and their culture. Benefits from these forests go well beyond wood and fiber products and affect aesthetic values, recreational enjoyment, ecotourism, carbon sequestration, specialty non-timber forest products, water conservation, improved air quality, coral reef protection, and many other important resources.[34] Increased economic and development pressures that alter land use and management will continue to be challenges for the state’s forest industry.[34] It is important that forest industry potential in Hawai‘i be considered from a holistic perspective in order to sustain the growth and health of the forests over the long term and to provide for the services and benefits associated with healthy forests.

Forest industry in Hawai‘i has unique win-win opportunities to integrate the development and operation of a commercial forest industry based on the use of native and non-native species with other high-priority state goals to produce clean and renewable energy, provide jobs and economic growth in rural communities, restore native *koa* forests to underused lands, control invasive species such as albizia, integrate commercial forestry activities as a tool in the restoration and management of badly degraded forest ecosystems, and generate additional revenue to fund conservation management activities on all state lands. The Hawai‘i forest industry must look toward and integrate new technologies, programs, and cooperative opportunities that provide alternatives that are compatible with the unique resources of Hawai‘i.

Strategies for Issue 8: Forest Products and Carbon Sequestration

Forest Products and Carbon Sequestration: Support Development of a Forest Products Industry

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai‘i Environmental Literacy Plan Goals
1. Foster the development of an integrated forest products industry in Hawai‘i.	See maps.	Address solid wood products, non-timber forest products, carbon sequestration, biomass for energy and fuels reduction, economic growth, salvage, and invasive species control.	Rural development, FSP, EQIP, farm bill programs: biomass and biofuel, FSCG, Cooperative Fire Assistance.	Public and private forest landowners, TNC, OHA lessees.	HFIA, WFLC, HCA, TNC, IPIF, Hawai‘i Legislature, FS.	Increased public and private lands under commercial forestry management; more leases executed for commercial timberlands; greater proportion of energy or raw materials produced locally versus imported.	1.1 1.2 3.1 3.4 3.5 3.6	1.3 1.5
2. Develop and implement strategic research plan based on existing symposia and research findings regarding forest products industry.	Statewide.	Inform investment strategy, improve best management practices, inform public.	Farm bill: biomass and biofuel programs, S&PF Rural Development Program, Ecosystem Services Program, FSP.	Private landowners, PICCC, USFWS, TNC, UH.	Same as above.	Hawai‘i forest product literature made available at appropriate clearinghouses, websites, and research stations; new research projects initiated and completed.	1.1 1.2 2.1 2.2 3.1 3.4 3.5 3.6 3.7	
3. Improve opportunities for forest product entities doing business in Hawai‘i. Provide career training for forest industry jobs.	Statewide.	Create economic opportunities, support solid wood, biomass, and biofuel production.	FRS, HCA, Special Technology Development Program, FSP, FLP, CREP, LLCP, FSCG, OHA.	HCA, NPS, HDOT, Office of Planning, HDOA, TNC.	Same as above.	Low-interest loans made available to private entities; cultural products made available throughout the year; export potential enhanced.	1.1 1.2 3.1 3.4 3.6 3.7	1.3 1.5
4. Develop regulatory tools and approaches to enable the forest products industry to operate compatibly with conservation of protected species and habitat.	Statewide.	Create economic opportunities, support biomass and biofuel production, conserve native biodiversity.	FRS, HCA, FSP, FLP, CREP, LLCP, FSCG, Native Biodiversity Program, Threatened and Endangered Species Program, PEPP, HIP.	HFIA, ESRC, USFWS, FS, public and private forest landowners, TNC, HCA.	HCA, TNC, USFWS, NARS, IPIF, ESRC, PEPP, HIP, DLNR, NPS.	Increased public and private lands under commercial forestry management; increased conservation of native flora and fauna.	1.1 1.2 2.2 3.4 3.5 3.7	1.2 1.3 1.5

Strategies for Issue 8: Forest Products and Carbon Sequestration

Forest Products and Carbon Sequestration: Explore the Feasibility of Carbon Credits on State Lands

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Research and develop a carbon market for Hawai'i.	Statewide.	Sequester carbon, identify cap and trade and voluntary carbon markets for landowners, protect and enhance watersheds.	FRS, HCA, Special Technology Development Program, FSP, FLP, CREP, LLCP, FSCG, OHA.	Resource managers, private landowners, OHA, TNC.	HCA, OHA, DOD, Office of Planning, TNC, WFLC, IPIF, HETF, HISC, UH, carbon brokers.	Discussions held with State Attorney General's office and various carbon credit companies; one or more carbon credit market demonstration projects established.	1.1 1.2 3.1 3.4 3.6 3.7	1.3.a, b, c

Forest Products and Carbon Sequestration: Research Hardwood and Native Trees

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Conduct research focused on improving growth form and fusarium resistance for koa and resistance to wilt and rust diseases for ohia. Research restoration and sustainable commercial production of sandalwood. Include local schools and communities to collect data for research.	Statewide.	More deliberately plant native forest species (e.g., koa, sandalwood, milo, kou, and ohia) for forest production purposes as well as native biodiversity benefits.	FRS, HCA, Special Technology Development Program, FSP, FLP, CREP, LLCP, FSCG, OHA.	Resource managers, private landowners, OHA, TNC.	HCA, OHA, DOD, HDOT, Office of Planning, TNC, WFLC, IPIF, HISC, CGAPS, HAWP.	Improved genetic native tree stock distributed throughout the state; reduced dieback of koa and ohia; enhanced economic potential for koa due to more straight boles.	1.1 1.2 2.2 3.1 3.4 3.6 3.7	1.2 1.3 1.5
2. Identify invasive species vectors and pathways to reduce potential introductions, such as new plant diseases and *Erythrina* gall wasp.	Statewide.	Share inform literature with Pacific neighbors.	HDOT, HDOA, PIER, HEAR, FSCG, FSP.	Multi-state, international neighbors, HAWP, private landowners.	HCA, OHA, DOD, HDOT, Office of Planning, TNC, WFLC, IPIF, HISC, CGAPS, HAWP.	Improved biosecurity at sea and airports; reduced biosecurity threat to native flora and fauna.	1.1 1.2 2.2 3.1 3.4 3.6 3.7	

Strategies for Issue 8: Forest Products and Carbon Sequestration

3. Research social, cultural, and non-traditional forest products. Educate communities on gathering rights, responsible harvesting, and culturally appropriate protocols.	Statewide.	Elucidate cultural uses, benefits to human health, and recreational opportunities.	Conservation education, UCF, FSCG, TPL, TNC, land trusts.	Community groups, individuals, public and private landowners, recreation organizations.	OHA, DBEDT, DLNR, TNC, HCA, NPS, USFWS refuge system.	Reduced negative impacts on public lands, due to increased education; more implementation of Hawaiian land management practices.	3.1 3.2 3.4 3.5 3.6	1.2 3.1

Key:
CGAPS = Coordinating Group on Alien Pest Species
CREP = Conservation Reserve Enhancement Program
DBEDT = Department of Business, Economic Development & Tourism
DLNR = Department of Land and Natural Resources
DOD = Department of Defense
EQIP = Environmental Quality Incentive Program (of the Natural Resources Conservation Service)
ESRC = Endangered Species Recovery Committee
FLP = Forest Legacy Program
FRS = Forest Reserve System
FS = U.S. Forest Service
FSCG = Forest Service Competitive Grants
FSP = Forest Stewardship ProgramHAWP = Hawai'i Association of Watershed Partnerships
HCA = Hawai'i Conservation Alliance
HDOA = Hawai'i Department of Agriculture
HDOT = Hawai'i Department of Transportation
HEAR = Hawai'i Ecosystem At Risk
HETF = Hawai'i Experimental Tropical Forest
HFIA = Hawai'i Forest Industry Association
HIP = Hawai'i Invertebrate Program
HISC = Hawai'i Invasive Species Council
IPIF = Institute of Pacific Islands Forestry
LLCP = Legacy Land Conservation Program
NARS = Natural Area Reserves System
NPS = National Park Service
OHA = Office of Hawaiian Affairs
PEPP = Plant Extinction Prevention Program
PICCC = Pacific Islands Climate Change Cooperative
PIER = Pacific Island Ecosystems at Risk
S&PF = State and Private Forestry organization (FS)
TNC = The Nature Conservancy
TPL = Trust for Public Lands
UCF = Urban and Community Forestry Program
UH = University of Hawai'i
USFWS = U.S. Fish and Wildlife Service
WFLC = Western Forestry Leadership Coalition

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Issue 9: U.S. Tropical Island State and Territorial Issues

Overview

Tropical forests fill essential life-supporting roles for unique cultures and biodiversity around the world. As such, tropical island communities have the potential to be leaders in the global dialogue pertaining to climate change adaptations and conservation of rare plants, animals, and cultures. Pacific islands have been dubbed the “canaries in the coal mine” in that they are among the first to feel the impacts of sea level rise and climate change, and that they are warning the rest of the world about what to expect.[1] The forested ecosystems on Pacific islands are also heavily impacted by deforestation from urban growth, changing ecosystem functions due to invasive species invasions, and an ever-growing number of threats to the unique biodiversity that depends on these forests.

The Hawaiian Islands have myriad ecosystems, with high rates of endemism among the plant, animal, and invertebrate communities—over 10,000 Hawaiian species are found nowhere else on earth.[2] These islands also afford opportunities for many different human cultures to coexist, owing to their proximity to different continental and island nations. There are also world-class marine and terrestrial opportunities for tourists and locals, such as marathons, surfing events, boating races/events, extensive hiking options, bicycling, scuba and snorkeling, fishing, and unique research opportunities. The U.S. military presence in Hawaiʻi is quite substantial across the state, but it is also on Guam and, to a smaller extent, on other U.S.-affiliated Pacific islands.

This chapter will offer a broad look at some of the important historical, present, and future issues related to Hawaiʻi’s interaction with other people, cultures, and countries in the Pacific arena and around the world. It will also explore ideas about how to improve technologies, expand opportunities, and better manage and protect Hawaiʻi’s natural resources.

Neighbors and Visitors

Hawaiʻi is located between several continents: Asia, Australia, and North and South America. Nearby countries are Mexico and other Central American countries, South American countries, Canada, Russia, Japan, New Zealand, Fiji, Tuvalu, Kiribati, Tahiti, Tonga, Samoa, Cook Islands, and Easter Island. There are a number of U.S. territories and affiliated islands in the Pacific.

Hawaiʻi’s beauty and convenient location in the Pacific make it a natural place for travelers to visit by air and sea using transportation such as personal yachts and small aircraft, cargo vessels, national and international airlines, cruise ships, and a variety of military air and sea crafts. In 2015, the Hawai‘i Tourism Authority reported that a record total of 8,679,564 visitors came to the Hawaiian Islands, a 4.3% growth from the previous year.

Hawai‘i became a major stop on trade routes when the whaling industry found it to be a convenient and hospitable port of call. This trend increased as international trade among Pacific Rim countries grew during the 20th century (see Figures 9.1 and 9.2).

Being ideal places for millions of visitors, Hawai‘i and other Pacific islands inevitably struggle with cultural and ecological resiliency. Despite having one of the most expensive costs of living in the nation, and with limitations on economic opportunities, Hawai‘i's resident population continues to grow. This puts more strain on the natural environment and the services derived from it to sustain these growing populations.

U.S. Tropical Islands

The Hawaiian Islands are among many U.S. Tropical Islands (USTIs) that together contain virtually all of the tropical forests associated with the United States. These highly diverse native ecosystems on small land masses are subject to increasing development pressures, are frequently susceptible to significant storm events, and are often very dependent on energy and food imports to sustain current populations. Because of their strategic locations, many of these islands play important roles in trade, cultural exchange, and maintaining the national security of the United States. Most of these islands have significant indigenous populations, many of which continue to live traditional subsistence lifestyles. Many of the USTIs share similar natural resource concerns, lifestyles, and cultural practices. Table 9.1 provides some basic information regarding the relative size, forest acreage, number of islands and population of each of the nine USTIs.

Pacific islands are particularly vulnerable to a number of natural and human-caused perturbations such as tsunamis, earthquakes, hurricanes, drought, sea level rise, and climate change. The problem is so dire that Mr. Fredrick Mueller, Secretary of Environment, Republic of Marshall Islands, stated that “at the current rate of sea level rise the Marshall Islands will be gone in 50 years.”[3] Low islands and atolls must face climate change and sea level rise issues with cooperation from the United States and international governments, as well as begin implementing management and adaptation actions, if they are to survive beyond the next four decades.

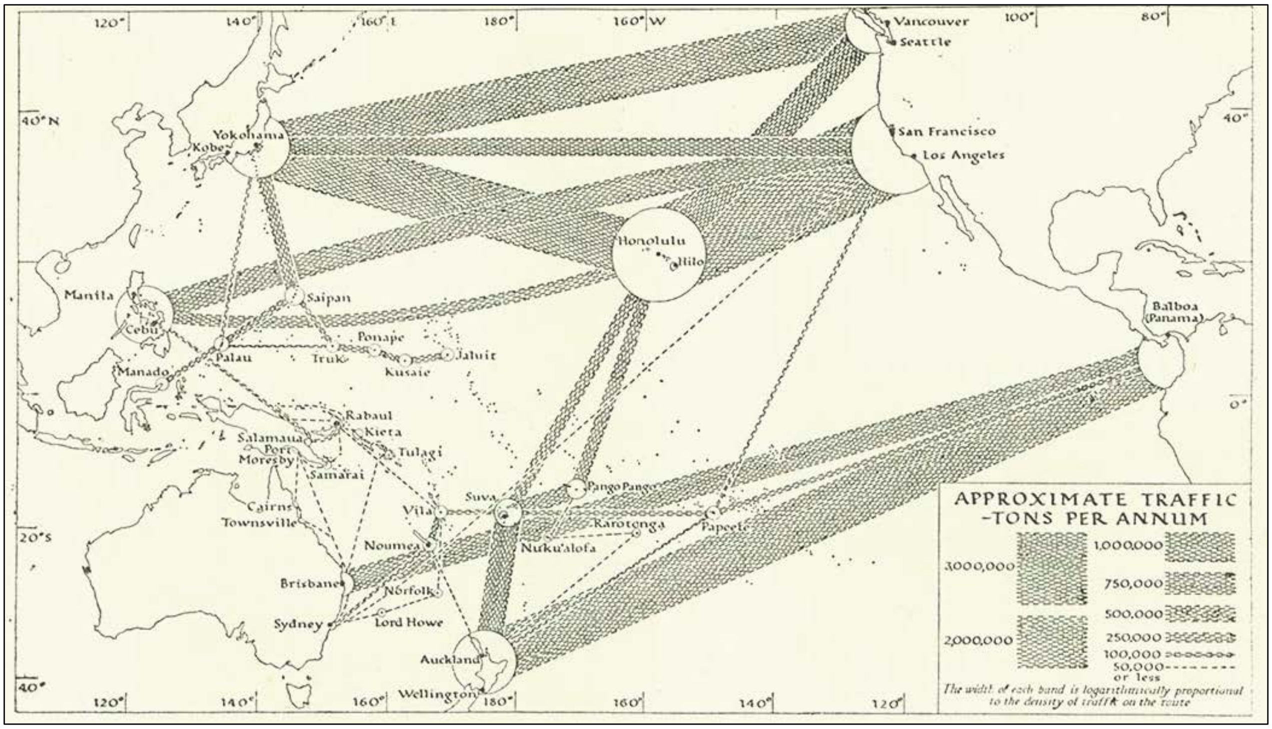

Figure 9.1. Density of Pacific shipping routes in 1938.

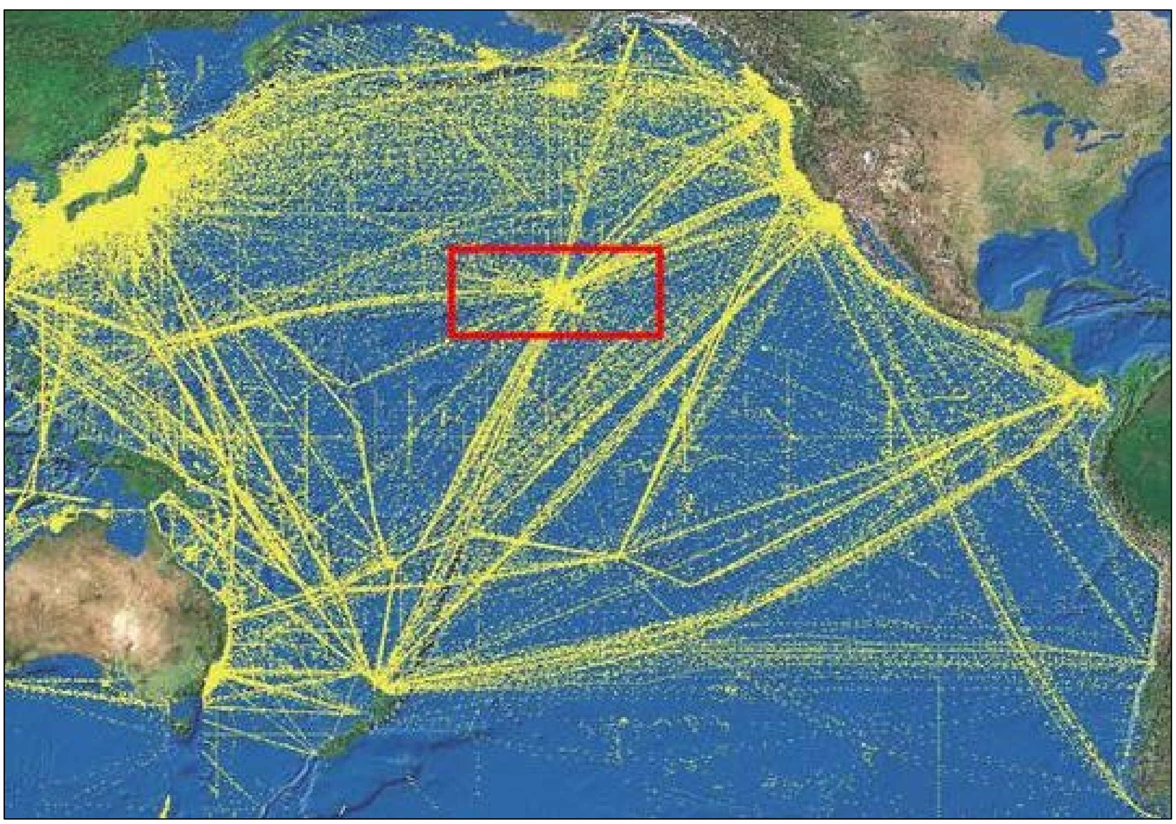

Figure 9.2. Pacific shipping traffic routes around 2003.

Table 9.1. U.S.-affiliated tropical islands circa 2015.[4, 5, 6]

Islands	Total Area (acres)	Existing Forest (acres)	Number of Islands	Population
Hawaiʻi*	4,110,720	1,490,901	8 main islands, with numerous atolls	1,431,603
American Samoa**	49,280	43,631	5	54,343
Commonwealth of the Northern Mariana Islands**	113,280	53,665	14	52,344
Guam**	135,680	63,833	1	161,785
Puerto Rico**	2,199,901	1,261,332	3	3,474,182
Virgin Islands**	85,760	52,478	4	103,574
Republic of the Marshall Islands***	44,800	43,144	5 and 29 atolls	55,000
Federated States of Micronesia*** (Kosrae, Pohnpei, Chuuk, Yap)	149,804	76,527	607	103,000
Republic of Palau***	114,560	96,688	4 main islands, 200 rock islands, 6 remote islands	17,000

* State, ** U.S. Territory or Commonwealth, *** Freely Associated State (U.S. Compact Agreement)

Some human-caused problems that exacerbate challenges to natural resource management and sustainability are climate change, deforestation, coastal development, hydrologic changes, over-harvesting, and invasive species. Outcomes of these pressures on the land include reduced water percolation into aquifers, increased soil erosion, coral reef siltation, reduced marine resources, compromised food security, increased fire frequency and severity, and reduced biodiversity habitat. These pressures can lead to the loss of indigenous cultures and traditional knowledge, and in some cases exodus of large portions of the population to places that hold the chance of a better life.[7]

Benefits and National Interests in the U.S. Tropical Islands

- The USTIs preserve a rich array of flora and fauna—a national and international biological heritage found nowhere else in the nation or the world.
- Sustainability of the tropical forests is integral to sustaining resilient communities, to diversifying local economies, and to mediating the impacts of growing tourist industries.

- Forests replenish important freshwater aquifers and river systems, protect reefs, and shelter and protect shorelines and coastal communities from hurricanes, storm surges, tsunamis, and floods.
- The USTIs are the equivalent of "canaries in the coal mine" for issues of global warming, sea level change, storm frequency and severity, environmental degradation, and effects of climate and environmental change on human populations that are vulnerable because of ecosystem sensitivity and connectivity.
- The USTIs provide unique opportunities for scientific research in a number of subject areas. Testing adaptations to natural disturbances and to invasions of alien plants and animals offers many opportunities to develop management approaches.
- The USTIs are home to significant cultural diversity. To know, understand, and maintain these intact cultures, with their knowledge of sustainable agroforestry systems and cultural uses of forest products, may help guide the future management of continental areas.
- The USTIs are important in creating bridges to international neighbors and a window to the cultures of the Caribbean, Latin America, and the Pacific and Asian countries. These islands can be models for sustainable tropical forestry management in the international arena.
- The USTIs, especially Guam, Kwajalein, O'ahu, and Puerto Rico, include strategic military locations, highlighting the need to sustain the services provided by the environment (e.g., potable water) to support military personnel and their families. Today, the islands are stepping stones for movement of people (including illegal aliens), drugs, weapons, and invasive species that could threaten national security. The United States has an intrinsic interest in ensuring a sustainable environment, vital economic development, and safety for those who live in and visit these special places.

Threats and Concerns

A summary of the threats and concerns pertaining to regional Pacific island issues is provided in Table 9.2. Although many are stand-alone issues, they often relate to and exacerbate each other, leading to complicated connections that require complex solutions. Vast distances amongst Pacific islands can be a buffer for unwanted species entry; however, these distances can also present large logistical challenges in managing resources and limit an already strained human collaboration capacity. The U.S. Pacific islands spread across the vast range of the central and western Pacific Ocean, and cover an area comparable to the mainland U.S. (Figure 9.3). More education and capacity building is needed in the Pacific if these threats and concerns are to be adequately addressed.

Table 9.2. Key regional threats and concerns.

Threats and Concerns	Forest Service National Themes
Aquatic health concerns; i.e., pollution, sedimentation, sustainable fishing practices, wetland protection, and implementation of best management practices.	2.2, 3.1, 3.5, 3.6, 3.7
Climate change: changes in temperature, rainfall patterns and drought, fire frequency, frequency and severity of storms, and other potential impacts. *(Refer to "Issue 5: Climate Change/Sea Level Rise.")*	1.1, 3.5, 2.2, 3.1, 3.3, 3.7
Food security (land, sea, and near-shore reefs): loss of traditional crops, loss of native plants and genetic diversity, dependence on imports, increase in invasive species.	1.1, 1.2, 3.4, 3.6
Loss of endemic species, habitats, and the associated indigenous knowledge/culture.	1.1, 1.2, 2.2, 3.4, 3.6
Human health concerns related to water quality (schistosomiasis, leptospirosis), mosquito-borne diseases (malaria, dengue fever, Zika), and drainage and industrial waste contaminants.	1.1, 1.2, 2.2, 3.1, 3.4, 3.5, 3.6
Need to target research and educational efforts and communicate results with partners and neighbors in the Pacific.	1.2, 3.6
Human population increases, expansion of visitor industries, and associated development pressures.	1.1, 1.2, 2.2, 3.5, 3.6
Impacts on biodiversity: plant and animal extinctions due to loss of habitat, insects, and disease.	1.1, 1.2, 2.2, 3.4, 3.5, 3.6, 3.7
See "climate change," above.	1.1, 1.2, 2.2, 3.1, 3.5, 3.7
Invasive species and biosecurity threats; e.g., brown tree snake, coconut rhinoceros beetle, *Erythrina* gall wasp, coqui frog, little fire ant.	1.1, 1.2, 2.2, 3.4, 3.5, 3.6
Need for smart urban growth and improvement of urban tree care.	1.1, 1.2, 3.1, 3.5, 3.6
Sea level rise and associated migration.	1.2, 2.2, 3.4, 3.6
Tourists' and visitors' influence on cultural land ethics.	2.2, 3.6

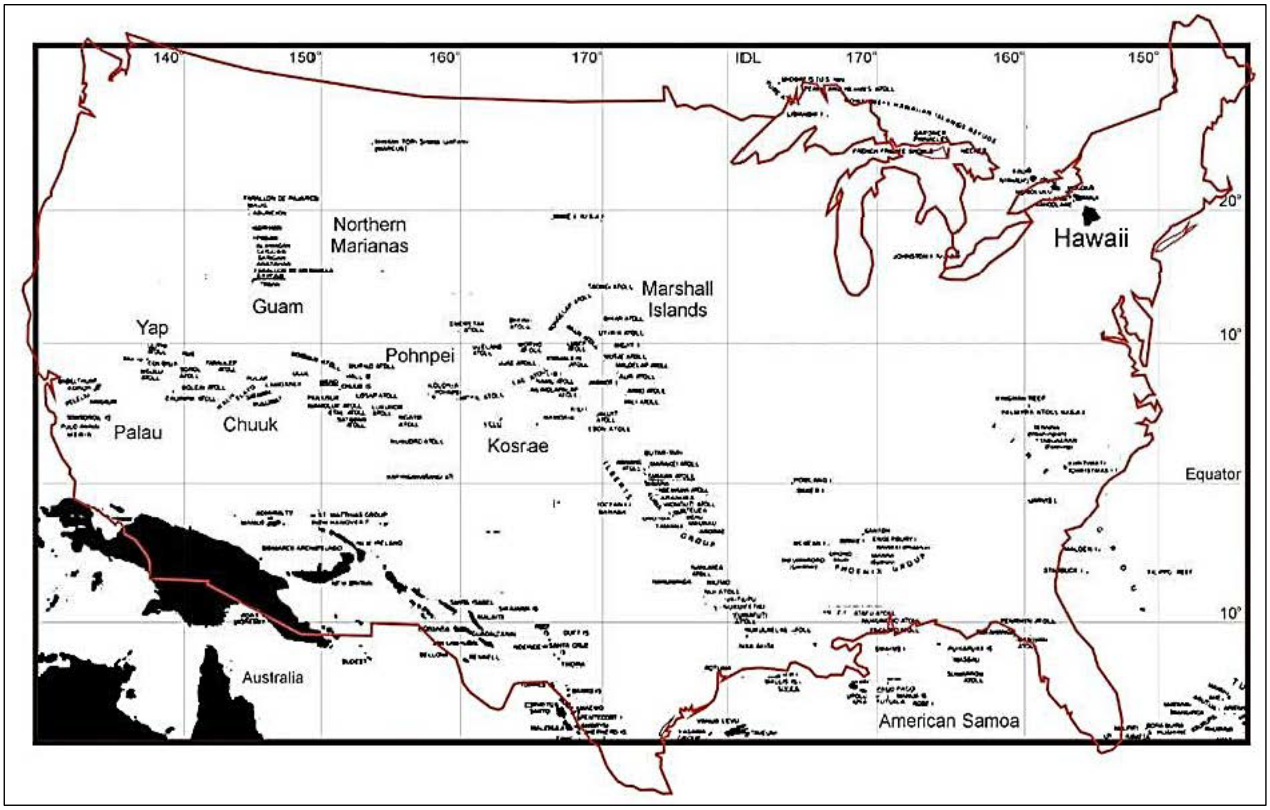

Figure 9.3. Map with an overlay of the U.S. Pacific islands on the U.S. mainland, illustrating the vast distances and area encompassed by the U.S. Pacific islands in relation to the mainland U.S. states.

Present Conditions, Trends, and Opportunities

Traditionally, the U.S. Forest Service (FS) has not been deeply involved in coastal and near-shore marine resource protection, nor in the management of terrestrial threatened and endangered species. This is in part owing to the assumption that the U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration (NOAA), and other federal agencies or initiatives focus on and provide adequate funding for these resource needs. This is changing in the Pacific because of the overwhelming need and because scientific information is now available that supports coastal and marine resource conservation via upland forest management. There are many countries and organizations working collaboratively in the Pacific that understand the relationship between terrestrial and marine ecosystems. Tables 9.3 and 9.4 list a few examples of interactions in which Hawaiʻi is involved with a countries and international organizations that support education and technical capacity exchanges, research, and natural resource management cooperative efforts.

Table 9.3. Examples of Hawai'i's Collaborations with other countries in the Pacific region.

Country	Area of Focus
Micronesia: Federated States of Micronesian, Palau, Guam, Commonwealth of Northern Mariana Islands, Marshall Islands	Micronesian Challenge
French Polynesia (Tahiti)	Miconia Suppression
New Zealand, Australia	Weed Risk Assessment
Australia, Caribbean Islands	White Water to Blue Water
Thailand, Japan, Indonesia, Australia, New Zealand	Tsunami Technologies and Tsunami Warning System
Chile	Disaster Preparedness Collaborations

Table 9.4. A selection of international and U.S. organizations working on Pacific island issues.

Partnerships and Organizations	U.S. Natural Resource Agencies/Organizations
Pacific Island Ecosystems at Risk South Pacific Regional Environment Programme Secretariate of the Pacific Community International Union for the Conservation of Nature German Organization for International Cooperation/Deutsche Gesellschaft für Internationale Zusammenarbeit United Nations Food and Agriculture Organization Pacific Invasives Learning Network	National Oceanic and Atmospheric Administration U.S. Geological Survey Pacific Biodiversity Information Node U.S. Fish and Wildlife Service Natural Resources Conservation Service Farm Services Agency U.S. Forest Service Pacific Fire Exchange Pacific Islands Climate Change Cooperative Pacific Birds Habitat Joint Venture National Fish and Wildlife Foundation Trust for Public Lands Micronesian Conservation Trust The Nature Conservancy National Association of State Foresters Association of Fish and Wildlife Agencies National Urban and Community Forestry Advisory Council

The connection between uplands, lowlands, and marine areas has long been part of indigenous Pacific island life. The balance between what the people need and what the terrestrial and marine environments can offer has always been central to Polynesian and other Pacific island cultures' ability to live in harmony with the land and sea. Current practices result in extreme sedimentation from coastal and upland development, dredging, shoreline modifications, and upstream agriculture. Coral reef impacts include smothering of live corals and the prevention of successful establishment of new coral colonies during periods of peak freshwater storm events on land. Population increases, development, and reduced resources demand drastic changes in land use practices.

Simple changes to a limited number of these land use practices could bring about dramatic changes that could not only reduce the negative impact on coral reefs, but also improve the environmental services provided by these land use practices for the communities that use them.

It is important to "strengthen policy frameworks and institutional capacities to reduce impacts to coral reef ecosystems from pollution due to land-based activities."[7] Traditional land tenure systems include ridge-to-reef management of the land and are models of whole watershed or ecosystem-function management systems that are valuable to contemporary conservation.

Priority Issues and Strategies for Inter-Pacific Island Coordination

Invasive Species

This is one of the most important threats to Pacific biota and native ecosystems. The challenge is not only to control existing populations of invasive species, but also to prevent new introductions. The most detrimental exotic invasive species can vary from country to country or island to island, but there are a number of species that appear to be a problem on almost every island where they are found. For example, rats can reduce forest regeneration, and introduced insects such as the little fire ant (*Wasmannia auropunctata*) can affect human use of forests; the coconut rhinoceros beetle (*Oryctes rhinoceros*) can devastate native palms and important subsistence crops (Figure 9.4 and 9.5).

Figure 9.4. Coconut rhinoceros beetle (*Oryctes rhinoceros*) is a major pest of native palms and important subsistence crops, and introduced to several Pacific Islands including American Samoa, Palau, and Guam, and detected on Oʻahu in 2013, where a multi-agency eradication effort is underway.[8]

The classic example of the impact of an introduced predator is the brown tree snake (*Boiga irregularis*). In the past 40 to 50 years, this predator from the Papua region has caused the extinction of nine of 11 native species of forest birds and the apparent extinction of three skink species and two species of gecko on Guam.[9] The snake has now spread to Saipan, and there are serious fears that if the snake were to spread throughout the Pacific it would cause similar devastation everywhere.[10]

Figure 9.5. Little fire ant (*Wasmannia auropunctata*), a major pest and nuisance with a painful sting. It readily invades disturbed habitats such as forest edges, agricultural fields, and urban areas. It is a threat to native insects and birds, and has been introduced to Hawai‘i, Guam, Puerto Rico, U.S. Virgin Islands, and other Pacific islands.[11]

Figure 9.6 shows a real-time snapshot of flights in and out of Hawai‘i at 7:00 p.m. primarily coming from the U.S. mainland. Additionally, flights originating in many parts of the world also use Honolulu as a hub, but because it is a U.S. state, Hawai‘i cannot unilaterally implement quarantine procedures to the extent that an independent country can. In addition to commercial air traffic, many military flights and ocean vessels that frequent areas around the world and through the Pacific are subject to an even greater variety of regulations or lack thereof. It is important that individual states and islands increase the level of biosecurity to protect their islands from inadvertent entry of landscape-level damaging weeds and pests. New Zealand, with its strict plant and animal quarantine procedures for incoming and outgoing travelers, could serve as a model for all Pacific USTIs in the effort to prevent the introduction of new invasive species. Hawai‘i and New Zealand have developed invasive species control programs that integrate public and private efforts, including industry and conservation organizations, to control and eradicate invasive species. Both have developed programs and techniques geared for island situations, including biological control of long-term, established pests. Biocontrol agents are carefully researched before introduction to ensure that they will not inadvertently affect non-target species. Successful biocontrol depends upon a network of international cooperators, availability of trained personnel, specialized quarantine facilities, and sustained funding. Both Hawai‘i and New Zealand have expertise and experience that can be shared with other islands to assist with their invasive species control programs. *(See “Issue 2: Forest Health: Invasive Species, Insects, and Disease,” for additional information.)*

Figure 9.6. Real-time flights to and from Hawai‘i, 7 p.m., June 3, 2010.

Climate Change and Sea Level Rise

Because of global climate change, sea level rise is expected to continue, and accelerate, for several centuries. Research indicates that sea level may exceed 3 feet above the 1990 level by the end of the 21st century.[12] Recent modeling in the Northwestern Hawaiian Islands shows that the combined effect of storm-induced wave-driven flooding and sea level rise on island atolls may be more severe and happen sooner than previously thought.[13] Many atoll islands will be flooded annually, contaminating the limited freshwater resources with salt water, and likely forcing inhabitants to abandon their islands within decades, not centuries. Sea level rise is particularly critical for low-lying coral reef-lined atoll islands in the Marshall, Micronesia, Palau, and Northwest Hawaiian Islands. Atoll islands have limited land and water available for human habitation, limited food resources, and ecosystems that are vulnerable to inundation from sea level rise. Coastal and low-lying areas on high islands will also be susceptible to damage by climate change–induced sea level rise. Island states, territories, and nations should collaborate to inform the world of unique island conditions and to share information on how to mitigate impacts. *(See "Issue 5: Climate Change and Sea Level Rise," for additional information.)*

Fire

Wildfires place communities at risk, destroy irreplaceable cultural resources, cost money, negatively affect drinking water supplies and human health, increase soil erosion, impact near-shore and marine resources, destroy native species and native ecosystems, and threaten rare, threatened, and endangered species in all the Pacific USTI ecosystems. Wildfire significantly contributes to the spread of fire-adapted invasive species, often displacing native vegetation. FS has a long history of providing funding, technical assistance, and training to help states and territories better respond to and fight wildfire. All the Pacific USTIs can benefit from shared training, experience in wildfire responses, and knowledge of how different states and territories have built fire-fighting partnerships. Likewise, island entities can learn from and share fire behavior models based on fuel types and island geography, and can improve modeling for the potential impacts of climate change on fire-adapted invasive species. *(See "Issue 3: Wildfire," for additional information.)*

Public Land Management Funding

USTIs do not have National Forests, which receive substantial funding from FS to manage and maintain. (The exception is El Yunque National Forest in Puerto Rico.) As such, state- or territory-owned lands represent the majority of productive (ecosystem service–producing) lands in the USTIs, yet they are rarely eligible for landowner assistance funding programs. *(See "Appendix C: Forestry-Related Assistance Programs.")*

Unique Inventory/Monitoring Needs

In order to understand the trends, threats, and patterns in the loss of forests and their biodiversity, tropical foresters need more intensive survey, inventory, and monitoring methods that are specifically devised for tropical forests rather for less diverse continental forests. If surveys are to be used to assess forested conditions and trends locally, and then aggregated for the determination of national funding levels, the changes in tropical forest structures need to be accurately assessed and considered. The FS Forest Inventory and Analysis program is available to assist USTIs with periodic surveys that fit tropical island forest conditions. New sampling techniques, such as large-scale aerial Light Detection and Ranging (LiDAR) remote-sensing data collection, are increasingly available and can be used to characterize forest conditions for biomass, distribution of invasive species, key species, and forest disease. The high degree of spatial variability in tropical forests must be captured in vegetation surveys in order to adequately define and describe these unique forests and how they are changing over time.[14] Also needed are specialized wildlife inventory and monitoring techniques that are used in conjunction with forest inventories. The forests, its inhabitants, and the people are intrinsically tied to each other and should all be considered when determining natural resource health and function over time.

Equally important is the need to inventory and monitor urban forests where population increases and frequent storm events are projected. Catastrophic storms are not localized, but regional. Typically, when storms damage urban trees, large populations and multiple jurisdictions are affected. The abilities of individual citizens, communities, and local governments to prepare and respond can be quickly overwhelmed. Regional and national organizations should organize emergency plans along regional lines so that recovery efforts and resources are delivered more efficiently to multiple communities, states, or countries.

Land Development Pressures

In Hawai‘i, agriculturally zoned lands that were once used for production of monocrops like sugar or pineapple are being converted to support human development pressures rather than being restored to food crop production. In some worst-case scenarios, relatively intact native forests in agricultural lands are also subject to conversion to support human development or agricultural purposes. Formerly forested or marginal pasture lands also are being used to support human development needs and to produce biomass using fast-growing single species, which are often invasive. The influx of new landowners and developers from the fast-growing economies of Asia can also exert pressure for development of land and natural resources on the Pacific USTIs.

Food Security

Pacific island societies have traditionally depended on the environment and natural resources, via agriculture and fisheries, for food, shelter, water, and medicine. Today, these traditional resources are vulnerable to increasing pollution, invasive species, overharvesting, climate change, and sea level rise. In 2010, at the Pacific Island Committee meeting held in Chuuk, Federated States of Micronesia, representatives from seven island states and territories gathered to talk about forestry issues and their importance to local communities. Food security was a top priority for nearly every representative at the meeting. The Federated States of Micronesia has launched an intensive project to gather baseline data to answer questions such as: How much food does each island generate from its own lands? How vulnerable are individual islands to sea level rise? And what are current development and land use threats? This initiative also integrates marine and terrestrial biodiversity information with socio-economic data. In Hawaiʻi, an estimated 80 to 90% of food is imported. There is a growing interest in local food production and sustainable practices. Hawaiʻi has set a statewide sustainability goal of doubling its local food production by 2030 and government agencies, the University of Hawaiʻi, and private and non-profit groups are working on increasing local food production to reduce Hawaiʻi's dependence on imported food.[15] How vulnerable is Hawaiʻi's current and future food supply to impacts of climate change, and can producers adapt to climate change impacts quickly enough (Table 9.5)?

Table 9.5. Climate Change and its Effects on Food & Agriculture in Hawaiʻi.[14]

Primary Vulnerabilities	Primary Adaptions
1. Changes in temperature and sea level 2. Changes in rainfall amount and patterns 3. Rising atmospheric concentrations of CO_2 4. Changes in water availability 5. Increase in extreme weather events (droughts, floods, hurricanes)	1. Develop new crops and explore use of genetically modified organisms 2. Manage water 3. Alter management practices 4. Shift crop species production 5. Change human development areas and increase coastal vegetation resiliency

Technology Sharing and Capacity

There are a number of positive examples demonstrating the effectiveness of collaboration—sharing technologies, methodologies, and information for resource management in the Pacific. A good example is Hawaiʻi's use of the New Zealand– and Australia-developed "Weed Risk Assessment." *(See "Issue 2: Forest Health: Invasive Species, Insects, and Disease," for additional information.)* Another example is the Pacific Tsunami Warning System operating out of Hawaiʻi for the USTIs, linked to warning centers in Japan, Indonesia, Australia, and New Zealand, which protects communities and resources across the Pacific with pre-warning of the arrival of potentially deadly and damaging tsunamis (Figure 9.7).

An important need in the Pacific is imagery. The Pacific Imagery Consortium is a collaboratively funded group of federal agencies that purchase satellite imagery on a regular basis. These images are used for a variety of purposes throughout the Pacific. Typically, the images cover very large areas around the specific island they are being used for; however, none of the images are shared with neighboring countries, despite many needing this type of resource management tool.

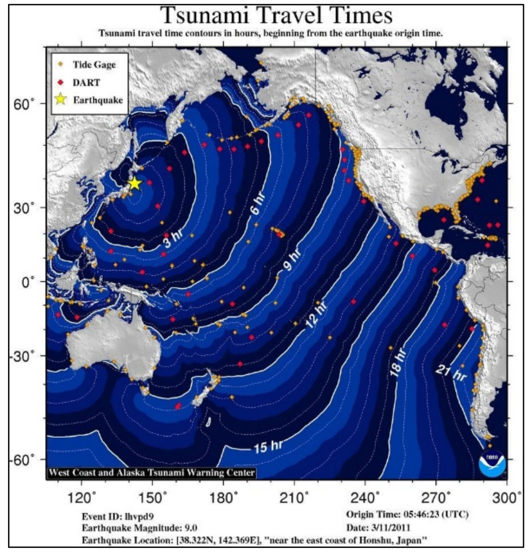

Figure 9.7. A tsunami travel time map for the Honshu, Japan, earthquake-generated tsunami in March 2011 that occurred across the Pacific.

However, one of the most limiting factors in implementing successful natural resource programs and sharing of resource management technology throughout the USTIs is limited technical capacity. Local professionals are essential for participation in collaborative efforts, implementation of on-the-ground actions, integration of cultural knowledge and practices into conservation practices, and raising local community awareness about inter-island environmental threats, such as invasive species transport.[14]

Environmental Education Capacity

Education, outreach, and training need to be elevated in priority for the Pacific islands. Conservation education is a component of many existing U.S. Forest Service State and Private Forestry programs, and is an integral aspect of all environmental work done on Pacific islands. Hawaiʻi has developed a statewide Hawaiʻi Environmental Literacy Plan[16] to improve education in schools through environmental education, which builds environmental literacy in the population as a whole. An environmentally literate population is informed, values Hawaiʻi's unique resources, and practices environmental stewardship and a sustainable lifestyle, which support the goals of this plan. More effort should be made to be creative with sharing information, developing capacity, and ensuring that important land management actions are based in best management practice technologies and shared with the public throughout the Pacific.

Coastal Area Protection

On tropical islands, the majority of human populations are found in coastal areas. These areas are important in protecting the inland areas from ocean storms/events, as well as in protecting the near-shore marine resources from inland/upland erosion and deposition of sediment. Coastal vegetation is important for shoreline protection and wetland preservation.[17] FS should support comprehensive land use plans for all islands and coastal communities, including coastal zone protection plans and regulations; watershed and land use management plans; local and regional ordinances to implement comprehensive land use plans; and vegetation selection guidelines for coastal protection (mangroves, for example).[18] Because of the interdependence of island ecosystems from ridge to reef, we cannot separate marine and coastal areas from our forest management planning efforts.

Seabirds, Shorebirds, and Migratory Waterfowl

Figure 9.8. *Kolea,* or Pacific golden plover (*Pluvialis fulva*).

These birds can travel tremendous distances in the Pacific. For instance, *ʻuaʻu*, or Hawaiian petrel (*Pterodroma sandwichensis*), undertake epic, multi-week journeys from their tropical nesting sites to a large area of ocean south of Alaska and the Aleutian Islands. The male and female parents alternate between short trips, often one or two days, and longer trips, some lasting several weeks and involving journeys farther than 4,600 miles, in search of food for their chick. One bird flew more than 33,000 miles—greater than the circumference of the earth—during a three-month period as it traveled to and from its burrow in the mountains of Kauaʻi.[19] Kolea or Pacific golden plover (*Pluvialis fulva*) (Figure 9.8) breed in Alaska and winter anywhere from American Samoa to Hawaiʻi to Saipan. "Kolea can spend eight months away from Hawaiʻi each year and then return to the same grassland or wetland."[20] Habitat protection for these migratory birds must be undertaken collaboratively because they use and need more than one type of environment in order to flourish.

Hawaiʻi and its Pacific island neighbors share many of the same threats, challenges, and opportunities for native wildlife conservation. The impacts of invasive species and the need for programs and tools to control existing pests and prevent their spread is a shared problem common to all island ecosystems. Introduced predators such as rats, feral cats, dogs, and other vertebrate pests (such as the brown tree snake) are huge problems for native land bird, waterbird, and nesting seabird populations on tropical Pacific islands. Similarly, climate change impacts such as sea level rise, inundation of coastal wetlands and seabird nesting habitat, warming temperatures, and decreasing precipitation (causing an increase in drought conditions and wildfires) are common shared problems.

All of the islands could benefit from more collaborative research to develop and share bird conservation and restoration techniques such as landscape predator control methods, translocation techniques for land birds and seabirds, and better survey and monitoring techniques that can be applied across the region. Likewise, increased knowledge, tools, and capacity to monitor, detect, and mitigate the adverse impacts of climate change can be used by all islands.

Rare Forest Types and Species That Occupy Them

These are a priority in Hawai‘i. For instance, “90% of Hawai‘i’s native dryland forest has been destroyed largely by human activity and encroachment.”[21] Hawai‘i’s Rare Plant Program states on its website, “Hawai‘i is often referred to as the endangered species capitol of the world,” with 366 plant taxa listed as endangered or threatened, and 44% of all endangered plant species in the U.S., yet Hawai‘i represents less than 1% of the U.S. land area.[22] Today, Hawai‘i is home to an overwhelming 238 plant species that have fewer than 50 individuals remaining in the wild (Figure 9.9).[23] A collaborative public and private conservation program, Plant Extinction Prevention Program has been developed to specifically target the conservation needs of extremely rare plant species (Figure 9.9).[23] It is important that more collaborative efforts like this take place in the Pacific to ensure that rare species protection and proliferation occur within and among island groups that can sustain them.

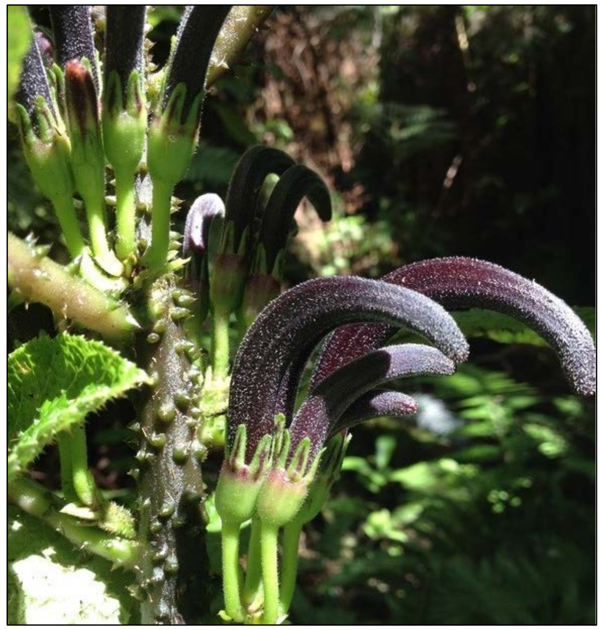

Figure 9.9. Extremely rare endangered plant, *Cyanea marksii*, from the island of Hawai ‘i. This is one of only eight known individuals surviving in the wild and is being managed under the Plant Extinction Prevention Program.[23]

Development of Staff and Operational Capacity for Collaborative Planning, Training, and Communication

These actions are needed across the Pacific USTIs to help address regional resource conservation issues. Joint development of plans such as regional invasive species biosecurity plans, climate change research, monitoring and response plans, and regional seabird and shorebird conservation plans will help all entities to manage shared threats and conserve natural resources. For example, collaboratively developed biosecurity plans will help prevent the spread of threats like the brown tree snake, mongoose (*Herpestes auropunctatus*), and *Miconia* (*Miconia calvescens*). Regional plans can also build in elements of staff training, transfer of technology, and reporting to keep on track, with capacity to implement effective programs. Mutually developed plans and programs require reporting that helps keep lines of communication open and facilitates sharing of other information that will contribute to natural resource management.

Professional Development and Retention

This is an issue facing most of the Pacific USTIs. The high costs of living and lower salaries typically paid to professional foresters and ecologists in the region makes it hard to attract and keep experienced professionals. Generally, the cost of living on the islands is higher than that on the mainland, particularly for housing, and yet state and territorial governments typically lag behind salary scales paid for comparable professional positions in federal agencies. There is often a revolving door of personnel, with states and territories providing entry-level training and experience in natural resource management, then losing staff to federal agencies working in the region that can offer higher salaries and, if experienced positions are lost, find replacements in a timely manner. One way to resolve the situation is to document the discrepancy in salaries for comparable positions and advocate for more equitable pay scales. Another solution is to increase the pool of trained professionals to work on natural resource management in the region. Developing regional training programs for communities to attract local young people into the profession would help meet this need and resolve this problem.

Capacity in Forestry

Forestry, especially forest products, represents an important opportunity for the Pacific USTIs. The focus on renewable energy and self-sufficiency in energy production provides an opportunity for islands to develop small-scale biomass energy products and deal with the issue of power generation and disposal of green waste (which can be generated from forestry, agro-forestry, and urban forest management practices). The islands also have the opportunity to develop tourism markets for non-timber forest products. Examples include developing tours around agro-forestry farming operations, or small businesses producing local crafts, and woodworking products for sale.

Priority Areas for U.S. Tropical Island State and Territorial Issues

The areas described at the beginning of this chapter are frequently involved in Hawai‘i’s economy and therefore are high priorities for future collaborations. However, the greatest priority will be given to those areas with which Hawai‘i interacts the most: the mainland U.S., New Zealand, Tahiti, Fiji, Tonga, Samoa, Australia, the Philippines, Indonesia, the Caribbean islands, and all of the U.S. territories and affiliated island groups, including Puerto Rico and the U.S. Virgin Islands.

As technologies, climates, and interests change, so too will priority areas upon which to focus natural resource management efforts. For the immediate future, collaboration with Pacific islands and Pacific Rim countries will be the priority for Hawai‘i.

Summary

The USTIs offer unique opportunities to collaborate on implementation of U.S. Forest Service State and Private Forestry Programs and other local, regional, and national programs *(see “Appendix C: Forestry-Related Assistance Programs”)*.

Working collaboratively on biosecurity, transport of invasive species, health of coral reefs, preservation of traditional knowledge, protection of rare species, sustainable fishing practices, and other shared issues benefits not only the natural resources and communities on tropical islands but also our nation as a whole. The islands are harbingers of the future because of their high population densities and dependency on external energy, food, and materials. USTIs are also where the effects of global climate change are expected to be first and most seriously observed and experienced.

The way in which islands address and resolve these issues will benefit the nation and the world. The lessons from our tropical islands are exportable to continental systems where connections between social and ecological conditions are sometimes not as obvious as they are on islands. Vibrant programs and efforts, while uniquely crafted to suit islands and their associated cultures, will create valuable benefits that can be leveraged by states and nations located far from the islands themselves. Multi-state and regional programs, projects, and collaborations are essential for sustainable management of island ecosystems and are essential for our nation to learn from the past and present as we plan for the future.

Strategies for Issue 9: U.S. Tropical Island State and Territorial Issues

Tropical Islands: Invasive Species Transport

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Develop and implement a collaborative improvement strategy to raise awareness and implement programs to stop transport of insects and diseases and export/import of species rated highly invasive across the Pacific.	Pacific-wide, U.S., and international.	Have airlines contribute to screening protocols; add inspectors at high-vector areas; coordinate message across the Pacific; identify opportunities for env. ed. in schools and informal programs.	Forest Health Protection and Monitoring, UCF, conservation and environmental education, EQIP, CIG, FSCG, UNFAO, SOPAC, NARF, CGAPS, SPREP, SPC.	USDA, HCA, PIC, SPREP, SPC, New Zealand DOC, Australia, NPS, NOAA, NRCS, FS, HDOT, TNC, U.S. airline companies, APHIS, Homeland Security, RISC, DOD.	USFWS, PICCC, UH, University of Guam, Australian universities, New Zealand universities, community colleges, heads of forestry across the Pacific, NOAA and National Weather Service, NRCS, TNC.	Better broader entry protocols; more awareness of invasive species issues by travelers that visit Pacific islands and countries; more stringent screening for incoming visitors to Pacific islands; reduced transportation and relocation of highly invasive species.	1.1 2.2 3.1 3.4 3.5 3.6	1.2.c 1.5.b, c, d

Tropical Islands: Protection of Genetic Diversity and Important Food Plants

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Hold workshops among Hawai'i and various Pacific islands to share technical and cultural knowledge related to sustainable agro-forestry and marine resource practices.	Chuuk, American Samoa, Yap, Hawai'i, and other international Pacific islands.	Protect coral reefs and critical habitat; share cultural knowledge.	Seacology, FSCG, conservation and environmental education, FSP, Forest Health, UNFAO, SOPAC, USFWS, Sea Grant.	Private and public landowners in the Pacific, HCA, PICCC, TNC, NOAA, DOD, UH Ocean and Earth Sciences, USGS, NWHI, Sea Grant.	Same as above.	A series of workshops aimed at bringing together highly successful agro-foresters and near-shore fishery management experts that allows cross-sharing of their rare knowledge. Brochures and videos describing the techniques and rotational practices made available to the public and env. educators.	1.1 2.2 3.1 3.4 3.6	1.2.c 3.1 3.2

Strategies for Issue 9: U.S. Tropical Island State and Territorial Issues

2. Work collaboratively to mitigate impacts of loss of genetic diversity of food plants, native species, and culturally important species.	Pacific-wide.	Protect T&E species; improve remote nursery installation techniques; control invasive species; identify opportunities for env. ed. in schools and informal programs.	USFWS Section 7 grants, UCF, conservation education, FSP, FLP, schools, volunteer groups, NARF, PEP.	HCA, PICCC, USFWS, NPS, USDA, HDOA, HDOT, TNC, NOAA, DOD, CWRM, UH Ocean and Earth Sciences, USGS, NWHI.	USFWS, departments of agriculture across the Pacific, local and federal EPAs, HDOT, NOAA, CZM, FS competitive grants, PBIN.	Increased food security; more studies that define monitoring of Hawaiian biodiversity; testing of new crop species under new climate conditions; shift of agriculture to suitable new lands; initiation of more trainings and expanded nurseries/ production areas for rare plant seed protection and propagation with forest plants and food crops; use of methodologies that can be duplicated.	1.1 2.2 3.1 3.4 3.6	1.2.a, c, d 1.5 2.1 2.2.a, b

Tropical Islands: Migratory and Regional Bird Protection

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Collaborate on protection and enhancement of known migratory seabird and shorebird populations and habitat. Increase capacity to monitor and protect these birds. Engage school and community groups in the protection of habitat and birds.	Pacific-wide.	Protect wetland and upland bird habitat; improve best management practices for bird habitat.	USFWS Section 7 grants, FLP, Forest Health Protection, watershed partnerships, Fire and Aviation, EQIP, WHIP, FSP, FSCG, NARF, SPREP, SPC.	HCA, NOAA, DOD, HTA, USFWS, NPS, HDOT, Office of Planning, HDOA, TNC, HDOH, Marine and Coastal Zone Advocacy Council, USCG, Sea Grant, SPREP, SPC.	PICCC, CZM Pacific-wide, USFWS Section 7 grants, Audubon Society, Ducks Unlimited.	Increase in habitat; increase in knowledge about these birds; more cooperation with international countries in the Pacific for collaborative opportunities.	1.1 2.2 3.1 3.5 3.6 3.7	1.2 1.5.b, c, d 2.2

Strategies for Issue 9: U.S. Tropical Island State and Territorial Issues

2. Collaboratively research, develop, and share bird conservation and restoration techniques applicable across the region. Increase capacity to monitor, detect and mitigate adverse impacts of climate change.	Pacific-wide.	Improve techniques for protecting T&E and native species; control invasive species; restore wildlife habitat; identify opportunities for env. ed. in schools and informal programs; improve best management practices for bird habitat.	USFWS Section 7 grants, FLP, Forest Health Protection, watershed partnerships, Fire and Aviation, EQIP, WHIP, FSP, FSCG, NARF, SPREP, SPC.	HCA, NOAA, DOD, HTA, USFWS, NPS, HDOT, Office of Planning, HDOA, TNC, HDOH, Marine and Coastal Zone Advocacy Council, USCG, Sea Grant, SPREP, SPC.	Same as above.	Increase in habitat; increase in knowledge about Pacific land and sea birds; more cooperation with states, territories, and international countries in the Pacific for collaborative research and conservation opportunities.	1.1 2.2 3.1 3.5 3.6 3.7	1.2 1.5.b, c, d 2.2

Tropical Islands: Collaborative Multi-Regional Planning, Training, and Communication

Long-Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas That Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives	Supports Hawai'i Environmental Literacy Plan Goals
1. Work collaboratively across the Pacific to identify the highest-priority issues.	Pacific-wide.	Incorporate multiple resource needs.	UCF, Forest Health Protection, watershed partnerships.	HCA, NOAA, DOD, USFWS, NPS, Office of Planning.	ICAP at UH.	Development of a clearly defined plan detailing priorities; reiterations in the process to review management actions, identification of successes and gaps.	1.1 2.2 3.5	
2. Develop staff and operational capacity for collaborative planning, training, and communication across the Pacific to address regional resource conservation issues.	Pacific-wide.	Develop human resources; protect island resources; prevent the spread of invasive species; coordinate monitoring of climate change; share good ideas and solutions for natural resource conservation problems; coordinate message across the Pacific.	UCF, Forest Health Protection, watershed partnerships, PICCC, Coral Reef, National Marine Monuments, IPIF.	PICCC, HCA, TNC, NOAA, USFWS, NPS, Office of Planning, Office of Insular Affairs, HISC.	PICCC, USFWS, NPS, EPA, NOAA, CZM, FS, HCA, HISC.	Increase in collaborative regional planning, coordinated implementation, and reporting on regional projects; increase in workshops and training; increase in information exchange on conservation initiatives and projects; better preparation and response to natural disasters and climate change impacts.	1.1 2.2 3.4 3.5 3.6 3.7	1.5 2.3 3.1 3.3

Strategies for Issue 9: U.S. Tropical Island State and Territorial Issues

Key:
CGAPS = Coordinating Group on Alien Pest Species
CIG = NRCS Conservation Innovation Grant Program
CWRM = Commission on Water Resources Management
CZM = Coastal Zone Management
DOC = Department of Conservation
DOD = Department of Defense
env. ed. = environmental education
EPA = Environmental Protection Agency
EQIP = Environmental Quality Incentive Program
FLP = Forest Legacy Program
FS = U.S. Forest Service
FSCG = Forest Service Competitive Grants
FSP = Forest Stewardship Program
HCA = Hawai‘i Conservation Alliance
HDOA = Hawai‘i Department of Agriculture
HDOT = Hawai‘i Department of Transportation
HTA = Hawai‘i Tourism Authority
ICAP = Center for Island Climate Change Adaptation and Policy
IPIF = Institute of Pacific Islands Forestry
NARF = Natural Area Reserve Fund
NOAA = National Oceanic and Atmospheric Administration
NPS = National Park Service
NRCS = Natural Resources Conservation Service
NWHI = Northwestern Hawaiian Islands
PBIN = Pacific Biodiversity Information Node
PEP = Plant Extinction Prevention
PIC = Pacific Information Center
PICCC = Pacific Islands Climate Change Cooperative
SOPAC = Secretariat of the Pacific Applied Geoscience Commission
SPC = Secretariat of the Pacific Community
SPREP = South Pacific Regional Environmental Program
T&E = threatened and endangered
TNC = The Nature Conservancy
UCF = Urban and Community Forestry Program
UH = University of Hawai‘i
UNFAO = United Nations Food and Agriculture Organization
USDA = U.S. Department of Agriculture
USFWS = U.S. Fish and Wildlife Service
USGS = U.S. Geological Survey
WHIP = Wildlife Enhancement Incentive Program

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Appendices

Appendices are available online at https://dlnr.hawaii.gov/forestry/info/fap/. Below is a list of each appendix, with a link to the individual appendix document online.

Appendix A: Stakeholder Involvement
https://dlnr.hawaii.gov/forestry/files/2013/09/Appendix-A-Stakeholder-Process.pdf

Appendix B: Plans & Methodologies Incorporated and Referenced
https://dlnr.hawaii.gov/forestry/files/2013/09/Appendix-B-Plans-Methods.pdf

Appendix C: Forestry-Related Assistance Programs
https://dlnr.hawaii.gov/forestry/files/2013/09/Appendix-C-Forestry-Assistance.pdf

Appendix D: Hawaiʻi Community Wildfire Protection Plans
https://dlnr.hawaii.gov/forestry/files/2013/09/Appendix-D-CWPPs.pdf

Appendix E: Conservation Education Program
https://dlnr.hawaii.gov/forestry/files/2013/09/Appendix-E-2016-Education-Update.pdf

Appendix F: Timeline of Forest History in Hawaiʻi
https://dlnr.hawaii.gov/forestry/files/2013/09/Appendix-F-Forest-History.pdf

Appendix G: General Description of the Hawaiian Forests, 1902
https://dlnr.hawaii.gov/forestry/files/2013/09/Appendix-G-Hawaiian-Forest-Description.pdf

Appendix H: Koa Action Plan
https://dlnr.hawaii.gov/forestry/files/2013/09/Appendix-H-Koa-Action-Plan.pdf