

# Hawai'i Statewide Assessment of Forest Conditions and Trends: 2010 An Assessment of the State of Our 'Āina

Department of Land and Natural Resources  
Division of Forestry and Wildlife  
Honolulu, Hawai'i  
June 18, 2010

Paul J Conry, State Forester  
Prepared by Ronald Cannarella, Forester





# THE WATER OF KANE

In the Hawaiian pantheon, the god Kane 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 Kane?*

*At the Eastern Gate, Where the Sun  
comes in at Haehae;  
There is the water of Kane.*

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

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

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

*Yonder on mountain peak, On the  
ridges steep, In the valleys deep,  
Where the rivers sweep;  
There is the water of Kane.*

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

*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 Kane.*

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

*Up on high is the water of Kane,  
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 Kane.*

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

*Deep in the ground, in the gushing  
spring, In the ducts of Kane 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 Hawaii: 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.



# Hawaii Statewide Assessment of Forest Conditions and Resource Strategy

June 18, 2010

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Cover Photo: View from Kaala, the tallest point on Oahu looking west over the community of Waianae. For an explanation of the word `aina, please refer to the explanation of the Hawaii state motto on page 16. Photocredit Ron Cannarella.

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**Note from Hawaii State Forester Paul Conry**

Aloha,

It is my pleasure to invite you to join the Department of Land and Natural Resources, Division of Forestry and Wildlife to help assess the conditions of our forests, native species, forests products industry and forest recreational opportunities and plan our 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, has asked each state and territory to complete a Statewide Forest Assessment and Resource Strategy that will help inform our federal agency partners and national policy makers on where and how to direct natural resource funding and more importantly, help us work together to guide our efforts here in the state to be more collaborative and productive.

The basic requirements of this effort will be to:

- Identify and provide an analysis of present and future forest conditions, trends, and threats on all land ownerships.
- Identify any areas or regions of that 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.

Every state has the responsibility to deliver a Statewide Forest Resource Assessment and Strategy to the U.S. Secretary of Agriculture by June 2010.

This effort is unique in many ways, it involves all landownership - state, private and federal, and views forests and trees as a whole and not by programs. It will enable the Division to seek and base funding on landscape scale management and not only on narrow program mandates. This initiative offers us an opportunity to plan, and 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 describe our strategy to work together to protect our forests from harm, and conserve forests in a working landscape. Hopefully, this information will be useful to influence our communities, our State and national legislators, and our government leaders to invest in Hawaii's forests for the future.

This document represents the beginning of a process, not the end, where we will work together to continually update and inform our collective understanding of our forest assets and what is affecting them, and apply that knowledge to guide and improve our management. This is our initial assessment and strategy, it will evolve over time, we will need your help to update and improve upon it. Please join us in this effort.

Mahalo for your participation, assistance and support.

Paul J. Conry  
Hawaii State Forester



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## Acronyms

ACRONYM	MEANING
AAA	Aloha Arborists Association
APHIS	Animal and Plant Health Inspection Service
BISC	Big Island Invasive Species Council (Island of Hawaii)
BRD	Biological Resources Division (of the U.S. Geological Survey USGS)
BWS	Board of Water Supply
C&C	City & County of Government of Hawaii
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 (Dept. of Homeland Security)
CFP	Cooperative Fire Protection
CREP	Conservation Reserve Enhancement Program
CWCS	Comprehensive Wildlife Conservation Strategy
CWPP	Community Wildfire Protection Plan
CZM	Coastal Zone Management
DAR	Division of Aquatic Resources
DFWG	Dryland Forest Working Group
DHHL	Department of Hawaiian Homelands
DHS	US Department of Homeland Security
DLNR	Department of Land and Natural Resources
DOA	State of Hawaii Department of Agriculture
DOD	State Department of Defense
DOFAW	Division of Forestry and Wildlife
DOFAW FP	Division of Forestry and Wildlife - Fire Management
DOH	State Department of Health
DOT	State Department of Transportation
DPCH	Department of Planning for County of Hawaii
DPCK	Department of Planning for County of Kauai
DPCM	Department of Planning for County of Maui



ACRONYM	MEANING
EE	Environmental Educational
ELP	Environmental Literacy Plan
EQIP	Environmental Quality Incentive Program (a program of the NRCS)
FAO UN	Food and Agriculture Organization of the United Nation
FEMA	Federal Emergency Management Agency
FGDC	Federal Geodata Data Committee
FH	Forest Health
FHMP	Forest Health Monitoring & Protection
FSP	Forest Stewardship Program (both State & Federal programs)
FLP	Forest Legacy Program
Friends	Friends of Urban Forests
FRPP	Farm & Ranchland Program
FRS	Forest Reserve System
FS	Forest Service
FSCG	Forest Service Competitive Grants
FSP	Forest Stewardship Program
FWS	Fish & Wildlife Service
FWSR	Fish & Wildlife Service - Refuge
GIS	Geographic Information System
GMA	Cooperative Game Management Areas
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
HARC	Hawaii Agriculture Research Center
HAWP	Hawaii Association of Watershed Partnerships
HCA	Hawaii Conservation Alliance
HCRI RP	The Hawaii Coral Reef Initiative Research Program
HDOA	Hawaii Department of Agriculture
HEAR	Hawaii Ecosystem At Risk
HETF	Hawaii Experimental Tropical Forest
HFIA	Hawaii Forest Industry Association
HFRA	Healthy Forest Restoration Act
HIGAP	Hawaii Gap Analysis Project
HISC	Hawaii Invasive Species Council
HP-WRA	Hawaii-Pacific Weed Risk Assessment
HTA	Hawaii Tourism Authority

ACRONYM	MEANING
HUD	US Department of Housing and Urban Development
I&E	Information and Education
ICAP	The Center for Island Climate Adaptation and Policy
ICS	Incident Command System
IPIF	Institute of Pacific Island Forestry
ISC	Invasive Species Committee (there are five ISC's operating at an island-level for Kauai, Oahu, Molokai, Maui and the "Big Island" of Hawaii)
KISC	Kauai Invasive Species Committee
LICH	Landscape Industry Council of Hawaii
MAA	Mutual Aid Agreement
MCZAC	Marine & Coastal Zone Advocacy Council
MISC	Maui Invasive Species Committee
MoISC	Molokai Invasive Species Committee
Na Ala Hele	State Na Ala Hele Trails & Access Program
NPS	National Park Service
NAPP	Natural Area Partnership Program
NARF	Natural Area Reserve Fund
NASF	National Association of State Foresters
NGO	Nongovernment Organization
NOAA	National Oceanographic and Atmospheric Administration
NRAG	Natural Resources Advisory Group (to Hawaii Tourism Authority)
NRCS	Natural Resources Conservation Service
OHA	Office of Hawaiian Affairs
OISC	Oahu Invasive Species Committee
ORMP	Ocean Resources Management Plan
OP	Office of Planning
PBIN	Pacific Biodiversity Information Node
PIER	Pacific Island Ecosystems at Risk
PICCC	Pacific Islands Climate Change Cooperative
PIER	Pacific Island Ecosystems at Risk
PR	Pittman-Robertson Funds
PSWRS	Pacific Southwest Research Station
RLA	Recovery Land Acquisition Program
SAF	Society of American Foresters
SCORP	Statewide Comprehensive Outdoor Recreation Plan

ACRONYM	MEANING
SOEST	University of Hawaii 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
T&E	Threatened and Endangered (species)
TAT	Transient Accommodation Tax administered by HTA
TNC	The Nature Conservancy
TPL	The Trust For Public Lands
UCF	Urban & Community Forestry (Kaulunani)
UH	University of Hawaii
UH/SOEST	University of Hawaii School of Ocean & Earth Science and Technology
UH/CTAHR	University of Hawaii College of Tropical Agriculture and Human Resources
UHHERO	University of Hawaii Economic Research Organization
UNFAO	United Nations Food and Agricultural Organization
USACE	U.S. Army Corps of Engineers
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	U.S. Geological Survey
UXO	Unexploded Ordinance
WFLC	Western Forestry Leadership Coalition
WHIP	Wildlife Enhancement Incentive Program
WRA	Weed Risk Assessment
WUI	Wildland-Urban Interface
YCC	Youth Conservation Corps





View of Mauna Kea from Hilo, Island of Hawaii. 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, as seen in this photograph covered in snow. From this vantage point, mankind 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 Hawaii's Statewide Assessment of Forest Conditions (2010) and Resource Strategy. It was produced by the Hawaii Department of Land and Natural Resources/Division of Forestry and Wildlife (DOFAW) to fulfill a mandate of the Redesign effort of the State and Private Forestry (S&PF) organization within the U.S. Forest Service. The S&PF Redesign and the requirement to produce this document are part a suite of new provisions added to the Forestry Title of the 2008 Farm Bill (P.L. 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 addressed all of the related plans, directly engaged all of the committees and worked with our stakeholders as set forth in the Official Checklist.

We have used this process as an opportunity for DOFAW to promote new collaborative efforts among the many agencies, institutions and landowners actively involved in the stewardship of Hawaii's natural resources.

The 2008 Farm Bill in conjunction with the Redesign process for the State and Private Forestry organization of the U.S. Forest Service made it a requirement that each state forestry agency coordinate with the State Forest Stewardship Coordinating Committee, the State Technical Advisory Committee of the Natural Resources Conservation Service, the State Urban Forestry Council, state wildlife agency and applicable federal land management agencies to ensure that their completed Assessment and Strategy addresses the rural-to-urban landscape continuum and identifies opportunities for program coordination and integration.

In addition, the Farm Bill explicitly directed the states to integrate the Comprehensive Wildlife Conservation Strategy (CWCS), and the Statewide Comprehensive Outdoor Recreation Plan (SCORP), all Community Wildfire Protection Plans (CWPP's), and other relevant plans. States were required 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. We accomplished this and more in the process of completing our Assessment and Strategy.

In a series of meetings with our stakeholders we identified 9 issues. For each issue we characterized the trends, the existing conditions, the threats and benefits of our forest and treed landscapes. We created maps with the most current public information available, and then developed a set of strategies for addressing the issues identified in partnership with our stakeholders.

The required deliverable products from this project are the Hawaii Statewide Assessment Forest Conditions and Trends: 2010, and our Resource Strategy for the next 5-10 years. In the process

of completing our project we produced a great variety of products and data that will be of use to others in the future.

*The Aloha Act of 1986*

Anyone who comes to Hawaii will experience the Aloha Spirit for themselves. It permeates every aspect of life in these islands. Section 5-7.5 of the Hawaii 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 Hawaii State government. In preparing this document, we fulfilled the requirements of the 2008 Farm Bill and were mindful to conduct ourselves according to the values in our State law.

**THE ALOHA ACT  
HAWAII 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 emotive 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;
- "**Olu'olu**" meaning agreeable, to be expressed with pleasantness;
- "**Ha'aha'a**", meaning humility, to be expressed with modesty;
- "**Ahonui**", meaning patience, to be expressed with perseverance.

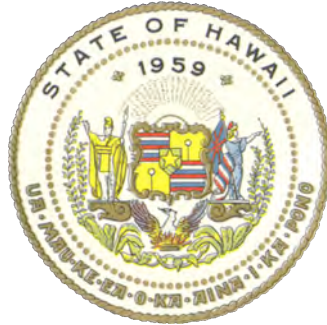
These are traits of character that express the charm, warmth and sincerity of Hawaii's people. It was the working philosophy of native Hawaiians and was presented as a gift to the people of Hawai'i. "**Aloha**" is more than a word of greeting or farewell or a salutation. "**Aloha**" means mutual regard 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]

Perhaps the most valuable and enduring legacy of this project will be the sum of the new relationships we have established, the enhanced capabilities of our staff to use new tools and data, and the educational experiences of our interns. 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 *aina* (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 21<sup>st</sup> century *ahupuaa*. All of these concepts are discussed at length throughout this document.



The Hawaii State Motto and Land Stewardship  
***Ua Mau Ke Ea, O Ka Aina 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 Hawaii 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 Hawaii by British Navy Admiral Richard Thomas. Months earlier, the Captain of another British warship had unilaterally seized control of Hawaii 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 Hawaii. In his speech of gratitude, the King proclaimed "*Ua mau ke ea o ka 'aina i ka pono*", meaning that the Kingdom's 'aina (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 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 'aina for that word has a special connotation. The root of the word 'aina is 'ai, (to feed), thus, the 'aina 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 Hawaii, be they native Hawaiian or not, often use the words 'aina 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 the Division of Forestry and Wildlife, 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 assure that the land is cared for and preserved into perpetuity.

## Notes on Orthography and Language

Note: Words and place names in the Hawaiian language are in italics throughout this document.

Hawaii 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 Hawaii and, in 1990, the Federal Government of the United States adopted a policy to recognize the right of Hawaii 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 Hawaii Department of Education.

The State of Hawaii, and the authors of this document recognize that proper pronunciation and spelling of Hawaiian is a requirement to properly and respectfully represent the words used in place names, cultural ideas, and the names of our native plants and animals, and physical attributes of our unique geography.

The information contained in this document will likely be used in many different media such as a printed report, word processing documents in several formats, the Internet, and PowerPoint presentations to name a few. Unfortunately, current computer-based word processing applications, keyboard layouts, and web browser technology do not facilitate universal and uniform representation of these diacritical marks by browser fonts, word processors, presentation applications and search engines. Our experience is that the *kahako* and the *okina* are often mistranslated to random characters thus rendering the intended Hawaiian word unintelligible or unreadable. For this reason we have italicized words in Hawaiian to inform the reader that they are Hawaiian, and that, without the *kahako* and *okina*, they may be technically misspelled.

The authors of this document share the aspirations of native Hawaiian speakers to one day 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, and the state of technology does not guarantee that unique Hawaiian orthography will be correctly represented to the person reading this document.

## **Background**

### **Purpose of This Document**

The Hawaii Statewide Forest Resource Assessment was initiated in response to a mandate from the U.S. Forest Service (USFS) and 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 the Hawaii Department of Land and Natural Resources/Division of Forestry and Wildlife (DOFAW) with the assistance of our partners and stakeholders in accordance with national direction issued jointly by the USFS and the National Association of State Foresters (NASF).

Statewide assessments are a key component of the USFS State and Private Forestry (S&PF) Redesign Initiative that was launched in 2008. These assessments will provide 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 the identification and address of priorities, the U.S. Congress and the USFS hope to ensure that S&PF funds are invested in those areas where funding will make the most significant difference for both the state and the nation.

In Hawaii, DOFAW and our partners will also use the state assessment and the associated GIS data layers as tools to identify where opportunities exist to facilitate forest management across jurisdictional boundaries and quantify the full scale of actions and resources needed to address Hawaii's forest health challenges.

### **USDA Forest Service State and Private Forestry Redesign Initiative**

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



The S&PF Redesign Initiative was conceived 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 these challenges, the USFS 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 is “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 the USFS 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.

## **National Objectives**

The new redesign approach focuses on three consensus-based national themes with accompanying strategic outcomes:<sup>1</sup>

### **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 the USFS and other key partners to develop the following documents:

**Statewide Assessment of Forest Conditions** – Provides an analysis of forest conditions and trends in the state, and delineates priority rural and urban forest landscape areas.

**Statewide Forest Resource Strategy** – 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 assessment and strategy, including the leveraging of funding and resources through partnerships.

According to the 2008 Farm Bill, each state is required to complete both the assessment and strategy by June 18, 2010, in order to qualify for most S&PF funds. This document represents Hawaii's completion of these requirements.

### **National Guidance for Statewide Forest Resource Assessments**

The development of a comprehensive statewide assessment of forest resources 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 statewide assessment 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 assessments 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.

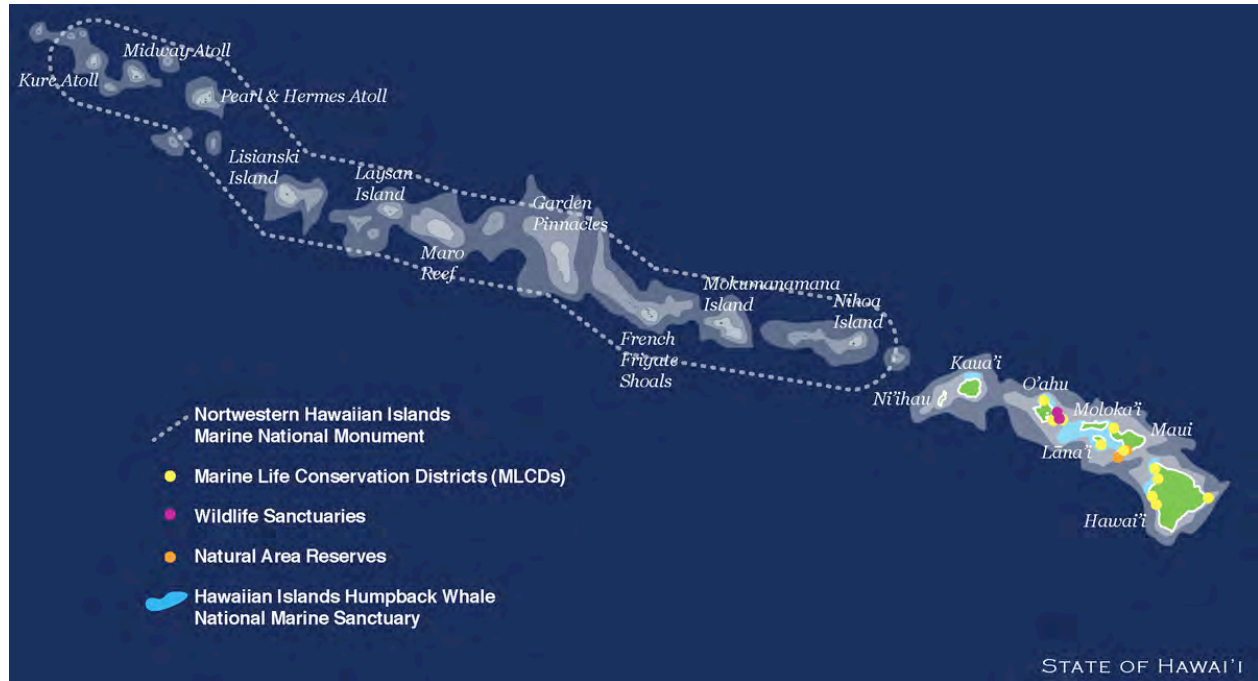
In developing a statewide assessment, each state forestry agency is directed to coordinate with the State Forest Stewardship Coordinating Committee, State Technical Advisory Committee, the State Urban Forestry Council, state wildlife agency and applicable federal land management agencies to ensure that 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.

### **Process for Development of Hawaii's Statewide Assessment**

#### Scope

The State of Hawaii consists of two distinctly different geographical regions; the Main Hawaiian Islands and the Northwestern Hawaiian Islands. (Please refer to the following section "Hawaii's

Forests: The Historical Context for more detail.) The Northwestern Hawaiian Islands do not support forests, and are now managed as the Papahānaumokuākea Marine National Monument. This assessment therefore pertains only to the forested Main Hawaiian Islands from Niihau to the Island of Hawaii as shown in Map A.1.



Map A.1. The State of Hawaii showing the Main Hawaiian Islands which are addressed in this Assessment, and the Northwestern Hawaiian Islands which are not included.

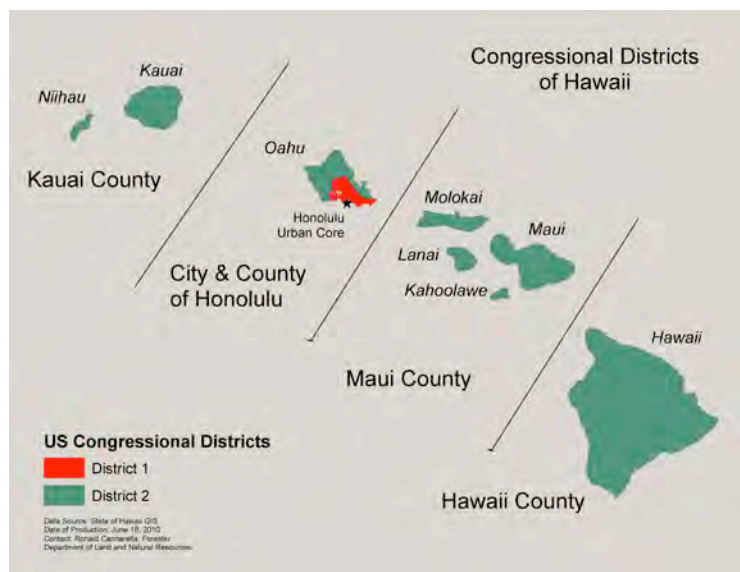
The reader should be familiar with several characteristics that are unique to the State of Hawaii in order to fully grasp some of the issues in this document. See Table 1.1 for an explanation of the difference between an island name and a county name.

1. When referring to people, the term “Hawaiian” is reserved for people of native Hawaiian descent. Residents of the state of Hawaii are referred to as “residents” or “locals”, and may or may not be of native Hawaiian ancestry.
2. The state of Hawaii does not have a municipal-level of government. The state of Hawaii has a governor, and the Main Hawaiian Islands are divided into 4 counties, each with a county council and a mayor who is elected by popular vote. Each inhabited island has a County Seat, but these are not incorporated. Because Hawaii does not have municipalities with defined boundaries, the Kaulunani Urban and Community Forestry Program faced the challenge of mapping their priority areas. Please refer Table 1 which clarifies the relationship between the island name, county name, named communities and county seats.

County Name	Islands Comprising the County and their County Seat
County of Hawaii	Hawaii (Hilo)
County of Maui	Maui (Wailuku), Lanai (Lanai City), Molokai (Kaunakakai), Kahoolawe (uninhabited). Legally, a 5 <sup>th</sup> County exists on the Island of Molokai named Kalawao which was formerly the leper colony of Kalaupapa, established by Saint Damien of Molokai 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 & County of Honolulu	Entire island of Oahu ("Honolulu" generally refers to the Honolulu Urban Core between Kalihi Valley and Kahala)
County of Kauai	Kauai (Lihue), and Niihau (privately owned)

Table 1.1: The relationship between County names, island names and population centers for the islands addressed by this document.

- The entire island of Oahu comprises the City & County of Honolulu. The terms Oahu, Honolulu, and City & County of Honolulu are used interchangeably throughout this document. Generally speaking, "Honolulu" refers to the Urban Core on the south side of the island. Much of the island of Oahu is very rural and these areas are distinctly different from the Urban Core. Again, "cities" on the island of Oahu, such as Kaneohe, Kailua, Wahiawa are not incorporated.
- Two of the Main Hawaiian Islands are entirely privately owned; the island of Niihau and the island of Lanai. Niihau is populated entirely by native Hawaiians whose principle language is Hawaiian. Access to Niihau is strictly controlled by the landowner, and there is very little interaction between the government and Niihau.
- 80% of the state's population lives on the Island of Oahu, with the greatest concentration in the



Map A.2. Congressional Districts of Hawaii reflect the population concentrated in the Honolulu Urban Core.



Honolulu Urban Core. This population distribution is clearly reflected in the district boundaries for Hawaii's two U.S. Congressional Districts. (see Map A.2)

### **Hawaii's Issues for this Assessment and Strategy**

The states were given a good deal of leeway in how they identified relevant issues. For Hawaii, we identified nine priority issues, listed below, using several questionnaires, on-line surveys and in collaboration with our partners. (*See Appendix A: Stakeholder Involvement for additional information on this process.*) The overall process for producing this document was coordinated by Ronald Cannarella our staff Resource Planner and GIS specialist. Our staff 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 cooperators before incorporating them into the final document.

Hawaii's Priority Issues are:

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

At the time we were preparing this document, our state began to experience the economic crisis that has affected so many other states. Declining revenues required that the State implement a number of cost saving measures that included a reduction in workforce, the implementation of a furlough system that reduced working hours by approximately 14%, and a general restriction on spending. As an island state, the only method of transportation between the islands is by air, and for most of this project inter-island travel was limited.

In order to complete the project, we found new ways to collaborate. We took advantage of every opportunity we could to get our project on the agenda for meetings and conferences that were already scheduled. In every case, our partners were glad to assist and in the process we developed new relationships between agencies and organizations that had not previously worked together. Notably among these conferences was the 2009 Hawaii Conservation Conference produced by the Hawaii Conservation Alliance, the Urban and Community Forestry Summit produced by the Kaulunani Urban and Community Forestry Committee, the Watershed Prioritization Summit produced by the Coastal Zone Management Program and the Hawaii Office of Planning, and the California/Nevada/Hawaii (CNH) annual Wildfire conference which was held on the island of Kauai in 2010.

In order to overcome the barrier of working on different islands, and to hold down our costs, we utilized the internet as much as possible, and adopted new technologies such as Google Docs, Dropbox, Basecamp and set up a website so that we could communicate at minimal cost, and often in real-time. Thus, it is difficult to document many of the formal “meetings” with our stakeholders, since in many instances several people on different islands would be collaborating on a document in real time. We held conference calls on a daily basis, and recorded the entire 2009 Hawaii Conservation Conference which focused on Climate Change. Presentations from this conference are posted the on the web at <http://hcc09.blip.tv>, and can also be downloaded as podcasts from iTunes at <http://itunes.apple.com/us/podcast/hawaii-conservation-conference/id329377708>. Producing these podcasts took three days, and they are hosted for free.

We also utilized in-house student interns, partnered with several University of Hawaii professors who provided students the opportunity to assist us in the production of this document as part of their class requirements. We utilized Americorps interns at critical points in the project.

We were very fortunate that while we were working on this project, LANDFIRE was just beginning its work in Hawaii. DOFAW staff and many of our cooperators worked closely with LANDFIRE staff specifically with the intent of making their data products directly relevant to this Assessment. The Hawaii Nature Conservancy provided invaluable assistance by applying for a grant from LANDFIRE to help us refine our biodiversity layer, and they continued to provide support long after the deliverables were provided to LANDFIRE.

In order to evaluate the enormous amount of historical data and other relevant plans, we scanned and converted over 10,000 pages of original source material to Adobe’s Portable Document Format (PDF). This allowed us to quickly search an enormous amount of information, and we are in the process of identifying a permanent repository for these scanned documents.

In doing the GIS analysis for the various issues we utilized publicly available data. In some cases, we utilized raster-based overlay analysis as we did in the Spatial Analysis Project, but many of our issues did not lend themselves to that particular technique. In the course of our analysis we identified a number of public layers that were out of date, and where possible we updated these layers and provided Federal Geodata Data Committee (FGDC) compliant metadata. These layers were then provided to the State of Hawaii Office of Planning and posted for public access via their website.

Two professional peer-reviewed papers have been produced and a chapter in a forthcoming book on Technical Writing will feature our collaboration with the University of Hawaii English Department.

Perhaps most importantly, this project has helped bring together the three basic constituencies that comprise the the 21<sup>st</sup> Century *Ahupuaa*<sup>1</sup>; the upland forested areas, the developed areas, and the coastal/marine areas. Our existing relationships are strengthened, new partnerships have been developed, and all parties are ready to play their part in managing their portion of the *ahupuaa*.

## Hawaii's Forests: The Historical and Cultural Context

### Summary

Hawaii 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. The “Aloha Spirit” is not an abstract concept or a marketing strategy; it is the law of the land.<sup>2</sup> Over the centuries the native Hawaiians developed a unique land stewardship system, called the *ahupuaa* system, that functioned in harmony with the geography and climate of the Main Hawaiian Islands. The *ahupuaa* 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 Hawaii. For this reason it is universally acknowledged that implementing a 21<sup>st</sup> Century version of the *ahupuaa* system is the path that will best serve the public interest.

Hawaii has a long tradition of comprehensive landscape-level planning for sustainably maintaining our natural resource base 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 Hawaii'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 Hawaii State Land Use Law of 1961 which established a unique class of protected lands known as Conservation District. The third assessment of all of Hawaii's forested lands resulted in “The Hawaii Tropical Forestry Action Plan” (which did include private lands, but not urbanized areas) in 1994. In addition, the Hawaii Water Resources Regional Study of 1975 provided a thorough assessment of the benefits, threats and trends affecting Hawaii's water resources with a considerable emphasis on the role of our forests in sustaining water quality and quantity.

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 Hawaii” in 1962, “A Plan for the State Forest Lands of Hawaii” in 1975, and the “Hawaii 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 (See Figure 3). This hot spot pushes lava upwards from deep with in the earth’s crust and over time forms a mountain which 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 1. Hawaii is the most isolated archipelago in the world. Image courtesy of Google Earth.

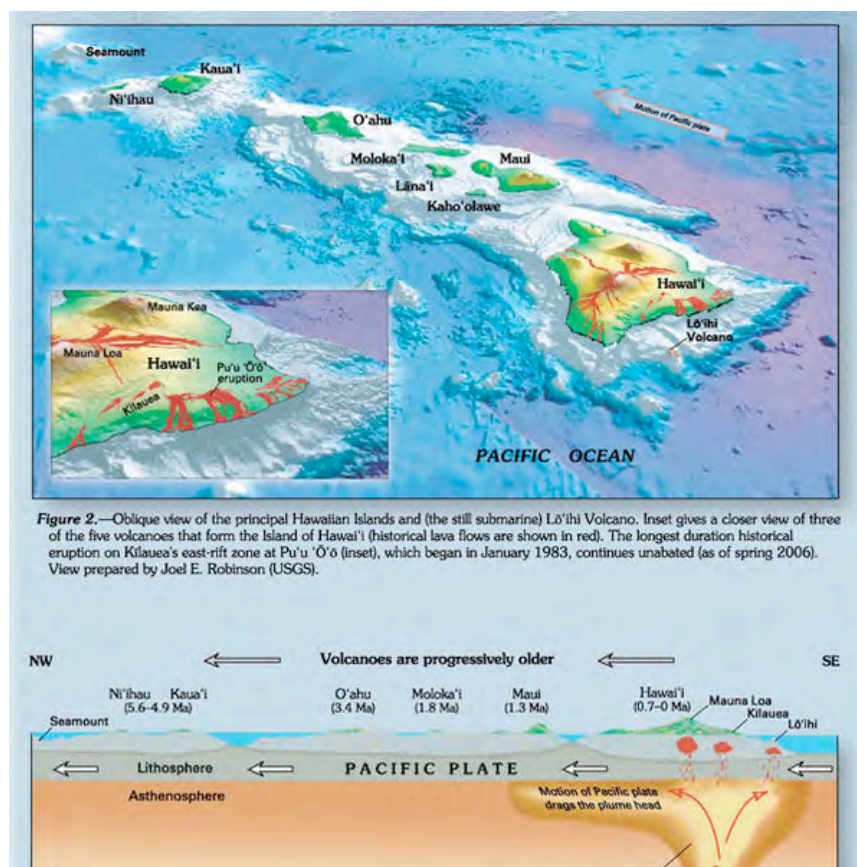


Figure 2.—Oblique view of the principal Hawaiian Islands and (the still submarine) Lō'ihi Volcano. Inset gives a closer view of three of the five volcanoes that form the island of Hawai'i (historical lava flows are shown in red). The longest duration historical eruption on Kilauea's east-ribs zone at Pu'u 'Ō'ō (inset), which began in January 1983, continues unabated (as of spring 2006). View prepared by Joel E. Robinson (USGS).

The process of creating new land from lava continues to this day. Kilauea volcano in Hawaii Volcanoes National Park has been continually erupting since 1983. Visitors to Kilauea are treated to a rare spectacle of molten lava pouring into the ocean. Kilauea lies on the eastern flank of another volcano, Mauna Loa, which rises to over 13,000 ft above sea level. When measured from the sea floor to the summit, Mauna Loa is the tallest mountain on the planet.

### The High Islands

Those islands that have not been eroded down to sea

Figure 3. The Hawaii Hotspot. Image courtesy of the U.S. Geological Survey.



level are known as “high islands”. The Main Hawaiian Islands which sustain permanent 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” of Hawaii is the youngest island in the archipelago. Mauna Loa, or “Long Mountain” on the Island of Hawaii is the highest island in the state and rises gently from sea level to 13,680 ft. The island of Hawaii has rich, young volcanic soils, and many portions of the island are still so porous that they do not support perennial streams.



Figure 2. Hawaii’s tallest mountain is Mauna Loa is often covered in snow from November to February.

At the western end of the high islands lies Kauai; the oldest of these high islands. Kauai has highly weathered and compacted soils, it supports many perennial streams and its highest peak is only 5,148 ft.

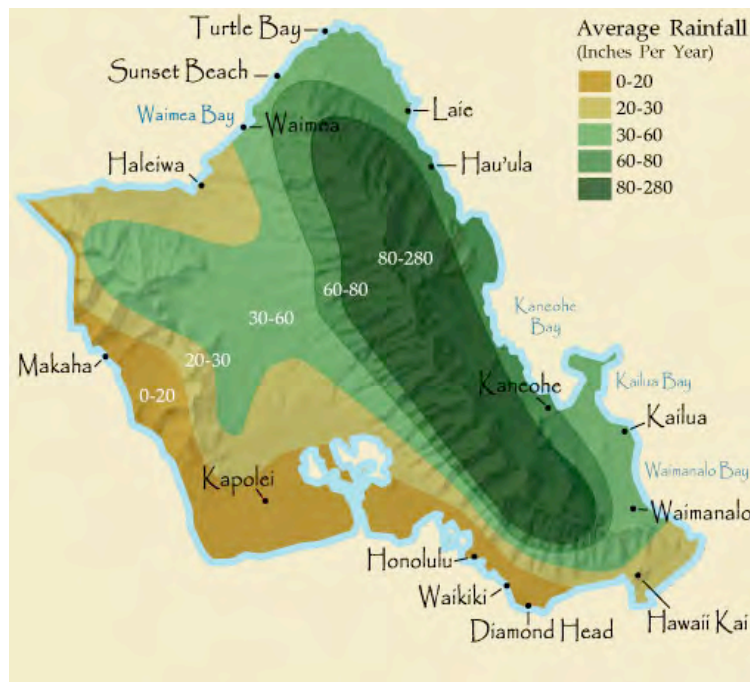


Figure 4. Average Rainfall on the Island of Oahu clearly shows wet “windward” side and dry “leeward” side found on all of the islands. Image courtesy of Chris Spears.

High islands also produce a precious commodity; water. As the tradewinds 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 portion of all of Hawaii’s high islands, known as the “windward side,” are wet and support rainforests and cloudforests.

As the winds cross the ridges, they have lost most of their moisture, and so little rain falls. The dry southwest portion of each island is known as

***"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.

the “leeward side”, or in Hawaiian, the *kona* side of the island. The forests of the *kona* side of the islands are very different from those found on the windward side. These dry forests grow more slowly and are more prone to wildfire. This difference is clearly shown in Figure 4.

For this reason, Ralph Hosmer, Hawaii’s first forester identified two types of forest in Hawaii: “protection forests”, defined as those on the wet windward slopes from which the most important product of which 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 Hawaii is no exception. The Puuwaawaa 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



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 5. The U.S. Mainland with the State of Hawaii overlaid.

Once a high island has eroded to sea level, all that remains is the live coral reef that once ringed the high islands. Corals require sunlight for their survival, and grow at the rate of approximately 1 cm 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 Hawaii includes these coral atolls, which are referred to as the Northwestern Hawaiian Islands. These atolls are not capable of sustaining permanent human populations because they do not have the ability to capture rainwater as the Main Hawaiian Islands do. Nevertheless, they are rich in marine life, and support 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 one of the largest marine conservation areas in the world. It encompasses 139,797 square miles of the Pacific Ocean (105,564 square nautical miles) - an area larger than all the country's national parks combined. (See Figure 5.)

### The First Hawaiians and The *Ahupuaa* System

Hawaii 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 close bond between the first people to populate these islands, the native Hawaiians. They developed a unique land stewardship system, called the *ahupuaa* system. In the *ahupuaa* system the land was managed a series of nested units. The most fundamental of these was the *ahupuaa*, which generally followed geographical watershed boundaries (Figure 6). The *ahupuaa* 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.

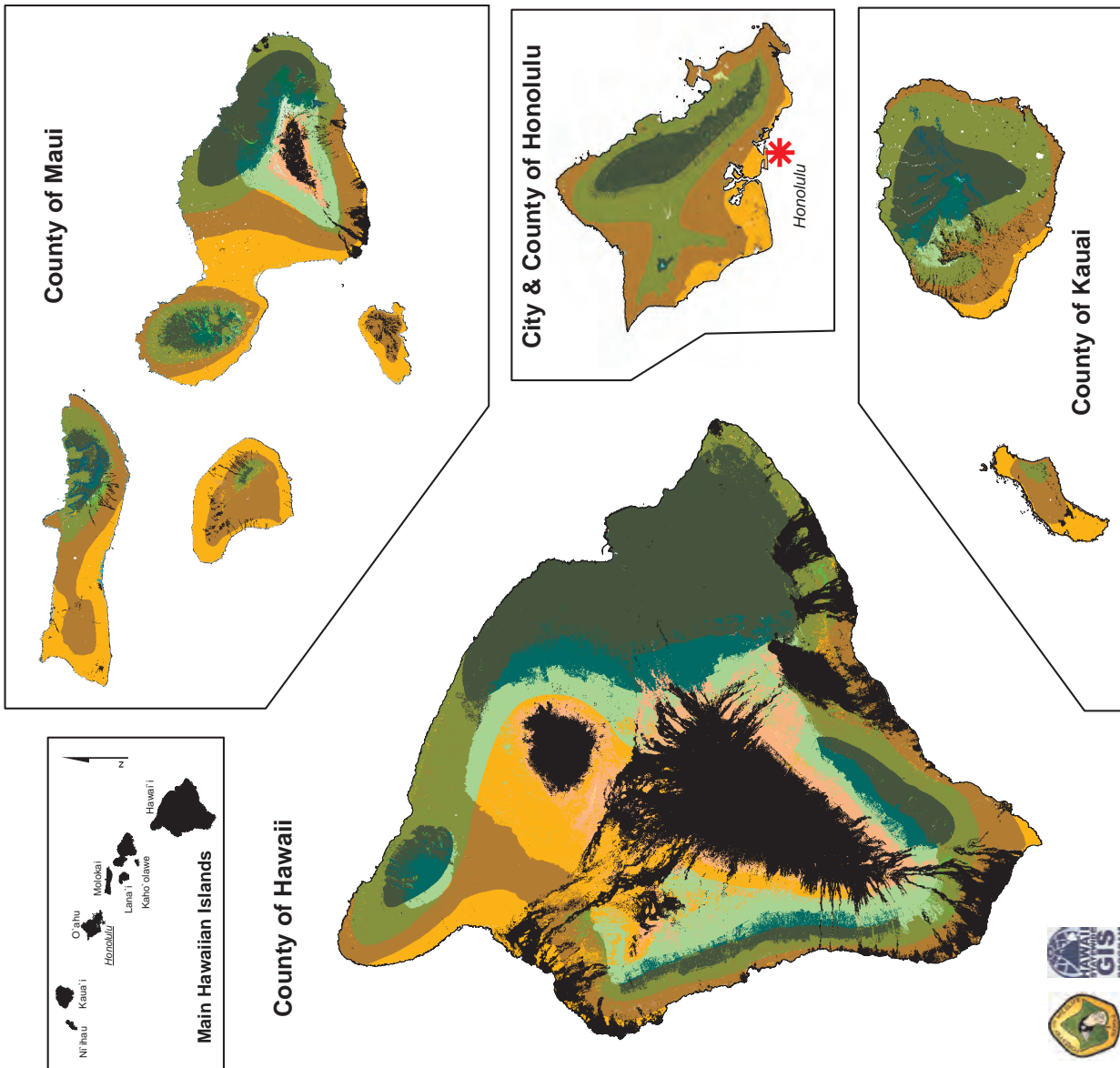
In 1778 the legendary explorer Captain James Cook happened upon the Hawaiian archipelago on



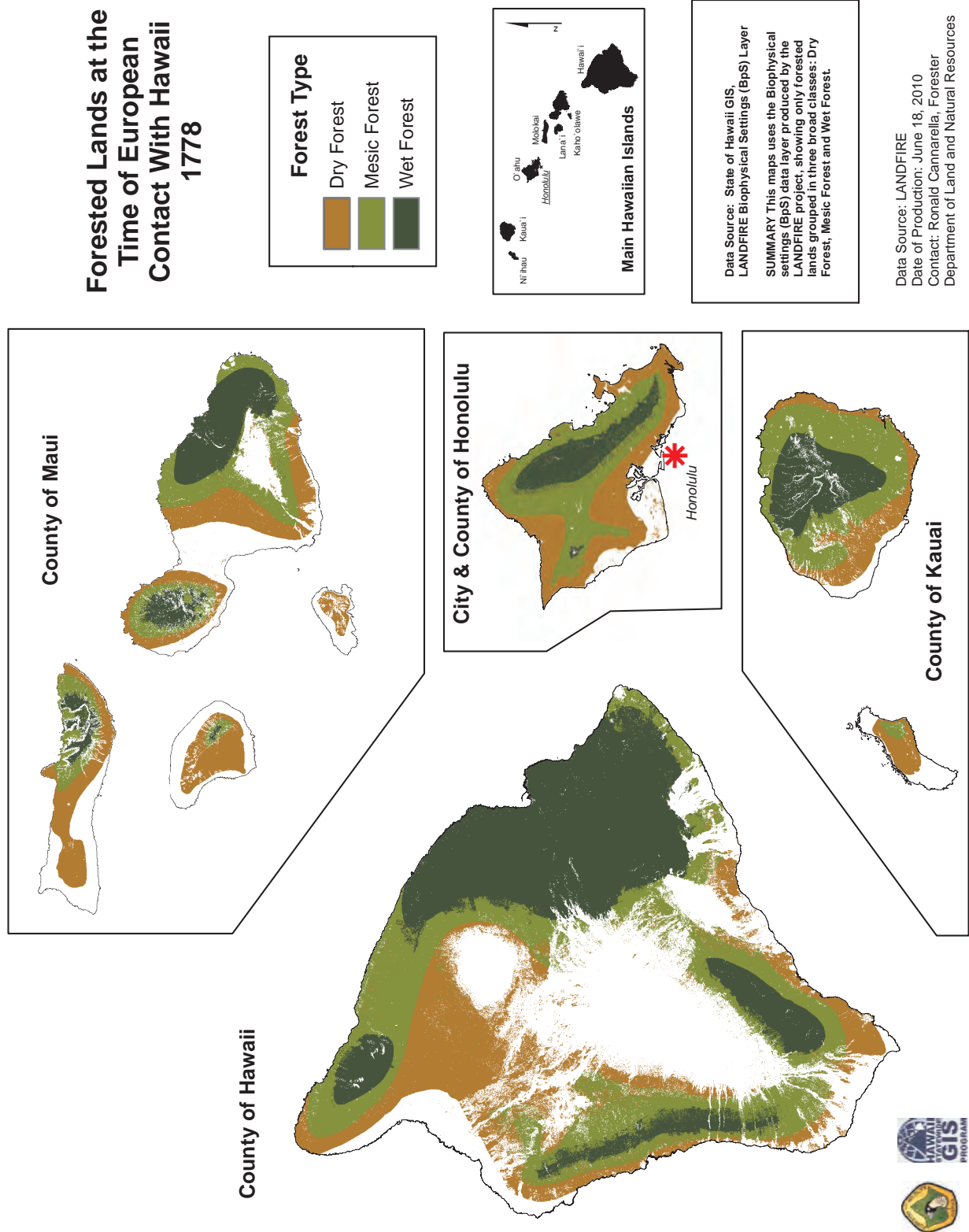
Figure 6. Organization of a Traditional Hawaiian ahupuaa.



# Landcover at the Time of European Contact With Hawaii 1778



Map A.3. Landcover at the time of first contact between Europeans and native Hawaiians.



Map A.4. Showing only the forested lands at the time of first contact between Europeans and native Hawaiians.



his third voyager of discovery. In Hawaii he encountered a large and thriving population and a healthy functioning ecosystem. See Map A.3 for a map of landcover at the time of European Contact and Map A.4 depicting only the forested lands at that time.

In the years that followed, change came swiftly to Hawaii 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.

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

Soon thereafter, Christian missionaries, whalers and entrepreneurs, mostly from the United States brought new ideas of religion and land tenure. Within two generations, in 1831 Queen Kaahumanu 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 *ahupuaa* 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 United States in a process known as the Great Mahele. The Great Mahele divided all lands into one of three classes; privately owned fee simple, lands reserved for the government and lands reserved for the Crown.

The consequences of the Great Mahele 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 American 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 Hawaii continued to

***"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. Nahoia Lucas, "No Ke Oia Pono o Ka Lahui Hawaii" Huihui: Multidisciplinary Research on Hawaiian Well-being, Kamehameha Schools.

deteriorate due to the ever-increasing number of feral animals pushing further 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 1800's the economy of the Kingdom was faltering, and the large colonial powers of the era, England, Spain, France and the United States all had their sights on Hawaii and its most coveted asset: the deepwater 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 war ship anchored in Honolulu harbor. In that moment the Kingdom of Hawaii was abolished and Queen Liliuokalani, last reigning monarch of the Kingdom of Hawaii 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, preserve their culture, and survive as a people.

In 1900, the United States officially annexed the Hawaiian Islands as the Territory of Hawaii. All government lands and crown lands from the Great Mahele, collectively referred to as the Ceded Lands, were transferred to the United States, 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 Hawaii Legislature and in Congress. Ironically, the native Hawaiian people are still not officially recognized by the Federal Government. This stands in stark contrast to the official relationship that the Federal Government has with all remaining Native American tribes in the other 49 states. This issue is still unresolved, but like so many other challenges that native Hawaiians have faced, this issue too will one day be resolved.

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

### **The Water Crisis of 1875 and Hawaii'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 Nuuanu Valley. The requirements of supplying whaling ships caused a waterfront storage tank to be installed at the lower end of Nuuanu Street. The water for that tank came from a taro patch on Emma Street. The demand for drinking water from various springs and the Nuuanu 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”<sup>3</sup>

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 the occurrence of artesian (well) water was just being discovered on Oahu. 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 Oahu. 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. The USDA dispatched E.M. Griffith, a forester with the USDA Bureau of Forestry to assess the condition and trends of Hawaii’s forests, and to recommend a long-term strategy for addressing the threats to the forests.<sup>4</sup> Mr. Griffith completed his assessment and recommendations in 1902. His findings and recommendations are included here in its entirety in order to provide us with a reference point documenting conditions and trends at that time, and to help us evaluate the effectiveness of his strategy.

## **GENERAL DESCRIPTION OF THE HAWAIIAN FORESTS 1902**

A Report of U.S. Forester E.M. Griffith on Hawaiian Forests  
Presented at Yokohama, Japan, on March 5, 1902

Note: This following was copied in its entirety in July 1991 from a manuscript hanging (framed) in the main office of the Division of Forestry and Wildlife,

Department of Land and Natural Resources. Typographical adjustments were made mainly to the title and opening portion of the manuscript for cosmetic purposes. It is assumed that the manuscript was a talk given by Griffith in Japan in 1902. It seems that it was made up of excerpts from a letter to Dole written by Griffith. Note also that a discussion of Kauai's conditions is missing.

His Excellency, Governor Dole  
Honolulu, Hawaii

Dear Sir

I have the honor to forward herewith my report upon the condition of the Hawaiian Islands for your consideration. During the course of my preliminary examination, I visited the Islands of Oahu, Maui, Hawaii and Molokai, and paid particular attention to investigating the rapid destruction of the forests. I feel perfectly satisfied that the indiscriminate ranging of cattle in the forests have been very largely responsible for the present conditions, and that the sure remedy will be to fence off the forests and confine the cattle to the lower slopes.

Very respectfully, /s/  
E.M. Griffith Assistant Forester  
Bureau of Forestry, U.S. Department of Agriculture

Formerly, the Hawaiian Islands were covered with dense and almost impenetrable forests which covered the steep ridges and deep canyons extending down to the narrow strip of arable land along the coasts and up to an elevation of 8,000 to 9,000 feet on the highest mountains. Ever-running streams and springs occurred on all the islands and the rainfall was fairly even and much heavier than it is today.

The old chiefs began the destruction of the forests by cutting enormous quantities of sandalwood but the blanks were soon filled up by other forest trees. The rapidity with which the native Hawaiian forest can be absolutely destroyed is truly remarkable and peculiar to the islands.

Dense forests which were absolutely impassable have, within the short space of five to ten years, been completely wiped out, so that at the present time, the soil is covered with a thick matting of grass. This comes from the fact that all the natives trees have a very shallow root system so that the least drying up of the soil immediately affects their vitality.

In nearly all sections of the islands, the undergrowth is composed largely of a dense mass of ferns which absorbs a very large amount of moisture thus affording a most favorable protection to the soil.



Stock, particularly cattle, are responsible for the destruction of the forests in as much as they eat and trample down the ferns and other undergrowth, thus allowing the soil to become dry and often hardened under the full force of the hot tropical sun so that the roots begin to dry up and the trees naturally die. The worst feature, however, is that as soon as the undergrowth is killed out, the heavy Hilo grass immediately covers the soil and forms such a thick mat that it is impossible for seed to reach the soil and germinate. Then the life of the forest simply depends on how long the old trees can survive, for as soon as they fall the space which they occupied in the forest is taken possession of by the grasses.

Stock also destroy many trees by stripping off the bark and by injuring the roots which they have already exposed by trampling. Another very bad feature of pasturing stock in the forests is that they eat and trample down the young trees.

In a virgin forest where no stock have been allowed to graze, with very few exceptions, the only trees which are dying are those which would naturally do so from old age. The virgin Hawaiian forest is healthy, but where stock have destroyed the undergrowth the trees are dying in great numbers and are found to be attacked by insects particularly borers and the large girdling worms.

Insects can readily be collected by breaking off the limb of a tree or injuring it in some other way. The forests which are being attacked by insects are those whose vitality has been affected in some other way, usually by stock grazing. After investigating the matter very carefully I should say that stock are alone responsible for the rapid destruction of the forests. This is readily admitted by those who have studied the matter carefully and from an unprejudiced point of view; so that it seems essentially wrong that the welfare of the whole islands should be sacrificed to benefit the cattle business which forms such a small part of the commercial prosperity of the islands.

With a few exceptions the forests are only valuable in conserving the water supply and increasing the rainfall. Koa and algaroba are the only two species which occur in sufficient quantities to be of any considerable commercial importance.

Koa is a high grade cabinet wood with a very handsome grain and capable of a high polish while the algaroba furnishes the bulk of the firewood for the islands.

The algaroba grows very well at low elevations, particularly on the leeward side of Oahu and it would pay the government to plant it on

rocky or denuded areas which are unsuited to any form of agriculture.

The chief characteristic of the native species is their small size averaging only fifteen to twenty inches in diameter and thirty to 40 feet in height, together with the short length of clear bole. As a rule the side branches extend low down on the trunk which is accounted for from the fact that the trees have grown up in open stands.

Ohia occurs far more frequently than any other species and together with kukui, koa, mamane and hala forms the bulk of the forest, while the undergrowth is composed very largely of ferns.

As the forest of the Hawaiian Islands contain such a very limited amount of merchantable timber, the question of the best methods of lumbering does not enter into consideration; the whole problem is conserving the water supply which depends upon the preservation of the existing forests and restocking some of the denuded slopes either by natural reproduction or planting.

During the course of my preliminary examination the forest areas on the islands of Oahu, Maui, Hawaii and Molokai were examined, particular attention being paid to the condition of the forests along the headwaters of all streams.

Forest protection means not only increasing the rainfall but--more important still--conserving the water supply. Upon the right solution of this problem depends to a very large extent the future welfare and agricultural prosperity of the Hawaiian Islands. Sugar, the backbone of the islands, comprising over 80% of the exports, is absolutely dependent upon a plentiful and constant supply of water. The planter who does not depend upon the natural rainfall but irrigates his cane is apt to think that forest protection does not directly affect his business; but in reality he should be far more solicitous about the preservation of the forest than the planter who depends on the rainfall, for whether he is taking his water from a stream or an artesian well his supply will be very quickly affected by any disturbance of the forest cover along the important watersheds. Particularly is this the case where water is being taken from a stream whose headwaters lie within the forest belt, which is the case with most of the streams on the islands.

Fluming cane is by far the cheapest means of transportation, for this reason to many plantations it is of vital necessity that their supply of water be at least held constant and increased if possible. The stockman or farmer and those engaged in growing rice or taro are

also dependent, though not to the same extent as the sugarcane planter, upon a water supply which shall be fairly constant through all seasons of the year.

As previously stated, the denudation of the Hawaiian forests has been brought about to a very large extent by the practice of pasturing stock in the forests. Certainly this has been admitted by those who have studied the question and it is believed that fencing and the absolute exclusion of all stock is the only sure remedy. There is no necessity for abandoning the cattle business in order to protect the forests, but the cattle must be confined to the lower slopes.

It is especially important that fences should be built along the upper limits of the forest in order to prevent the wild cattle, sheep and goats which at present are ranging on the higher grass slopes from working down into the forests.

Wherever fences have already been built, the reclamation of the forests is as surprisingly rapid as their destruction when stock are allowed to range freely. As previously stated, the first effort should be to fence and protect those forests along the headwaters of all the important streams.

In order to place the work upon a thoroughly efficient basis, it will be necessary for the government, planter, ranchers and all others owning or leasing land upon which water is the chief consideration to cooperate and see to it that the forests are thoroughly protected.

**A. Hawaii (the island).** During the three weeks which were spent in the examination of Hawaii, I was enabled through the courtesy of the plantation and ranch managers throughout the island to visit all the districts and obtain a general idea of the conditions of the forests and what was being done to preserve them. In treating the forest problems of this island, the various districts will be considered in their order commencing with Hamakua.

**A1. Hamakua.** This district extends from the northern slope of Mauna Loa, north to the sea and includes the greater portion of Mauna Kea which rises to an elevation 13,805 feet.

During the summer of 1901, a considerable portion of the forest lying between Mauna Kea and the coast on the north was burned over very severely. There is very little question but that most of the trees in this section are so badly burned that they will die and blow down, thus furnishing fuel for succeeding forest fires. The undergrowth had been destroyed by cattle so that the fire had swept; in fact, if this

had been a virgin forest with a rank undergrowth it would probably have been impossible to set it on fire. The forest had been so opened up by cattle that it died out thoroughly as is proved by the almost complete destruction of the humus so that the bare soil is now exposed. This latter result would be extremely favorable to the natural restocking of this burned area by self-sown seed but, very unfortunately, cattle are grazing in the forest and will destroy any young growth which may come up.

Within the present generation, forest fires have been almost unknown in the Hawaiian Islands but the indiscriminate pasturing of cattle in the forests makes their destruction by fire not only possible but extremely probable either through malice or carelessness in burning brush, cane trash or by camping parties.

A large part of the burned forest is on government land which has been leased until 1906, but it is extremely important that the government should induce the lessee, by an extension of time on his cane land lease or in some other way, to absolutely exclude cattle from this forest and protect it by fencing.

The forests in the remainder of the northern portion of the district of Hamakua are being rapidly destroyed by cattle, both wild and tame, so that the whole section within a few years will be a continuation of the Waimea plains unless adequate means are taken to protect the forests from cattle.

The wild cattle, sheep and pigs should be driven down from the mountains and the forests preserved by fencing.

On the north slopes of Mauna Kea, the mamane forest is spreading itself rapidly and appears to be holding out against the cattle, which is truly remarkable inasmuch as it is the only case of the kind which was seen anywhere on the islands. The mamane is a tough mountain tree and it is believed that it could be used to good advantage in restocking denuded slopes.

Between Mauna Kea and Mauna Loa the extensive plain or table land is covered with a rather broken growth of ohia, with scattering koa and mamane, while both mountain slopes are fairly heavily timbered.

On the whole the forests of Hamakua are in very poor condition and in some section fast disappearing solely on account of cattle grazing and the consequent forest fire.



**A2. North Kohala.** The Kohala mountains which extend northwest and southeast through the district were formerly covered with very dense forests which were practically impassable except by cutting trail with cane knives. Cattle, however, have absolutely destroyed all the forests on the lower slopes and are rapidly denuding the forests on the higher slopes. In order to save any of the remaining forests, they should be fenced off and protected as soon as possible. On the lower slopes which have been absolutely denuded, artificial restoration will be necessary.

Some of the planters in this district have fenced their forests, but concerted action on the part of the government, planters and ranchers will be necessary in order to save the water supply.

**A3. South Kohala.** The Kohala mountains extend along the northern portion of this district, but here too the forests have been very badly damaged by the cattle. The central and southern portion include the Waimea plains and the open grazing country west of Mauna Kea. On all sides of Waimea the country is a rolling plain which is unquestionably suited to agriculture and should not be covered with forests. But this fine agricultural land will be almost useless unless a constant water supply is assured and this can only be accomplished by carefully protecting the forests on the Kohala mountains, particularly north of the village of Waimea.

At present, cattle are being run on this range and it is possible to ride through a large portion of the forest which a few years ago was impassable. Here, as elsewhere, there is no necessity for abandoning the cattle business but it should be carried on with much more system, with paddocks or an open range on the plains and the mountain forests protected from all grazing.

**A4. Kona.** This district is covered to a very large extent with lava flows a very restricted area of land suitable for any form of agriculture and nor running streams of any importance. Here the need of protecting the forests is not so pressing as in many parts of the island, as there are no headwaters of streams to be protected and the chief value of a large area of forest land will be to increase the rainfall and maintain an equable climate.

Here lava flows are gradually being covered with a forest growth composed chiefly of ferns and ohia which assist greatly in the rapid disintegration of the lava and the formation of a fairly rich soil. Such tracts are naturally suited to forest growth and as they are not, at present, capable of producing any more valuable crop, they should be

used as forest reserves. Cattle grazing on such lands does not yield sufficient returns to justify the destruction of the young forests.

On all parts of the island, the heaviest rains occur within the forests on the higher slopes of the mountains. Hence it is extremely important that the forest growth should be encouraged on Hualalai and the existing forest protected.

The combined area of the rocky slopes and the lava flows is considerable and the territorial government should see to it that these sections are kept under forests as they are almost worthless for any other purpose. Provided such a definite policy is adopted, it would be entirely safe to permit the clearing of all forest land for agriculture within the district.

**A5. Kau.** Formerly this was considered the driest district on the island of Hawaii, but since the plantations and ranches have commenced to preserve the forests by means of fencing out the cattle, the rainfall has increased materially.

Great credit is due the gentlemen who have been so far-sighted and liberal thus preserving a magnificent stretch of forest. Over 31 miles of protection fence have been built on the slopes of Mauna Loa back of the Pahala plantation and ranch, and within five years, since the fence has been constructed, the young growth, composed for the most part of ferns and ohia, has come up in such dense masses that it is almost impassable and the land is rapidly regaining its marshy character. This very satisfactory reclamation of a large forest belt which had been severely thinned out by both wild and tame cattle within a few years speaks for itself and points out the way both for the government, corporations and private owners who are all vitally interested in preserving the water supply.

Within this district, also notably, in the vicinity of the crater of Kilauea, are large tracts of land covered with lava and upon which the young forest growth which is struggling to gain a foothold and make soil should be absolutely protected. The growth of all species which are easily self-sown, particularly the pines, should be encouraged. This is especially true on the mountain slopes and higher elevations where it is important to conserve the heavy rainfall which, at present, is very largely lost through the rapid evaporation on soil which is exposed to the full force of the sun's rays.

**A6. Puna.** Puna is called the tropical district of the island and contains the truly magnificent forests of Olaa which are composed

very largely of tree ferns which are composed very largely of tree ferns which grow to a height of from 30 to 40 feet with a mass of smaller ferns as an undergrowth. In this connection the fact should be emphasized that a dense of ferns conserves the water more completely and gives it off more gradually than a more open forest of native trees. The ferns act as a sponge, absorbing an enormous amount of moisture and giving it off very gradually, especially if the ferns are in dense shade from an overhead or second-storied forest of trees.

Puna has a vast forest area and while large tracts are being cleared for sugar and homesteads, yet it is probable that there will be no diminution of the rainfall or water supply for fluming or irrigating provided the upper slopes of the forest are protected.

**A7. Hilo.** This district contains nearly all the running streams on the island of Hawaii and it is therefore more important to protect the forests on the headwaters of these streams than in nearly all other section combined. Most of these streams come from underground water which rises to the surface at a comparatively low elevation and are used extensively for fluming cane along the line of plantations which extend from Hilo to Hamakua. The loss or decrease in flow of these streams would be a severe blow to the plantations as they depend on fluming almost exclusively for the transportation of their cane to the mill. Above the plantations, the extensive forest covered slopes of Mauna Kea produce a very heavy rainfall which seeps through the aa flows and is carried to the lower levels by the more or less solid pahoehoe.

The lower edge of the forest is protected by the cane lands but wild and tame cattle, sheep and goats are killing the forest along the upper slopes and so gradually narrowing the forest belt. The rains which fall on the higher grass covered slopes and which is not lost by evaporation runs off very rapidly thus causing the small streams to overflow their banks after a very heavy rain without conserving any of it for the drier season when it is most needed.

Nearly all of this government land has been leased for a long term of years and the plantations in order to protect the headwaters of the streams must fence along the upper forest slopes and drive out or kill the stock which remains below the fence.

The government should assist the plantations in every possible way to protect the forests and incorporate in all future leases a provision that all important forest areas shall either be fenced by the lessee or all cattle absolutely excluded.

**B. Maui.** The forests on the island of Maui, upon the whole, are in a fairly satisfactory condition although in certain sections they are disappearing very rapidly. Nearly all the sugar plantations and the bulk of the arable land lies between Wailuku and Honomanu and here the forests have been seriously injured by stock grazing.

The sugar planters and farmers in this locality all depend upon irrigation, the water being taken from small streams which for the most part rise on the slopes of Haleakala. For many years, cattle were allowed an unrestricted range in the forests along the headwaters of these streams so that in many sections the forest is either dead or dying.

The almost total destruction of the undergrowth has allowed the soil to bake and harden thus causing the rainfall to run off rapidly with the resultant effect of very low water during the dry season. The Haiku and Spreckelsville ditches have prevented stock from ranging in the upper forests and so have formed a protection belt from Haiku to Honomanu. Along the line of the Haiku ditch the almost total destruction of the forests by stock is clearly shown; for whereas the forests on the upper side of the ditch, which have been protected, are very dense and healthy, those on the lower side, which have been open to grazing, are either almost destroyed or in a very unhealthy condition.

The district of Kula is also a striking example and, in order to save the little remaining forest, the cattle must be absolutely excluded. It is far easier and a much better policy to save the existing forests than to certainly destroy them by grazing and attempt to realize by planting a forest in some other locality.

Planting is extremely expensive, especially if the trees are set out very close together as must be done if a dense forest is to be secured which will act as a sponge and hold the water supply. Then too, a small amount of planting here and there does very little good and such expensive work will seldom be necessary in the islands if a common sense forest policy is pursued.

The government owns some very important forests areas on Maui along the headwaters of the streams and the upper slopes of the mountains which should be segregated and set aside as forest reserves. It will probably be advisable to build fences and necessary to determine which lands are suitable for agriculture and those which should always be kept under timber.



The forests in the Iao valley are very well protected and consequently show no signs of deterioration while the streams are maintained with a fairly even flow. The forests in the remainder of the district of Lahaina show very plainly the effect of grazing and must be much more carefully looked after in order to conserve the all important water supply.

The whole question on the island of Maui is protecting the existing forests; it is of the most vital importance to the plantations that these should be done at once and thus save the very large expense of artificial planting.

**C. Molokai.** Cattle, goats and deer have totally destroyed the forests upon the larger portion of the island of Molokai so that the western half is practically destitute of any tree growth. It is possible that the algaroba forests which have secured such a strong hold along the coast near Kaunakakai may gradually spread over this end of the island. At present the soil is covered with a thin growth of grass which is apt to die down during the dry season thus allowing the top soil to cake and powder. Molokai is exposed to the full force of very heavy winds which are rapidly blowing most of this fine soil top soil off into the ocean. The algaroba will hold this soil, furnish splendid firewood and the bean pods make a very good feed for cattle during the dry season.

Planting in belts or strips is recommended on the western half of the island in order to form windbreaks and thus hold the shifting soils. The eastern half of the island including the entire Olokui section is by far the most important for here all the streams rise.

Cattle and deer, particularly the latter, have destroyed a large area of the forests but within late years their numbers have been greatly reduced by hunters who have been paid to shoot them.

The condition at present time is that the forest has been pushed back into the deeper and more inaccessible canyons and onto the highest slopes of the mountain. The effective watershed in respect to the conservation of the water supply has thus been greatly reduced and the careful protection of the remaining forests is an absolute necessity.

A small amount of fencing has already been done and the results are surprisingly satisfactory although the forests had been very badly denuded. The remaining fences should be constructed at once while there is still a small amount of undergrowth which will assist very materially in the rapid reclamation of the forests.

**D. Oahu.** Forest protection on Oahu is far more important than on any other island of the Hawaiian group on account of the large interests at stake and the great value of the water supply. Probably there is a greater daily consumption of water for irrigation purposes between Honolulu and Kahuku than on any equal area in the United States. The sugar plantations alone pump over 314 million gallons of water daily.

Both the Waianae and Koolau Mountain Ranges were formerly covered with a heavy forest growth extending down nearly to the shore line and in the center to the Waialua plains. But the indiscriminate ranging of cattle has resulted in the total destruction of all the undergrowth and trees on the lower slopes so that today the remaining forests are confined to the upper slopes and the more inaccessible canyons. Still the cattle continue to rapidly destroy the forest although in many cases the land and cattle owners are far more financially concerned in the welfare of the sugar plantations.

The water which is being pumped by the plantations to irrigate their cane is very largely that which falls within the forest belt on the higher slopes and gradually sinks to the artesian level. Consequently if the cattle and goats are allowed to destroy these forests, a considerable amount of water will be lost through largely increased evaporation on the exposed soil and the rapid run off.

There is a large amount of natural grazing land such as the Waialua plains and the lower slopes of the two ranges above the cane lands so that the necessary protection of the forest areas does not mean doing away with cattle business. There is also a large amount of fine agricultural land on the Waialua plains but these will be absolutely worthless unless the water supply is protected.

The reforestation of Tantalus by the Department of Agriculture and Forestry is an unusually fine piece of work very successfully carried out but it clearly demonstrates how difficult and expensive the reclamation of such land becomes when all the forest growth has been destroyed. It emphasizes the fact of how much easier it is to fence and protect the forests in time while a few trees remain to seed up the surrounding soil than it is to delay until artificial reforestation is necessary.

If the lower slopes of the forests on the Waianae and Koolau ranges are fenced off as soon as possible, the scattering trees will gradually reforest the slopes, the young koa, which at present is being eaten off and tramped by cattle, will come up and a small amount of planting of those areas which are absolutely denuded will be necessary. The



Figure 7. Nuuanu Valley in 1929. The hillsides were almost devoid of any trees. The bare patch of ground is the Oahu Country Club. Photo provided courtesy of Suzanne Case.

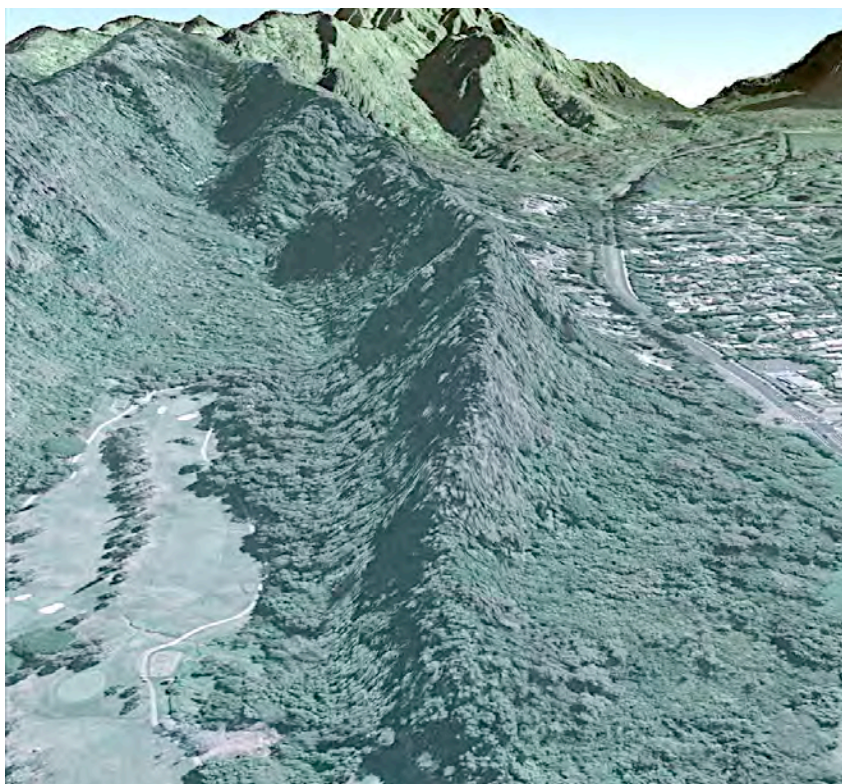


Figure 8. Nuuanu Valley today. Image courtesy of Google Earth.

fencing should have been done long ago and at present the reclamation of the forests will be very slow on account of the few seeds which remain and the mass of Hilo grass which has covered the soil and makes reproduction very difficult if not impossible.

So much of the government land on this island has been leased for a long term of years that the effective protection of the remaining forests depend upon the planters and other lessees will be benefitted. However, it is hoped that the government can assist in building the fences and they will appoint a ranger to patrol the forest lands not under lease and see to it that all cattle are excluded.

In future the forest areas on this island should never be leased for grazing purposes and the lessees of cane and agricultural lands should be obliged by the terms of their lease, to build stock fences and keep them in repair.

**I recommend that a Forest Force be organized. In order to thoroughly protect the forest areas and carry out the forest policy of the government, the organization of a field force is extremely important.** The following forest force which is similar to those in charge of the forest reserves in the United States is recommended, viz: A forest inspector who shall be a practical forester and have charge of all government forest land and direct the work of the forest rangers. Four forest rangers who shall have had some practical training in forestry, understand lumbering and tree planting, with rangers as follows: One on the island of Oahu; one on the island of Hawaii; one on the island of Kauai; one for the islands of Maui and Molokai.

Their duties should consist in patrolling all government forest land within their ranges and enforcing the terms of the lease, supervising the construction of all government fences, acting as fire wardens and taking charge of all the planting.

**If thoroughly competent men are appointed, such a force should prove wonderfully efficient in protecting and building up the forest reserves.**

~end~

### **Establishment of the Territorial Forest Reserve System**

Griffith's report was well received, and his recommended strategy was implemented. In 1904, Frank 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, Hawaii'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 Nuuanu Valley.

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 Hawaii attained Statehood. Tree propagation and planting were popular civic activities, and countless volunteers contributed to reforestation and protecting the Forest Reserves. That tradition continues to this day.

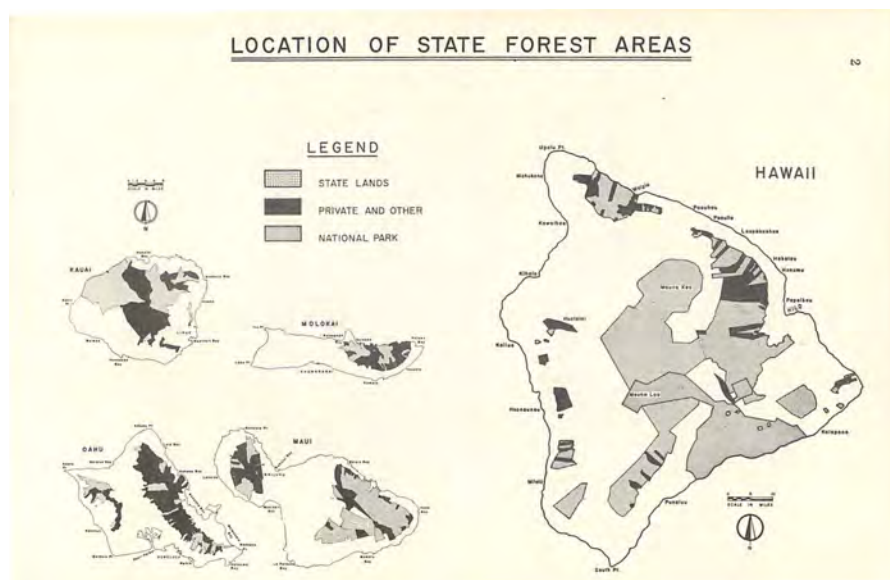


Figure 9. This map depicts the Territorial Forest Reserves immediately after statehood, but prior to the passage of the State Land Use Law in 1961.

During this same period the Boards of Water Supply on each island made it a policy to utilize 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"<sup>5</sup>. Today, nearly 100% of Hawaii's public water is withdrawn from wells. See Figure 10 and the following quote from the USGS regarding the importance of ground water in Hawaii.

"Ground water is one of Hawaii'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 Hawaii's domestic water and about



50 percent of all freshwater used in the State. Total ground water pumped in Hawaii 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 Hawaii. 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.”<sup>6</sup>

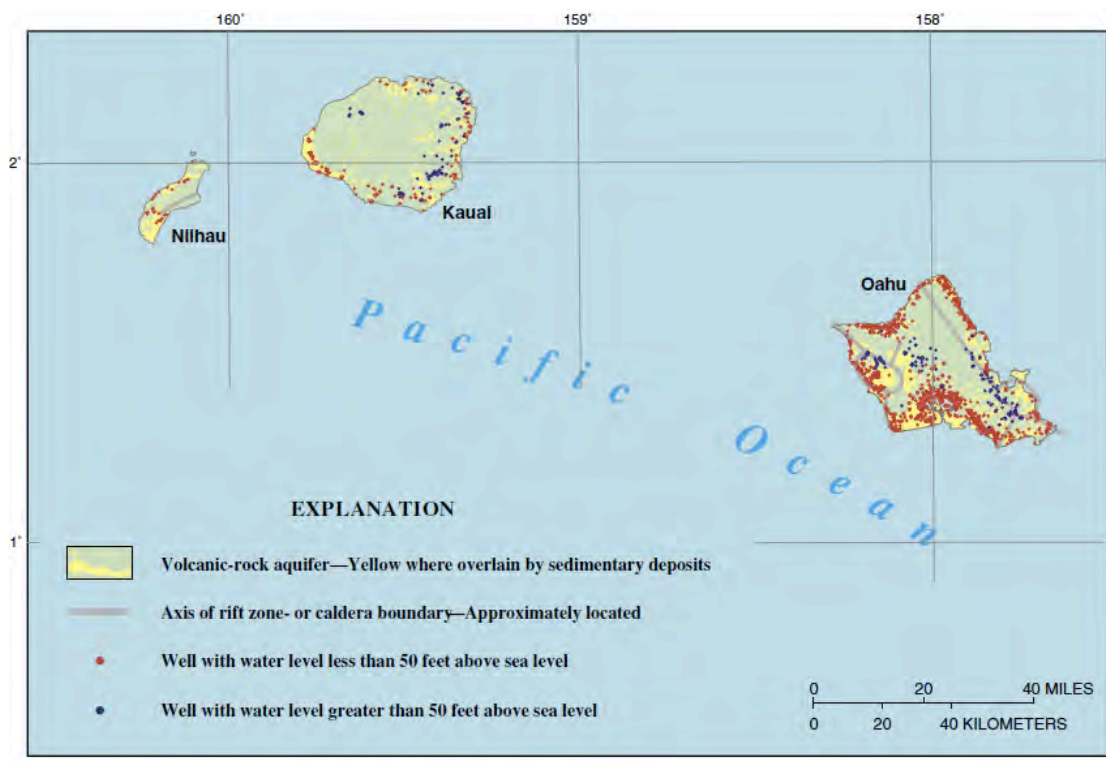


Figure 10. Location of artesian wells which are the source of water for the public water supplies for Niihau, Kauai and Oahu. Graphic courtesy of USGS.<sup>5</sup>

### One Problem Solved, New Threats Emerge

But in solving one major problem, how to reforest denuded slopes, that generation of foresters were unwittingly sowing the seeds of our greatest threat to Hawaii’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 plant in the field. From 1904 through the 1960's there was a thriving rivalry amongst forestry professionals on who could bring in the most number of exotic trees and ornamental plants. Many of these species are of great value to us today both in our urban areas and in our forests.

Horticulturalists and botanical gardens did likewise. Nearly every species they tried could grow somewhere in Hawaii's many ecozones. Even today, one can harvest peaches, walnuts, plums, and apples in a fruit tree grove on the island of Hawaii. Tulip poplar (*Liriodendron tulipifera*) thrives on the uplands of Maui, and provides shade for orchids (*Dendrobium spp.*). Our botanical gardens are filled with spectacular flowers and foliage plants which do not have to compete with the other plants, animals, insects and diseases which evolved along side them in their native habitats. Some of our most pernicious weeds, including *Miconia calvescens* escaped from botanical gardens.

Like the water crisis of the 1880's, 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 Hawaii" identified the values and threats provided by Hawaii's forests. That 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.<sup>7</sup> The threat from invasive plants, and the value of native biodiversity are not mentioned at all in the 1962 plan.

Since then, the rate of introduction for destructive new animals, 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, coral reefs. Shortly after the passage of the Endangered Species Act, Hawaii 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 our Issues sections.

### **Hawaii's Second Statewide Assessment and Resource Strategy: 1961 Hawaii State Land Use Law and the Establishment of the Conservation District**

Shortly after Hawaii became a state, the Hawaii Legislature passed the Hawaii 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 assure the protection our forested water recharge zones into 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.

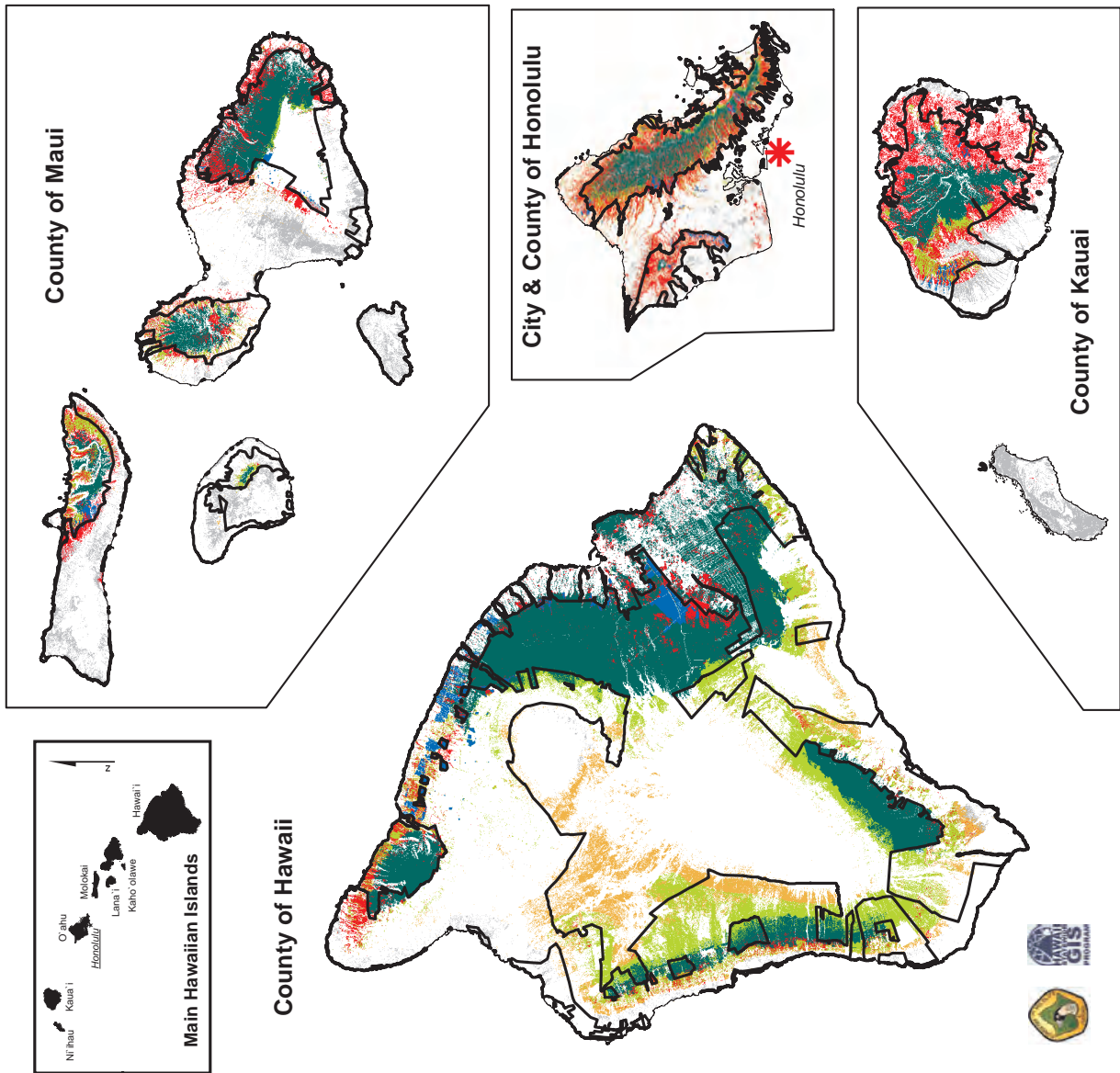
Once the Conservation District boundaries were established, the next District to be determined was the Urban District. The purpose of the Urban District was to direct urban growth to appropriate areas. This was significant for Hawaii since the state does not have a municipal level of government. Lands not assigned to the Conservation District or the Urban District were lumped 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 chose 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 Hawaii's sugar cane and pineapple industries in the 1990's 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 Oahu's "Second City" of Kapolei are of concern, since these lands will no longer be available for agriculture once developed. This issue is addressed in more depth in *Issue 4: Urban & Community Forestry* and *Issue 5: Climate Change/Sea Level Rise*.

### **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 the Department of Land and Natural Resources. If a landowner wishes to undertake any actions on lands in the Conservation District they must apply for a permit from the Department of Land and Natural Resources. Thus, the Conservation District is essentially Hawaii's Priority Landscape Area for conservation so as to ensure that those lands continue to provide vital ecosystem services into perpetuity. Map A.5 shows the current boundaries of the Conservation District. It clearly depicts 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. In one sense, a single mature *miconia* is like a melanoma, that if left untreated, has the capacity to spread at an exponential rate and completely overtake all other overstory tree species, native or non-native'.

# The Conservation District and Forested Areas of the Main Hawaiian Islands 2010



Map A.5: Lands in the Conservation District are permanently protected by state law to ensure that they continue to provide valuable ecosystem services into perpetuity. These lands are not at imminent risk from 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) was entrusted with management of the Forest Reserves, but had no jurisdiction over non-State lands that once comprised the Territorial Forest Reserve system. Federal and privately owned lands within the Conservation District were still subject to permitting requirements by the Department of Land and Natural Resources (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 United States and Asia, the rate of introduction of dangerous invasive plants, insects and disease increased significantly.

As awareness of environmental issues grew during the 1970's, the passage of Federal and State Endangered Species Acts focused energy and resources on saving individual species from extinction. Hawaii 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. The Division of Forestry and Wildlife established a new class of land managers specifically for the NARS. Although NARS and Forest Reserve System staff work side by side, their mandates differ. NARS staff focus primarily on conservation of biodiversity, and Forest Reserve staff focus on management of the Forest Reserve System under a multiple-use mandate.

Additional programs were created or transferred to DOFAW in the 1970's and 1980's. The regulation of hunting was transferred from the Division of Fish and Game to the Division of Forestry to create the Division of Forestry and Wildlife. 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, and 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 has been effectively managed. But at the same time, land management for our most precious resources of water, native species, and cultural resources, became incrementally fragmented and uncoordinated.



A similar scenario was evolving with Hawaii'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 use of motorized watercraft. Multiple state and federal agencies were charged with different mandates. At a national level, the same phenomenon was also taking place.

### **1990's; Hawaii's New Partnerships and Initiatives**

Approximately one 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 of 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. The authors of this document interact on a daily basis with these organizations. The organizations are:

#### **The Hawaii Conservation Alliance (HCA):**



**Hawai'i Conservation Alliance**  
*Leaders in Environmental Management, Research and Education*

The HCA is an alliance of 15 Federal, State, Hawaiian, and not for profit organizations engaged in the stewardship and conservation of Hawaii'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 their new Landscape Conservation Cooperative for the Pacific Islands region (PICCC) to address issues of climate change. Please see *Issue 6, Conservation of Native Biodiversity* and *Issue 5: Climate Change/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 Hawaii 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):** The HISC is the statewide coordinating organization for addressing the threat of newly introduced invasive species. Public and private agencies working on invasive species have founded to coordinate activities including the Coordinating

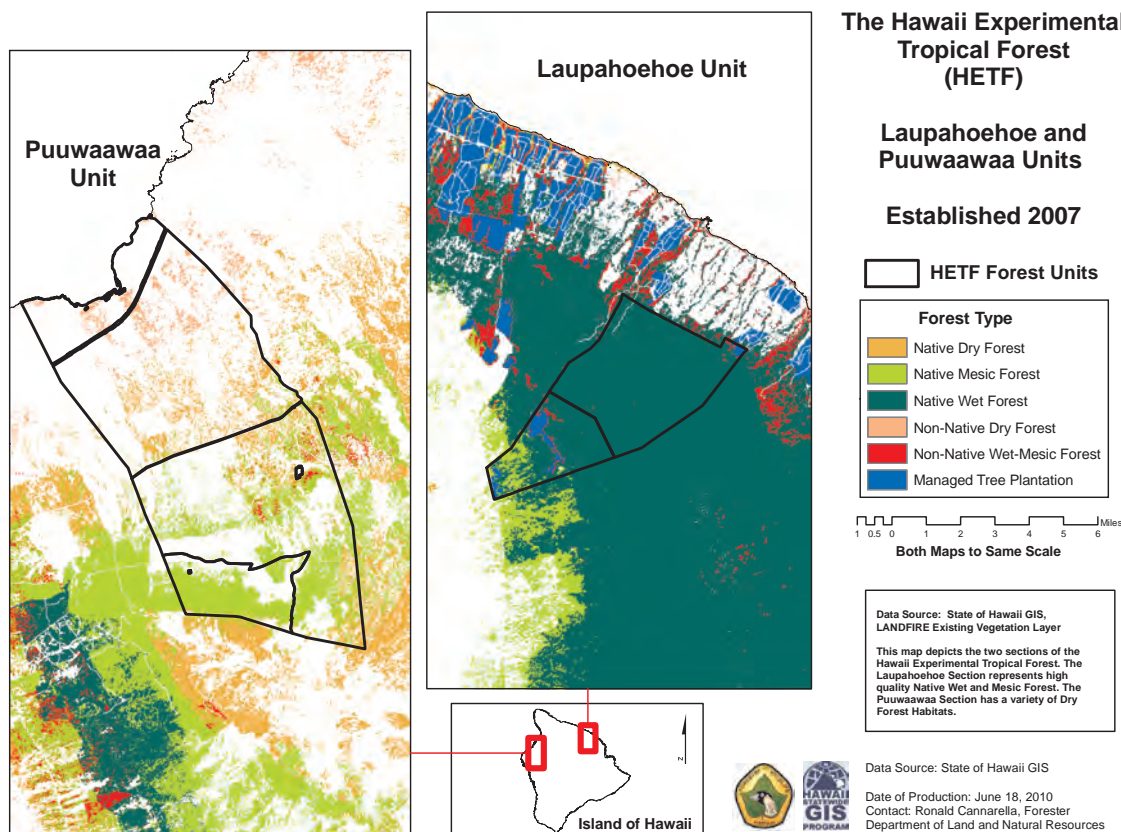


Group on Alien Pest Species (CGAPS), and the county-based invasive species committees ISC's). Like the HAWP, the HISC has been very effective at leveraging funding for the control of invasive species and for coordinating the activities of agencies working to protect Hawaii from dangerous invasive species that continue to arrive by air, sea and on the wind.

**The Ocean Resources Management Plan (ORMP) Working Group:** The Ocean Resources Management Plan (ORMP) was mandated by the Hawaii Legislature to provide a forum for coordinating the numerous agencies and organizations involved in the management and use of Hawaii's ocean resources. Like the HCA, the ORMP working group consists of representatives of many Federal, State, County and private organizations.



**The Hawaii Experimental Tropical Forest (HTEF):** The most recent comprehensive forest planning effort in Hawaii produced the Hawaii Tropical Forest Recovery Action Plan in 1994. One of the most significant outcomes of the action plan was the recognized need for an experimental forest in Hawaii 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 Hawaii Island and in 2007 The HETF is a cooperative partnership between the U.S. Forest Service's Institute of Tropical Island Forestry and the DLNR. See Map A.6 for the location and forest types represented



Map A.6: The Hawaii Experimental Tropical Forest.

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Section References

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<sup>1</sup> noun. Traditional native Hawaiian 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. Roughly analogous to the term "watershed".

<sup>2</sup> Hawaii Revised Statutes (HRS) Section 5-7.5, 1986

<sup>3</sup> Day, A. Grove (editor) (1966). "Mark Twain's Letters from Hawaii." Honolulu, University Press of Hawaii.

<sup>4</sup> For a detailed Timeline of Forestry in Hawaii refer to Appendix F.

<sup>5</sup> 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". P 65.

<sup>6</sup> USGS Hawaii District (2000) "Ground Water in Hawaii" Publication fs126-00.pdf. 6 pp.

<sup>7</sup> Staff of the Division of Forestry (1962). "A Multiple Use Program for the State Forest Lands of Hawaii.



### Lessons from History: What Could Have Been

On tropical islands healthy forests and functioning watersheds can only be maintained through sound policies and effective management as demonstrated in this image of the border between Haiti and the Dominican Republic. During the time of Napoleon, Haiti was the most profitable European colony in the world; it produced half of France's foreign revenue from sugar cane cultivated in Haiti's rich soils by slaves imported from Africa. In 1791 the slaves rebelled, and after a long and bloody revolution, all of the French fled the colony or were killed. Alarmed over the potential of the consequences of a successful slave rebellion, the U.S. imposed a trade embargo on Haiti, and the new country was left to fend for itself. With no unifying culture or tradition of land stewardship in their new environment, the Haitians had no effective government for centuries. Nevertheless, at the turn of the 20<sup>th</sup> century, Haiti still had 60% of its forests, but they were degrading rapidly due to overgrazing and harvesting wood for cooking.

The Dominican Republic, which shares the island of Hispaniola with Haiti, could see what was occurring and chose a different path to protect their forests. They banned logging, and subsidized gas stoves for cooking. The results of the differing approaches to land stewardship are evident in this image.



**"What's the point of rebuilding Port-au-Prince, or moving it south, if we don't reforest Haiti? Where are they going to get their water from? Where are they going to farm? It makes no sense to rebuild a country that won't have trees. . . That would be a largely cosmetic solution if it doesn't go hand-in-hand with other measures to make the country environmentally viable. Haiti needs trees — and natural-gas or solar ovens — just as much as bricks."** -Quote by Carlos Morales Troncoso, Foreign Minister of the Dominican Republic after returning from an international conference to kick off a 10-year plan for the reconstruction of Haiti after the devastating earthquake of January 12, 2010. Source: Andres Oppenheimer, The Miami Herald, Feb.4, 2010. Image courtesy of Google Earth.



## Issue 1: Water Quality & Quantity

*"In Hawaii, the most valuable product of the forest is water, rather than wood."*

Ralph S. Hosmer, First Territorial Forester

### Overview



Figure 1.1. Water is our most precious resource, and healthy forests are essential for maintaining water quality and quantity. Photocredit Chris Spears, Meteorologist; Waterfalls on Kauai.

Prior to the discovery of high “perched aquifers” in the late 1800’s all of the public water systems in Hawaii relied on surface water such as streams, springs and reservoirs for their source. The discovery of these groundwater sources came just in the nick of time. Between 1779 and the last half of 19<sup>th</sup> 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 into perpetuity. But the consequences of introducing these “feral ungulates” (hoofed grazing animals such as cattle, sheep, goats, deer and pigs living in the wild)



was disastrous for Hawaii's forests. By 1890 everyone was experiencing the secondary effects from the destruction of the forests; rivers and springs began to disappear in the dry season. 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 surface water to groundwater as their source. At the same time, the Forest Reserve System was established to protect and restore the upland forests which are vital for recharge of groundwater aquifers. In addition, fog drip and irrigation water not lost to runoff or evapotranspiration are critical components of Hawaiian watersheds' ability to retain rainwater. Fog condensation on trees high on forested mountains can increase rainfall collection and absorption by as much as thirty percent. Forests support infiltration of rainfall into the water table, where it percolates through permeable rock into groundwater aquifers formed by volcanic rocks.

Native Hawaiians recognized the important link between terrestrial and aquatic systems, and therefore designed land tenure systems within what is called "*ahupuaa*" - tracts of land capable of providing all that is needed to support the local families and populations living within. "Watershed" is the term used to describe the geographic area of land that drains water to a given destination such as a river or bay. This term is synonymous with *ahupuaa*, and includes not only the land from the mountains to the coast, but also the near shore marine 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." Hawaii's watersheds are rich in biological resources, unique ecosystems, and rare and endangered plant and animal species. Hawaii has 395 listed threatened and endangered species, the highest number in the nation. Of these species, 295 are plants.<sup>1</sup> These rare plants live in varied habitats—from windward coastal sea cliffs to montane bogs; and from remnant dry forest to some of the wettest forests on earth. Native animal species within the watersheds include endemic birds, hoary bats, snails, and arthropods. The many small streams that drain these systems are home to diverse native aquatic insects, fishes, crustaceans, and mollusks.

Hawaii'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, "*Haihai ka ua i ka ulu la au*" (The rain follows the forests). Native Hawaiians practiced wetland agriculture with taro in the fertile valleys, and other staple crops were intensively cultivated on many lower elevation windward slopes. On the leeward side of the islands, Native Hawaiians practiced dryland agriculture, in some cases transporting water for miles to crops in *auwai* (irrigation ditches or canals). Much later technological advances allowed for the development of complicated ditch & dam systems that even today support vast sugar and pineapple plantations.

Today, water quantity and quality remain critically important for all populations, and water is impacted significantly by human development and land use practices. Best management practices both in upland and coastal watersheds are needed to ensure groundwater recharge for drinking water, to protect habitat for threatened & endangered species, encourage native forest

carbon sequestration and support of 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, sediments and pollutants which negatively impact our near-shore areas. In addition, 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 zone ecosystems.

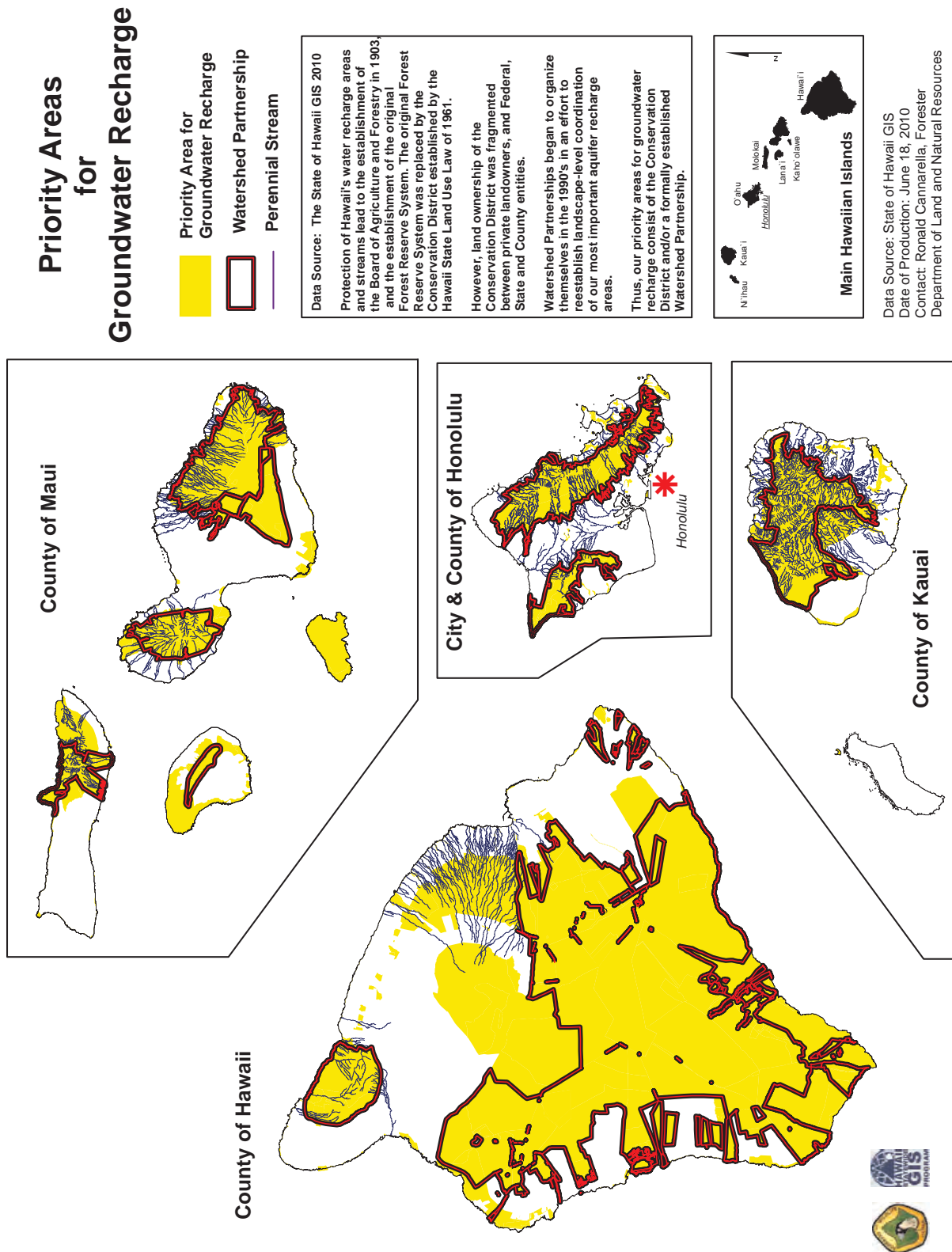
Thus, our upland forests, urban areas, our coastline and our near shore environment are all closely linked both spatially and culturally. This unique relationship was recognized when the Hawaii Coastal Zone Management (CZM) Program was established by the Hawaii legislature in 1977. In Hawaii, the CZM area encompasses all land in the state and not merely the “coastal zone” as it is interpreted on the U.S. Mainland. Because there is no point of land more than 30 miles from the ocean, a definite land-sea connection exists throughout the state. So, designating the entire state, up to the summit of our highest mountain Mauna Loa (13,679 ft), as the CZM area was logical. What occurs on land, even on the mountains, will impact and influence the quality of the coastal waters and marine resources. The CZM area also extends seaward to the limit of the State's police power and management authority, to include the territorial sea. This legal seaward boundary definition is consistent with Hawaii's historic claims over the Hawaiian archipelagic waters based on ancient transportation routes and submerged lands. (For more information on Hawaii's Coastal Zone Management Program visit their website at <http://hawaii.gov/dbedt/czm/program/program.php>).

In the course of doing this assessment, our Kaulunani Urban and Community Forestry Committee was presented with a similar challenge, to spatially define the urban areas that were appropriate for their program. Because Hawaii does not have a municipal level of government, our cities and towns do not have defined legal boundaries as they do on the U.S. Mainland. So after a great deal of collaborative work with our GIS team, they developed the Urban Realm concept. Beginning with the definition of “Urban Forests” as places where people work, play and live, it was decided that Hawaii's Urban Realm would extend beyond the coastline out into our nearshore waters (about as far out as a person can wade), and up into the mountains along hiking trails. This unorthodox approach to defining urban areas is consistent with the Hawaii CZM approach. It recognizes the direct linkage between all segments of our island geography, and recapitulates the concept of a 21<sup>st</sup> Century *ahupuaa*. (See Issue 4: Urban & Community Forestry for more detail on this topic.)

#### Priority Issues and Areas for Water Quality & Quantity

This Assessment and Strategy explicitly supports all existing approved plans and programs of our Federal, State, County and watershed partnerships. Our priority areas for groundwater recharge consist of all lands classified as the Conservation District by the Hawaii Land Use Law and/or any lands managed by a watershed partnership (Map 1.1).

In the process of developing this document we have begun to work closely with the Office of Planning and other local, state and federal partners through the Ocean Resources Management Plan Working Group in an effort to collaborate more effectively at a whole watershed, or



Map 1.1 Priority areas for groundwater recharge

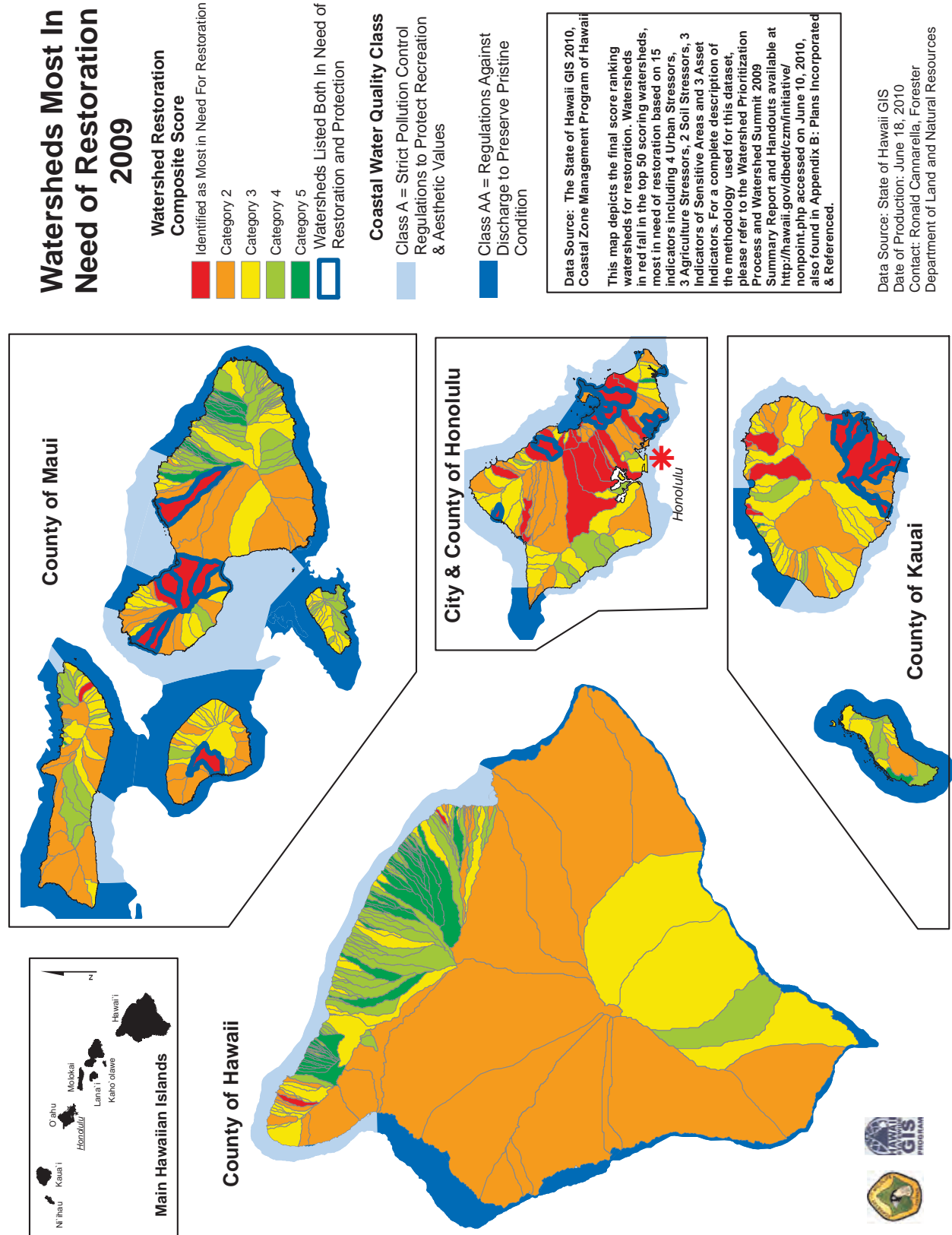
ahupuaa level. The Hawaii Coastal Zone Management Program (CZM) and the Hawaii Department of Health (DOH) are working to develop a comprehensive Coastal Nonpoint Pollution Control Program in conformance with Section 6217 of the federal Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) (see <http://coastalmanagement.noaa.gov/nonpoint/docs/6217progguidance.pdf>).

The Coastal Nonpoint Pollution Control Program is intended to be comprehensive and 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). The State has met most of the management conditions and has been working with EPA and NOAA to address the remaining conditions through the development of a watershed guidance package. The watershed guidance package is intended to guide the preparation and implementation of watershed plans. Further, the package will utilize 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 the State's Polluted Runoff Control Program supported by EPA Clean Water Act, Section 319 funds.

The State will be targeting the use of the watershed guidance package in watersheds identified as being in need of restoration and/or protection where there are also interested and capable stakeholders to develop and implement watershed plans. Map 1.2" "Watersheds Most In Need of Restoration 2009" is included here to summarize the most current statewide assessment of watersheds identified as most in need of restoration. Please refer to Appendix B: Plans Incorporated and Referenced for the complete Watershed Summit 2009 Summary Report and methodology for developing Map 1.2. The handouts from the Summit provide some insight into the numerous watershed planning projects currently underway. Map 1.2 is meant to merely provide a snapshot of one aspect of these efforts.

### Benefits

Water quality and quantity conservation practiced at the watershed level creates benefits within and beyond the management area of interest. The magnitude of the benefits also depends considerably on economic policies accompanying conservation measures.<sup>2</sup> One of the most important ecosystem functions is a consistent supply of water, which is needed for domestic, agricultural, industrial, and tourism needs. As important, forests 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 and functional hydrologic processes are critical to ensuring our waters are fishable and swimmable, and that beaches and coastal watersheds are healthy, which are critical to food production and tourism; Hawaii's largest industry.



Map 1.2 Watersheds Most In Need of Restoration 2009



Other ecosystem services provided from 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 is practiced under the enticement of quick economic gain.

In Hawaii the steep mountainous areas have long been recognized as crucial elements of a sustainable ecosystem. There is a direct connection between forest quality and water quality.<sup>3</sup> A University of Hawaii study estimates the Koolau Mountains on Oahu alone provide benefits worth up to \$14 billion. Beginning more than a century ago, upland areas began to be set aside for protection. The lands currently zoned “Conservation District” and those within the “watershed partnerships” are managed and responsible for providing billions of gallons of water each year. Some of the benefits of these partnerships are:

- More economical management of resource threats across landowner boundaries
- Limited state funds are leveraged with federal, county and private funds
- 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 results from decisions made by humans. Sometimes the impact of the lack of action is as important as that of action. A proactive approach to reducing long term threats is needed if we are to affect impacts such as:

*Fracture of Hydrologic Functions:* Watersheds are impacted by humans through development and land use practices. There is a need to assess the health of, and distribute knowledge about, hydrologic functions and watershed sustainability to the public to inform policy makers.

*Destructive Animals:* Feral ungulates like pigs, goats, sheep, deer, and cattle trample and destroy vegetation, tear up the ground with their hooves, leaving the ground bare and exposed. This can further result in increased erosion, and allow seeds of fast growing non-native species to germinate and thrive.

*Destructive Weeds:* Habitat-modifying invasive species shade out natives, especially those that are shallow rooted and contribute to erosion. Some alien invasive species such as strawberry guava (*Psidium cattleianum*) or albizzia (*Falcataria mulucana*) have been shown to significantly alter the microhabitat rendering it less conducive to the support of native species.

Other important threats include urbanization, wildfire, the effects of climate change, terrestrial and aquatic pollutants, invasive species, pests, diseases, human activities such as use of ATVs and motorcycles, and the loss of important cultural practices.

*Urbanization:* The effects of urbanization and human activities such as burning, logging, cattle grazing, large scale agriculture and associated chemicals and fertilizers, and development have permanently altered many coastal and lowland areas and the native species that once inhabited them. 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 non-point source pollution. These terms both refer to pollutants that enter a body of water as a result of water flowing over the surface of the land, such as rainfall or irrigation or common non-point source pollutants include soil, fertilizers, animal wastes, oil, grease, litter, and agricultural chemicals. These and other pollutants end up in public waters all across the country. In Hawaii, land-based activities are the primary source of polluted runoff problems statewide.<sup>4</sup> The consequences of non-point source pollution are all too well known; increased risk of disease from water recreation, algae blooms, fish kills, destroyed aquatic habitats, and turbid waters. Some polluted runoff results from natural causes. Most, however, result from people's activities on the land and water.

*Feral Ungulates:* The effects of Hawaii's extreme isolation from other land masses are illustrated well by its 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 Hawaii's evolutionary history. The pressures associated with ungulates such as trampling, heavy browsing and grazing have resulted in the loss of many species and/or their ability to evolve and adapt to new evolutionary pressures and climate change.

*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 without harm from the native Hawaiian population. During that time, they exacted heavy impacts on the native vegetation as well as cultivated crops.<sup>5</sup> Currently, most cattle grazing takes place on private and State leased lands. However, wild cattle persist in many areas where inadequate or absent fencing have allowed them to wander into the forest in search of highly palatable foods. Unmanaged cattle are widely recognized as a major destructive agent in Hawaiian ecosystems and have had a significant effect on montane mesic forests.<sup>6</sup>

*Pigs:* Initially introduced by the Polynesians was the relatively small, forty to fifty pound Polynesian pig. Europeans arrived over 1,000 years later and brought with them the domestic hog, a much larger animal than the Polynesian pig. Over the first 100+ years of occupation, the hog became well-established in the wild. In a 1930 Hawaii Planter's 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, vector disease and pathogens, and facilitate erosion.<sup>7,8,9,10</sup> (See Issue 2: Forest Health: Invasive Species, Insects and Disease for more information.)

*Non-Native Animals:* Fifty-three birds, 33 reptiles and amphibians, and 19 mammals are naturalized in Hawaii, and have the potential to become serious pests in watersheds. Rats, in particular, have significant affects on native vegetation and birds. Black rats (*Rattus rattus*) and Polynesian rats (*Rattus exulans*) are the dominant species throughout most of Hawaii'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. 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 may pose problems in Hawaii's watersheds include mongoose, feral cats, dogs, mice, chameleons and 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 are vectors for the spread of alien plants. Over 3,300 alien arthropods are estimated as naturalized in Hawaii; this number grows by 20 to 40 per year. Alien arthropod species have been introduced intentionally and unintentionally over the past few centuries for a variety of reasons. Impacts of alien invertebrates include direct consumption of rare plants, interference with plant reproduction, predation and parasitism of native animals, transmission of disease, alterations to soil formation processes, and hybridization with native forms.<sup>11</sup>

*Pathogens:* Koa (*Acacia koa*) is one of the two dominant tree species in Hawaii's native forests. Pathogens have limited the success of numerous native species; most significantly, koa wilt disease, caused by *Fusarium oxysporum*, threatens the health of this tree. This soil born disease causes dieback and decline of koa in native forests by compromising the trees vascular system.<sup>12</sup> Additionally, rust species have the potential to negatively affect the other dominant tree species in Hawaii's native forests, *ohia lehua* (*Metrosideros polymorpha*). A recently introduced strain of *Puccinia psidii* was found to be pathogenic to ohia. Although this race of rust has demonstrated low virulence to ohia, scientists are concerned about introductions of future strains. Compromised health of Hawaii's dominant native tree species, koa and *ohia*, would have devastating effects on Hawaii's forested watersheds. (See Issue 2: Forest Health: Invasive Species, Insects and Disease for more information.)

*Human Activities:* Hikers and hunters can spread seeds or propagules of invasive plants on their shoes, equipment or vehicles. Illegal trails have been created by ATVs, motorcycles, and bicyclists. Over harvesting of some culturally important plants may be occurring. Fires, whether caused inadvertently or maliciously, are a threat, primarily in dry forest or during drought periods.

*Aquatic Pollutants:* Numerous alien aquatic species that exhibit the characteristics of being invasive threaten to cause ecological and economic harm. The loss of these native stream fauna would degrade the entire native stream ecosystem. Invasive aquatic species could also cause economic impacts to agricultural users of water, resulting in crop damage, infrastructure damage, or contamination. Introductions of aquaculture and aquarium species into streams occur via flooding, effluents discharged back into streams, intentional introduction, and by overland travel. In addition, disease and pathogens associated with cage-reared species could potentially spread

through streams and ditches. A number of fish distributed via the aquarium industry, directly compete with native stream fauna for food and other resources.<sup>13</sup>

### *Sediments*

Most water quality problems in the upper watershed do not have anthropogenic origins. They are related to soil erosion, a natural process in forested areas that can be amplified by animals and to lesser extent human disturbances. Sediment pollutants occur as siltation, suspended solids, turbidity, nutrients, and pathogens. Suspended sediments 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/or lower dissolved oxygen concentrations, which at decreased levels 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 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.

*Toxins and Bacteria:* 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. About 500 cases, including seven deaths, have been reported in Hawaii in the past decade. Cryptosporidiosis is a diarrheal illness caused



Figure 2. Brief but intense rainstorms are typical events in Hawaii. In this photograph, sediment from denuded uplands of Molokai quickly reach the ocean and negatively impact near shore habitats and smother coral reefs.



by a microscopic intestinal parasite, *Cryptosporidium*. People are typically exposed by eating food or drinking water contaminated with feces of infected animals, including cattle, rodents, cats, dogs, and humans.

*Wildfire:* Because Hawaii'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 frequency and/or intensity of fires. Increased occurrence of fire leads to erosion, and the whole cycle thereby reduces the integrity and biodiversity in Hawaii's watersheds. (*See Issue 3: Wildfire for more information*).

*Climate Change:* Global and local climate change have the potential to affect Hawaii's hydrology through the alteration of rainfall patterns and cloud banks thereby effecting agricultural water users over a broad geographic area. Sea level rise, an inevitable outcome of climate change, will impact islands dramatically by killing vegetation that is not adapted to salt water intrusion. Many cities and villages located near the ocean are already being impacted 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 relatively quick changes in precipitation, temperature, and humidity that result from a rapid and drastic change in regional or local climate patterns. Such intensive rainfall events can cause flooding and damage to crops, human infrastructure and health. Climate change could also impact the local culture and lifestyle by causing a decline in culturally-used plants that are dependent on niche environments. Recreational opportunities might also be adversely affected. (*See Issue 5: Climate Change/Sea Level Rise for more information*).

## 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 has affected hydrologic functions. One legacy of Hawaii'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 and channelization are more modern modifications created to support the ever increasing urban populations with negative impacts to Hawaii'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 Hawaii, including a number of 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 Hawaii, Maui, Molokai, Oahu, and Kauai.

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 (see Figure 3). Monthly mean base flows generally were above the long-term average from 1913 to the early 1940's and below average after the early 1940's to 2002, and 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 ground-water storage and recharge. Because ground water provides about 99 percent of Hawaii's domestic drinking water, a reduction in ground-water storage and recharge has serious implications for drinking water availability. In addition, reduction in stream base flows may reduce habitat availability for native stream fauna and water availability for irrigation purposes.

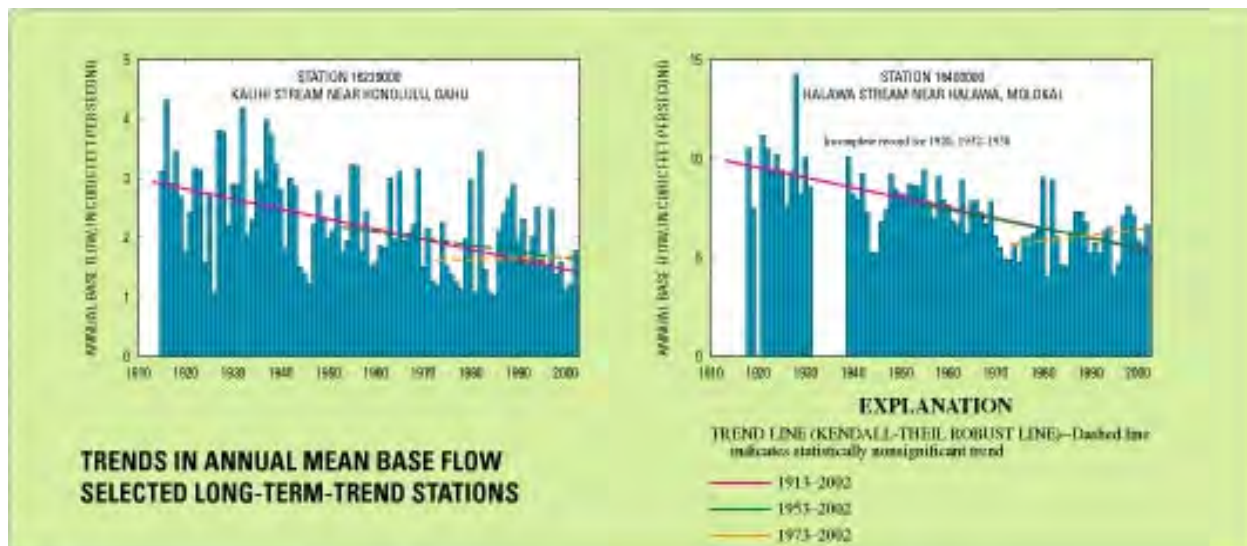


Figure 3. 1910-2001 trend depicting reduced mean base flow and annual rainfall in Hawaii. Image courtesy of U.S. Geological Survey.

Statistically significant downward trends in annual base flow during 1913-2002 were detected at all seven stations. Long-term downward trends in base flow are consistent with long-term downward trends in rainfall over much of the state during this period. Thus, the downward trends in base flow at the long-term trend stations may be representative of many other streams throughout the state as well. 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 (Oki, in press). For the period 1953-2002, a significant downward trend in base flow was detected at only one of 14 long-term-trend stations (16400000 on Molokai), and for the period 1973-2002, a significant downward trend was detected at only one of 16 stations (16019000 on Kauai). Detection of trends in base flow may 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 1940's, followed by a period after the 1940's 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 the seven long-term-trend stations (16229000 on Oahu). For more recent periods, such as 1953-2002 and 1973-2002, significant trends in total stream flow generally were not detected at the long-term-trend stations (Oki, In Press). For the period 1953-2002, a significant downward trend in total stream flow was detected at only one of 14 long-term-trend stations (16211600 on Oahu), and for the period 1973-2002, no significant trends in total stream flow were detected at 16 long-term-trend stations. (USGS 2010)

### Trends in Land Management & Collaborative Partnerships

Over 100 years ago the territorial government of Hawaii 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 alliance of watershed partnerships has grown. 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*

The watershed partnerships' goals are to develop and implement initiatives that support long-term sustainability of the watershed partnerships. The five main objectives identified to implement these goals are:

- Investigate long-term, sustainable funding options and determine solutions to support continued implementation of the 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 management plans.
- Facilitate the annual Watershed Symposium and/or other similar events to maintain communication amongst partners and facilitate information exchange.
- Expand outreach and education initiatives to develop support for the work done by watershed partnerships, particularly amongst 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 out plantings, and outreach and education involving schools and communities. Much of this success can be attributed to having committed partners, dedicated staff and leadership, directed management plans that prioritize threats and actions, effective organizational structures which insure dollars go directly to projects, and passionate volunteers and community support. To date, combined partnership success includes:

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



Figure 4. Watershed partnership staff in the field building fences, monitoring and removing invasive plants.

Today, there are twelve watershed partnerships on six major islands: Kauai,<sup>14</sup> Oahu,<sup>15</sup> Lanai,<sup>16</sup> Molokai,<sup>17</sup> Maui,<sup>18,19,20</sup> and Hawaii.<sup>21,22</sup> Together, these partnerships involve over 65 private landowners and 24 public agencies that cover over 2 million acres of land in the state. To learn more about the watershed partnerships and their many accomplishments visit the Hawaii Association of Watershed Partnerships website at <http://www.hawp.org>.

### *Urban Watershed Collaborations*

An increasing trend, particularly in highly urbanized watersheds, is the establishment of collaborations that take a whole-watershed approach, or as previously stated, embrace the 21<sup>st</sup> Century *ahupuaa*. These collaborations cross boundaries, such as the forested Conservation District which often abuts suburban residential communities and highly urbanized areas. This section highlights only a few of these initiatives.

While non-point source pollution is associated as the cause of many water quality issues, a large number of non-point source pollution issues are 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.<sup>23</sup>

One example of a grassroots, community based collaboration in Hawaii working on local water quality issues is the project at Maunalua Bay initiated by Malama Maunalua (see <http://malamamaunalua.org/>). Malama Maunalua is a community-based initiative dedicated to creating a more culturally and ecologically healthy Maunalua region in Southeast Oahu. Malama Maunalua works in collaboration with the Polynesian Voyaging Society, Malama Hawaii, The

Nature Conservancy, Hui Nalu Canoe Club, State Dept. of Land and Natural Resources, and many, many others. Key issues being addressed by this initiative 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.<sup>24</sup> 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 successful public-private watershed based collaborations include the West Maui Watershed Restoration Action Strategy spearheaded by the West Maui Soil & Water Conservation District (<http://www.hacdohawaii.org/districts/westmaui.html>), and the Ala Wai Watershed Project on Oahu (<http://www.alawaiwatershed.com/>).

The Ala Wai Watershed Project is a multi-purpose project being undertaken by the U.S. Army Corps of Engineers (USACE), the Hawaii State Department of Land and Natural Resources (DLNR), and the City & County of Honolulu. The goal of the project is to improve the overall quality of the Ala Wai watershed, from the crest of the Koolau Mountains to the nearshore waters, while minimizing the risk of flood damages to the public. Specific project objectives include:

- Flood risk management
- Ecosystem restoration
- Recreation
- Water quality
- Water supply
- Coastal issues
- Infrastructure maintenance

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 “Kaulunani”, an urban forestry program of the Division of Forestry and Wildlife, the USDA Forest Service, the Friends of Hawaii's Urban Forest, and The Outdoor Circle. (*See Issue 4: Urban & Community Forestry for more information*).

### Summary

The importance of water quality to the State of Hawaii cannot be overstated. Water quality 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 non point source pollution, the effects of climate change, terrestrial and aquatic pollutants, wildfire, pests, diseases, human activities, development, and the loss of important cultural practices. Watershed-level management requires collaboration and cooperation across

landscapes and organizations. The adoption of the *ahupuaa* approach, the work of the ORMP Policy and Working Groups, the Invasive Species Committees, The Hawaii Conservation Alliance and the watershed partnerships are only some of the examples of progress that we are making in managing our water resources in Hawaii. However if we are to successfully meet the new challenges of invasive species, conversion of prime agricultural lands to uses that negatively impact water, and climate change, then much more needs to be done. "Each time we lose another Hawaiian plant or bird or forest, we lose a living part of our ancient culture." Nainoa Thompson, Polynesian Voyaging Society.

#### Data Gaps & Opportunities

- Refinement of ungulate survey methods and conducting additional surveys.
- Increased monitoring of invasive species utilizing ground surveys in conjunction with aerial surveys using high resolution and multi-spectral imagery.
- Refined models of predicted effects of climate change at a spatial scale appropriate for Hawaii.
- Continued improvement in modeling and monitoring the effects of different land use practices on local water budget.
- Develop economic data and practical models for assessing the costs and benefits of “green engineering” effects on storm runoff mitigation on tropical urban areas.
- Increased collaboration with communities, government agencies, researchers and nongovernmental organizations (NGO) operating at the *ahupuaa*/watershed scale.
- Identify specific areas, regions or watershed to target for concentrated efforts.
- Increase community outreach and education efforts.
- Better communication between the watershed partnerships and the invasive species Committees to consolidate our GIS data regarding the location of invasive species and the actions being taken to control them.



## Strategies for Issue 1: Water Quality & Quantity

### Strategies for Issue 1: Water Quality & Quantity

There are many factors affecting the quality and quantity of water in Hawaii. The priority areas for one department of State or Federal government and private landowners may differ significantly from another, however collectively the goal is to monitor, manage and protect all areas that impact water. Certainly this includes watersheds, but it also includes understanding and addressing issues around, above and below watersheds. The below table strives to capture the majority of issues, stakeholders, programs and management priorities pertaining to water across the State of Hawaii. The State acknowledges and strives to incorporate all existing management plans pertaining to water.

Water Quality & Quantity: Invasive Species Control						
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Implementing Partners	Measures of Success
1) Control established and incipient invasive species by conducting weed surveys & creating and implementing prioritized weed management plans for important watersheds.	Watershed Partnership Areas Statewide, The Conservation District, Dept. of Health, CZM/EPA & Board of Water Supply Priority Watersheds.	Reduced soil erosion, increased carbon sequestration, coral reef protection.	Watershed Partnerships, NARS, FRS, HISC, USFS Forest Health and Special Technology Development Program, FSP, FLP, CREP, LLCF, NAPP's, FWS, FSCG	Private landowners, Watershed Partnerships, DHHL, OHA, HI Counties, NPS, TNC, County water Departments, visitors to HI	Special Technology Development Program, Americorps Internships, USFS, NRCS, USGS, US Army, USFWS, UH, CGAPS, HCA, YCC, DAR, IPIF	Acres surveyed/ treated for invasive species that threaten watersheds; # of weed management plans completed or updated, Improved hydrologic functions island wide.
2) Control feral ungulates through fencing, public and staff hunting, trapping and other approved methods.	Same as above	Improved coral reef health, reduced mosquitoes.	Same as above	Same as above	Same as above	# of acres fenced; Miles of fence line inspected and maintained; # of feral ungulates removed.
Water Quality & Quantity: Outreach & Education						
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Implementing Partners	Measures of Success
1) Increase public involvement in watershed management through outreach education and volunteer programs for children and adults that integrate science with Hawaii's unique cultural traditions.	Statewide	Improved policies & more incentives promoting water quality enhancement	Watershed Partnerships, NARS, FRS, HISC, USFS Forest Health and STDP, FSP, FLP, CREP, LLCF, NAPP's, FWS, FSCG	Same as above	Americorps Internships, HISC, Hawaiian County, CGAPS, YCC, DAR, OHA	# of outreach events and presentations; # of participants in outreach and education events; # of volunteers participating in watershed events; Increased partnerships.
						Supports National Objectives 1.1, 1.2, 2.1, 3.1, 3.4, 3.5
						Supports National Objectives 1.2, 2.2, 3.1, 3.4, 3.5, 3.6
						Supports National Objectives 3.6

*Strategies for Issue 1: Water Quality & Quantity*

2) Build public support, create sustainable funding, and develop new policies and laws supporting water quality and quantity.	Statewide	Improved wildlife habitat & reduced extinctions.	PICCC, HCA	Same as above & regional island neighbors	TNC, HCA, Watershed Partnerships, IPIF, Land Trusts, OHA	Increased State funding and programs supporting water; Water related Bills proposed to HI State Congress.	3.6
3) Raise the capacity of Watershed Partnerships to share watershed management expertise.	Statewide	Multi-state & International collaboration	DAR, HAWP, EQIP, CREP, EQIP, FSCG, NARF, UCF, HCA, FWS	Private landowners, Watershed partnerships, DHHL, OHA, HI Counties, NPS, TNC, visitors	HCA, TNC, IPIF, NOAA, UH	# of watershed symposia and meetings; Total annual funding for watershed partnerships; New policies or laws enacted.	1.2 2.2 3.1, 3.3, 3.4, 3.5, 3.6
<b>Water Quality &amp; Quantity: Improve coastal watersheds</b>							
<b>Long Term Strategy</b>	<b>Priority Landscape Area(s)</b>	<b>Secondary Issues Addressed</b>	<b>Program Areas that Contribute</b>	<b>Key Stakeholders</b>	<b>Resources Available &amp; Implementing Partners</b>	<b>Measures of Success</b>	<b>Supports National Objectives</b>
1) Protect surface water for economic, ecologic, cultural and aesthetic purposes.	Major surface water areas statewide.	Improved quantity of marine food stocks, lower salt water intrusion.	DAR, NARF, HAWP, FSCG, UCF, HCA, EQIP, WHIP, FWS, NOAA, Army Corps of Engineers	Same as above	Same as above	Increased drinking water, improved water quality, increased aquifer recharge.	1.2 2.2 3.1, 3.3, 3.4, 3.5, 3.6
2) Improve water quality in estuaries, bays and near shore waters.	Coastal bays & estuaries, streams statewide.	Improved quantity of marine food stocks.	DAR, HAWP, EQIP, CREP, EQIP, FSCG, NARF, UCF, HCA, FWS	Same as above	HCA, TNC, IPIF, NOAA, UH	Increased water quality assessments. Reduced negative chemicals in waterways and bays.	1.2 2.2 3.1, 3.3, 3.4, 3.5, 3.6
<b>Water Quality &amp; Quantity: Address key forest health concerns</b>							
1) Work closely with other programs to address additional key watershed threats such as fire, diseases, and inappropriate human use.	Statewide	Improve and increase native carbon sequestration	HAWP, DOFAW Fire, Forestry & Forest Health, FSCG, NRCS, FWS, Army, OHA	Same as above	NARF, CGAPS, HISC, HCA, HAWP, FSCG, Land Trusts	# of projects completed related to fire, disease, and human activity.	1.2 2.2 3.1, 3.3, 3.4, 3.5, 3.6
2) Restoration of native species in priority watershed forests and eroded areas.	Statewide	Increase native carbon sequestration	Watershed Partnerships, USFWS, USFS,	Same as above	NARF, US Fish and Wildlife Service, FSCG, Land Trusts	# of plants planted; # of plants surviving after 5 years.	1.1, 1.2 2.2 3.1, 3.4, 3.5

*Strategies for Issue 1: Water Quality & Quantity*

**Acronyms Used:**

1. CZM – Coastal Zone Management
2. OHA – Office of Hawaiian Affairs
3. HAWP – Hawaii Association of Watershed Partnerships
4. EQIP – Environmental Quality Incentive Program (NRCS)
5. NARF – Natural Area Reserve Fund
6. NARS – Natural Area Reserve System
7. FRS – Forest Reserve System
8. RLA – Recovery Land Acquisition Program – FWS
9. FRPP – Farm & Ranchland Program - NRCS
10. LLCF - Legacy Land Conservation Program
11. FLP – Forest Legacy Program – Forest Service
12. FSCG - Forest Service Competitive Grants

13. DAR - Division of Aquatic Resources
14. Na Ala Hele – State Na Ala Hele Trails & Access Program
15. HISC – Hawaii Invasive Species Council
16. FSP – Forest Stewardship Program
17. CGAPS – Committee Group on Alien Pest Species
18. NAPP - Natural Area Partnership Program
19. HCA – Hawaii Conservation Alliance
20. IPIF – Institute of Pacific Island Forestry
21. UCF – Urban & Community Forestry (Kaulunani)
22. NOAA – National Oceanographic and Atmospheric Administration
23. USGS – US Geological Service
24. YCC – Youth Conservation Corps
25. STDP - Special Technology Development Program

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## Issue 2: Forest Health: Invasive Species, Insects & Disease

### Overview

The Hawaiian Islands once comprised 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 relatively few plant, insect, and vertebrate visitors that arrived early in the islands' development. One particularly successful plant species among these, the ancestor of endemic *Metrosideros polymorpha* (in the myrtle family), now known in Hawaii as *ohia lehua*, arrived on Kauai nearly 4 million years ago and evolved to form the matrix of forests found throughout roughly 80-85% of the archipelago.<sup>1</sup> *Acacia koa* (in the legume family), likely arrived more recently, but co-dominates in 10-15% of the forest.<sup>2</sup> Hawaii has many other plant species, but most are endemic to very small areas, hence Hawaii's exceptionally high number of endangered species.<sup>3</sup> Hawaii, like oceanic islands in general, is especially vulnerable to the establishment of invaders and subsequent impacts of invasions.<sup>4,5</sup> While habitat destruction by humans has been a direct factor in Hawaii'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 Hawaii's shores, and with their arrival they brought plants and animals needed to survive the long voyage and settle a new land. The settlers quickly learned how to use the forest resources of Hawaii 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 Hawaii. By the time the first Europeans arrived in 1778, the native Hawaiians had developed land use practices that were sustainable and highly productive. This would change however, when wide-scale ecosystem degradation caused by non-native plants, insects, game species, and diseases were introduced by Europeans in the 18<sup>th</sup> century. As a result, over the past two centuries entire ecosystems have been replaced by invasive species in Hawaii.

Managing invasive species, along with reducing human impacts and protecting watersheds, are key elements of forest health in Hawaii 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 habitat, 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 Hawaii has led to a large number of introduced species that degrade forest resources. These invasive species are very widespread and include pigs (*Sus scrofa*), albizia (*Falcataria moluccana*), rats (*Rattus* spp.) and slugs. The only way to preserve the function of important watershed areas and native species habitat is to find new tools to target these species across large areas. Research into toxicants, biological control 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 Hawaii is so great that multiple federal, state, county, nonprofit and private agencies have developed separate programs to address the issue. The Hawaii 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://www.hawaiiinvasivespecies.org/hisc/strategicplan.html>.

The Coordinating Group on Alien Pest Species (CGAPS) which pre-dates the Hawaii Invasive Species Council, is a voluntary group including state, federal, and county agency directors and managers, nonprofit directors, and chairs and managers of island-based invasive species committees. CGAPS benefits from the knowledge and guidance of world-renowned scientists who are dedicated to protecting Hawaii from invasive species. Since its formation in 1995, CGAPS has met quarterly and has published strategic plans identifying priority invasive species needs (<http://www.hawaiiinvasivespecies.org/cgaps/pdfs/cgapsvisionactionplan200912.pdf>).

Field capacity to tackle invasive species as species-based projects is effectively provided by the Invasive Species Committees (ISC's) that have been established on each of Hawaii's counties; the Kauai Invasive Species Committee (KISK), the Oahu Invasive Species Committee (OISC), the Maui Invasive Species Committee (OISC), the Molokai Invasive Species Committee (MoISC) and the Big Island (Hawaii) Invasive Species Committee (BISC).<sup>6</sup> The ISCs 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. Maps 2.1 and 2.2 show where the ISC's have surveyed and/or treated incipient invasive species.

Landscape scale projects in Hawaii are carried out by the watershed partnerships who exercise area-based management to protect and restore native forest communities. Watershed partnerships are voluntary alliances of public and private landowners and other partners working collaboratively to 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. (For more information see Issue 1: Water Quality & Quantity).

### Threats

#### *Invasive Species – Plants and Animals*

The two main threats to watershed health in Hawaii and the focus of most on-the-ground management are feral ungulates and invasive plants.

Animals, such as pigs, goats, sheep, mouflon, deer, and cattle, trample, browse and

destroy vegetation that evolved without any protective measures 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.



Figure 2.1 Brought to the islands for its beautiful foliage, *miconia* is one of Hawaii's worst invasive. plant threats.

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*) shown in Figure 2.1 have been shown to be significantly less effective than native trees in allowing rain to slowly infiltrate watersheds and instead create runoff.<sup>7</sup> The tendency for invasive species to have shallow roots also reduces the ability of the forests on steep hillsides to withstand erosion, rockfall and landslides. See Figure 2.2.

There is also evidence that strawberry guava has higher evapotranspiration rates than ohia forest, but this has not been fully documented.<sup>8</sup> What has been well demonstrated for strawberry guava is that it reduces the proportion of rainfall that becomes available for ground water recharge when compared with native-dominated forests.<sup>9</sup>

Fifty-five birds, thirty reptiles and amphibians, and nineteen mammals are naturalized in Hawaii and have the potential to become serious pests in Hawaii's 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 Hawaii'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.<sup>10,11</sup> Like ungulates, rats can affect water quality by





Figure 2.2. A pure stand of *Miconia calvescens* in Tahiti illustrates what can happen if miconia is left unchecked. This landslide is attributed to miconia's shallow root system.

serving as vectors for water-borne diseases such as Leptospirosis and Cryptosporidiosis. Other non-native vertebrates that pose problems in Hawaii's watersheds include mongoose, 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, provide vectors for avian diseases, and are vectors for the spread of many invasive plants species such as miconia. Invasive vertebrate issues are managed through partnerships with federal and state agencies with jurisdiction over harmful and injurious wildlife such as the U.S. Fish & Wildlife Service and USDA Wildlife Services.

Global and local climate change has the potential to affect Hawaii's suite of established invasive species by extending their ranges to higher elevations. One well documented example of this threat of warming is potential range expansion of mosquito species to higher elevations, resulting in increasing exposure of remnant forest bird populations to mosquito-transmitted infectious diseases.<sup>12</sup> 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/Sea Level Rise* for further details.)

### *Insects & Disease*

Another two threats, introduced insect pests and disease are a continual threat to Hawaii's forests and occur in all areas in the state; forested areas, 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 Hawaii. Of special concern are pests that could cause widespread mortality to wide ranging dominant native forest species such as koa and *ohia*. Large scale dieback of these predominant forest species would be devastating to Hawaii's remaining native ecosystems.

does not have a particularly dramatic history of plant pathogen introductions to date, but given greatly increased movement of plant material with globalization and the tendency for a few endemic plant species to have dominance and broad elevational range, prevention measures

through rigorous pathway management are urgently needed. The Hawaii Department of Agriculture has succeeded in keeping important pathogens of coffee and coconut out of Hawaii for over a century using such a strategy. Most significantly, a rust species has the potential to negatively affect the dominant tree species in Hawaii's native forests, *ohia lehua*. A strain of *Puccinia psidii* was found to be pathogenic to *Metrosideros polymorpha*, commonly known as *ohia*, as well as many other species in the Myrtaceae family. Although this genetically non-variable race of rust has demonstrated low virulence to *ohia*, scientists are concerned about introductions of future strains.<sup>13</sup> The same disease has proven to be quite virulent on rose apple (*Syzygium jambos*), an introduced fruit tree very popular for its rose-flavored fruit (see Figure 2.3), and also on *Eugenia koolauensis*, an endangered native Hawaiian plant with only a few populations remaining.<sup>14</sup>



Figure 2.3. Dieback of non-native rose apple trees (*Syzygium jambos*) caused by *Puccinia psidii* has raised concerns for Hawaii's native *ohia* forests. Photo credit: Randy Bartlett

There is tremendous opportunity for the spread of pests of Myrtaceae through pathways such as establishment of commercial eucalyptus plantations. For example, *Coniothyrium zuluense*, a serious fungal leaf pathogen of Eucalyptus, believed to be derived from a pathogen on native Myrtaceae in South Africa, has already arrived in Hawaii.<sup>15</sup> Whether this pathogen can infect *ohia* is unknown, but its arrival further illustrates the need for careful management of the myrtle family pathway, not just for *P. psidii*, but for numerous forest pests.<sup>16</sup>

Another major pathogen is koa wilt disease, caused by *Fusarium oxysporum f.sp. koeae*, that threatens the health of koa. This soil born disease causes dieback and decline of in native forests by compromising the tree's vascular system.<sup>17</sup> Figure 2.4 shows the stain that this pathogen produces in koa. The disease has been especially virulent in lowland plantations of koa on former agriculture lands (James and others 2007) and greatly hinders the establishment of commercial plantations.



Figure 2.4 Stain on *koa* wood attributed to *Fusarium oxysporum* in a plantation.



Natural forest decline attributed to this disease has so far been limited to a couple of areas, although more work is needed to fully understand its effect and interaction with abiotic factors such as soil types and climate patterns. The full extent of the impact of koa wilt disease in natural forests is still unknown. 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.



Figure 2.5. An introduced thrips insect damaging native naio (*Myoporum sandwicense*) was first detected in 2009 on the island of Hawaii.

Invasive insect herbivores have wrought substantial damage to certain forest species in Hawaii. Particularly notable examples include the fern weevil (*Syagrius fulvitarisus*), established about 1900, especially damaging to species of the tree fern *Sadleria*; the black twig borer (*Xylosandrus compactus*), established in the 1970's, and particularly damaging to *Acacia koa*<sup>18</sup> 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.<sup>19</sup> A species of thrips (*Klambothrips myopori*) first detected on the Big Island in March

2009 seems to have the potential to severely damage naio (*Myoporum sandwicense*), a locally important tree in Hawaii forests.<sup>20</sup> (See Figure 2.6.) 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 had been very popular trees in urban areas. Figure 2.5 demonstrates the effect that this tiny wasp has on *Erythrina spp.* Black twig borer with a much wider host range is limited by elevation (found under 3000 feet) but is widely distributed in ecosystems at lower elevations.

The absence of social insects in Hawaii throughout its evolutionary history has had enormous implications for Hawaiian flora and fauna.<sup>21</sup> Over time, unfortunately, accidental introductions of social insects has greatly altered Hawaiian ecosystems. Today, Hawaii is home to over 40 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 and in tandem with the introduced ants are

common pests of many native Hawaiian plants.

Climate change is also expected to exacerbate pest impacts on Hawaii's forests. Warming temperatures at higher elevations where most remaining native forests exist could make them more vulnerable to pest damage by increasing the climatic range of certain pests that are still limited to lower elevation, non-native forests. Increased drought could also increase susceptibility to existing pests. (See Issue 5: *Climate Change/Sea Level Rise for additional information.*)

### Trends

#### *Invasive Species*

The numbers of invasive species establishing in Hawaii is increasing over time. While there are shifts from accidental introductions to new pathways such as internet mail order for some taxa, new species continue to be detected each year. Island wide plant surveys continue to find new island records as well as new species in cultivation. Through the Invasive Species Committees, there is more capacity to respond to new invasive species and at least a dozen species have been eradicated island wide preventing harm to the environment and economy of the state.<sup>22</sup>

#### *Insects & Disease*

Introductions of insects and disease is a continuing problem in part because Hawaii is so heavily dependent on imports. Approximately 20 insect species establish in Hawaii each year, about half from foreign countries and half from the U.S. mainland. The loss of 30% of existing Hawaii Department of Agriculture (HDOA) inspectors in 2009 reduced state quarantine capacity. Additionally, loss of HDOA monitoring and biocontrol positions in 2009 seriously compromised detection and assessment of new pests. (See Issue 9: *Multi-Multi-State Issues for additional information.*)

#### *Outreach & Education*

Public awareness surveys show that public knowledge of invasive species in Hawaii has improved in past years and the percentage of people who view invasive species as a serious



Figure 2.6. Damage to leaves by the erythrina gall wasp--responsible for the death of thousands of endemic and introduced trees in the genus *Erythrina* trees throughout the state. Photo credit: Ron Heu

problem is rising (see Figure 2.7). 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. Special efforts are now underway to increase public understanding of the important role of biological control in managing invasive species in Hawaii.

Although public awareness is quite high for the concept of invasive species in general and certain species in specific (see <http://www.hawaiiinvasivespecies.org/cgaps/whitepapersreports.html> for a full report on recent surveys), much more can be done to engage the public in understanding, preventing, detecting and controlling invasive species in Hawaii.

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### Have you heard of the concept known as "alien pest species" or "invasive species?"

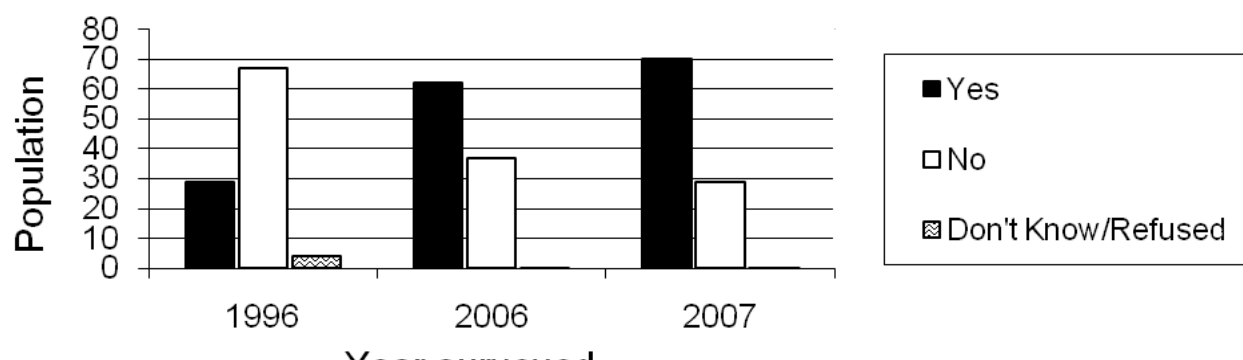


Figure 2.7. Results of a survey to assess public awareness of invasive species.

#### Present Conditions

##### *Invasive Species*

In response to the complaint that “you cannot conserve what you do not know,” the Hawaii Biological Survey embarked on a study of the numbers of species known to occur in Hawaii. This group, sponsored by Bishop Museum, scoured the published literature and compiled the names of all the plants and animals that reported to occur in Hawaii. The result of those efforts was the first tabulation of the numbers of species in Hawaii by Eldredge & Miller.<sup>23</sup> It provided a detailed table by kingdom, phylum, and class of the numbers of species that were known from the Hawaiian Islands. Each year subsequent to that study, supplements were published in the annual Records of the Hawaii Biological Survey summarizing in an abridged format the changes in the constituent fauna and flora of the islands (Miller & Eldredge, 1996, 2000; Eldredge & Evenhuis, 2002).<sup>24,25,26,27,28,29</sup>

The list of species identified in Hawaii is expected to continue growing. Approximately 10,000 alien plant species are or have been cultivated in the islands. Of these, it is expected that at least 10% will naturalize leading to additional species that could pose a threat to native species

survival, changes to the watershed, interfere with agriculture or decrease our quality of life. Building capacity to identify and address these species is a high priority and the following three areas are the focus of our partnership work with the U.S. Forest Service:

*Prevention:* It is well established that prevention is this most cost-effective tool for invasive species management. The agencies responsible for Hawaii's biosecurity are the Hawaii Department of Agriculture Animal and Plant Health Inspection Service (USDA APHIS), and The Department of Homeland Security U.S. Customs and Border Protection (DHS CBP). Working with these agencies DOFAW attempts to prevent new species from being introduced to the state as well as between islands. This includes invasive plants, insects, and diseases as well as any other organisms that could harm Hawaii's environment. Risk assessments for pathways and specific pests are an important tool for prevention.

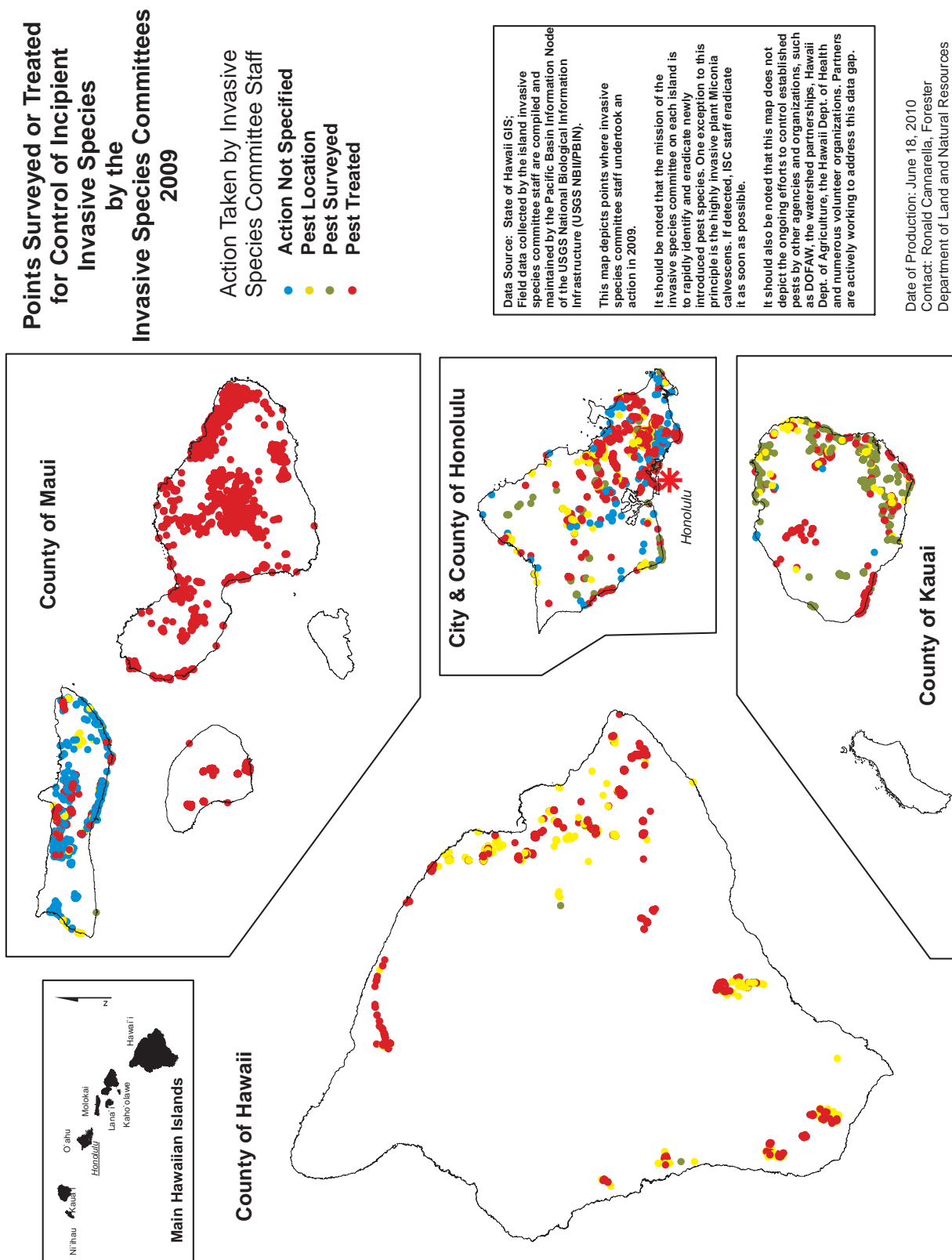
*Hawaii-Pacific Weed Risk Assessment:* The Hawaii-Pacific Weed Risk Assessment (HP-WRA) is used as a diagnostic tool to help predict a plant's likelihood to become a weed. The HP-WRA was developed in Australia and New Zealand and modified for use in Hawaii and other Pacific islands by Professor Curt Daehler of the University of Hawaii. 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. Although the HP-WRA was developed as a tool to prevent new invasions, it is also used to evaluate the threat of newly established plants. Use of the HP-WRA for directing biosecurity regulations is being pursued.

*Early Detection.* Several limited-term projects have been completed that focused on identifying the locations and extent of populations of plants known to have been planted in Hawaii and considered (*use link to Weed Risk Assessment process below*) to pose a threat to native ecosystems (<http://www.botany.hawaii.edu/faculty/daehler/WRA/default2.htm>). These surveys covered specific areas at high risk for introduction of vascular plants, creating a framework of agencies and data collection 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 been initiated on Oahu, the Big Island, Kauai, Lanai, Maui, and Molokai. Maps 2.1 and 2.2 show areas surveyed and/or treated by the Invasive Species Committees on those islands. Continued support is needed to complete or expand these surveys across the islands. A new survey is scheduled for Kauai this year. The Oahu Early Detection project employs two botanists based at the Bishop Museum who assist with identifying new plants found in early detection surveys statewide; these botanists will carry out the survey on Kauai.

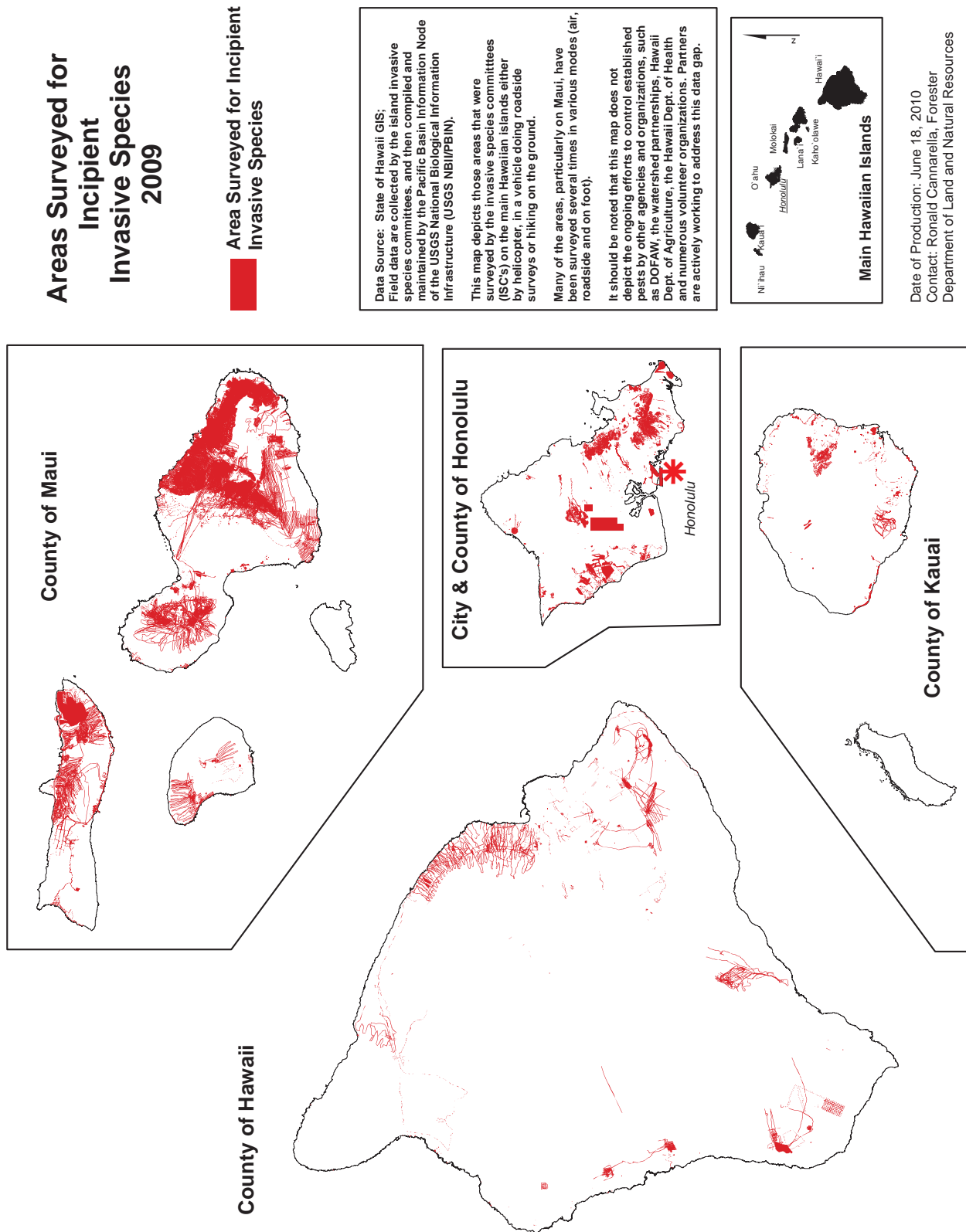






Map 2.1 Points surveyed or treated by the island invasive species committee staff.





Map 2.2 Areas surveyed for incipient invasive species.

Support is also needed to evaluate and prioritize rapid response targets following the identification of targets through these surveys. Detecting species when they are limited to a few individuals or cover less than ten acres greatly increases the likelihood of a successful eradication effort as supported by studies on invasive trees in the Galapagos. A process has been developed in Hawaii for evaluating species detected in early detection surveys (see above), and candidates will be evaluated on an ongoing basis.

Early detection efforts for insects and disease are also being developed in collaboration with U.S. Forest Service, Hawaii Department of Agriculture, USDA APHIS, and the University of Hawaii. While only now getting off the ground, it is hoped that this program will be as successful in finding new introductions as the plant early detection program has been. Efforts will focus on areas where introductions are likely to occur such as harbors and airports, new developments, and urban forests.

A significant improvement to the process of picking new invasive species targets has been the standardization of the evaluation process. Initially, the “Eradicate this weed or not?” decision tree created by the New Zealand Department of Conservation was used on Oahu and in a modified form on Maui. This decision tree has been modified to use the Hawaii-Pacific Weed Risk Assessment screening system to evaluate species as to their risk of becoming serious forest pests along with other factors relating to their ecology, distribution and known control techniques. This standardized process ensures that limited resources are used to control the species that pose the greatest risk and have the best possibility for island-wide eradication.

*Rapid Response:* Hawaii is unique in its extreme isolation from other terrestrial biodiversity centers. Even once an invasive species becomes established in the state, individual islands may remain free of pest species through intra-state quarantine practices and constant monitoring followed by effective control. Eradication, even island-specific eradication, is the most cost-effective, long-term protection for native ecosystems. While several of the highest priority plant species are fairly widespread, new targets will be prioritized by the level of the threat they pose to native forest ecosystems and the feasibility of eradication.

### *Insects & Disease*

Insect and disease pests damage all forest ecosystems in the state. Non-native insects and diseases are a primary threat in Hawaii. While current efforts focus on invasive pests such as the erythrina gall wasp (biological control), black twig borer (development/refinement of lures for local control), guava rust (trying to get regulation/capacity in place to prevent arrival/establishment of new strains), and naio thrips (assessment and exploration of biocontrol options), preventing new pests from entering Hawaii by strengthening quarantine agencies is key to protecting Hawaii’s forests.

Other pests such as koa wilt disease (*Fusarium oxysporum*) and the koa moth (*Scotorythra paludicola*), which is native to Hawaii, occur periodically causing defoliation or mortality.



Figure 2.8. Ohia seedling infested by *Puccinia psidii*. In nurseries where conditions are conducive to outbreaks the disease must be managed with fungicides.

Efforts to isolate genetic resistance in koa to *F. oxysporum* have been successful and continue to be developed. Abiotic stressors such as vog (volcanic fumes) and drought also impact forests in Hawaii and may interact with pest damage stress.

### *Biological Control*

As a part of an integrated pest management strategy, biological control is often the most effective, permanent, and best use of limited funds to control pest species, especially when a pest is

widely established. With current regulatory reviews and approvals, it is also the best environmental solution to controlling pest problems in Hawaii. Long-term suppression of ecosystem altering pests or pests that threaten key native species is often unachievable with any other tool. The Hawaii Department of Agriculture, the U.S. Forest Service, the University of Hawaii and the 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.

However, current statewide capacity to develop biological control is severely limited. Facilities are outdated, cramped, and inadequate for comprehensive non-target testing of multiple candidates. State budget shortfalls jeopardize HDOA's biological control program, and staff is frequently tasked with non-biological control duties. Funding for exploratory trips is rarely available. In order to adequately address invasive species issues in Hawaii, a substantial increase in resources for biological control is required. This needs to be accompanied by public 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, invasives are likely to return. Native forest restoration in Hawaii normally follows a two-pronged effort of fencing out harmful ungulate species and suppressing invasive plants. Outplanting native plants or 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 reestablishing. Restoration efforts need to be site-specific based on the climate and other physical factors. Invasive species management needs to take into consideration how treatment will affect future plant and animal communities.



Figure 2.9. The Septoria leaf-spot fungus has brought the weedy vine banana poka (*Passiflora tarminiana*) under control in many areas.

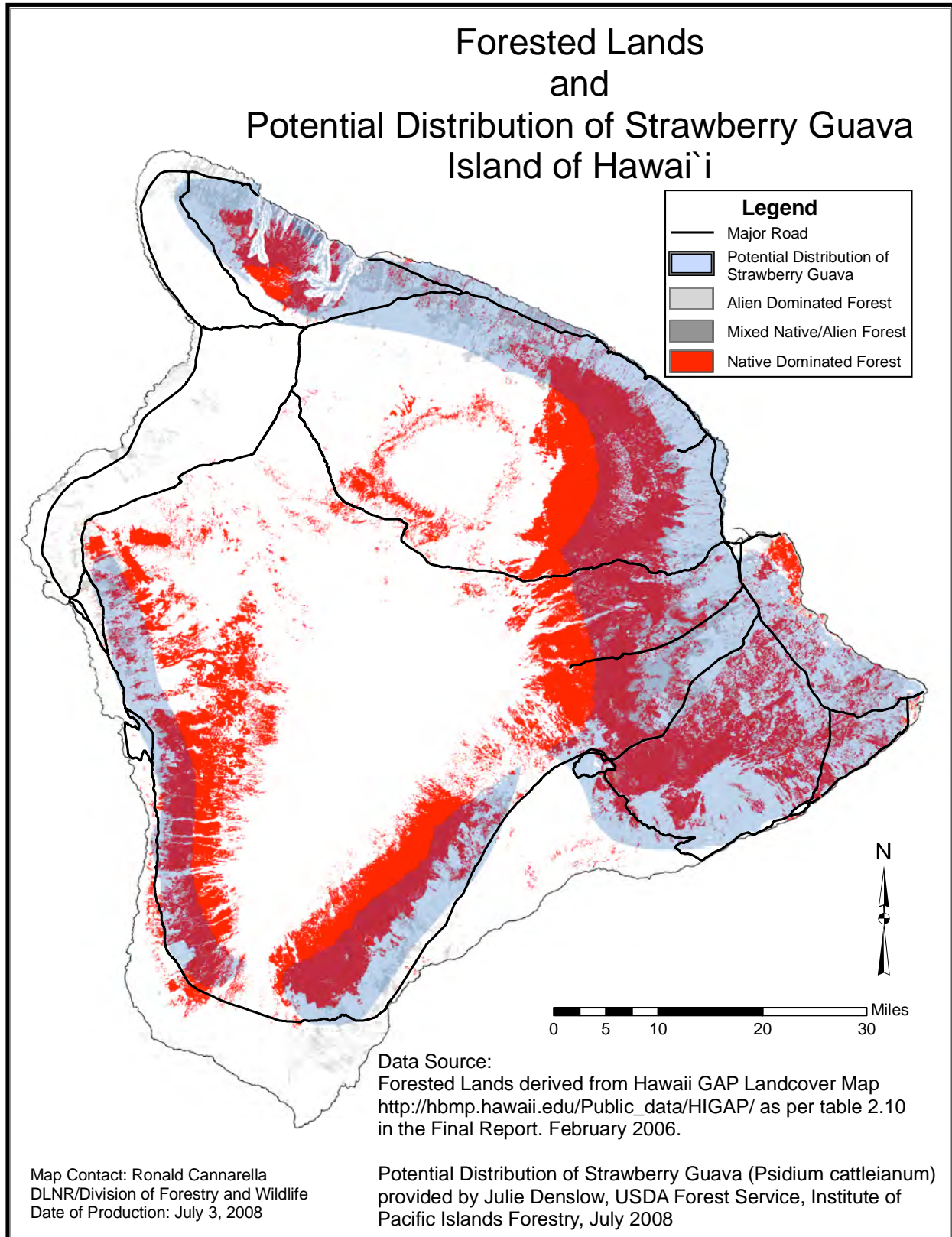
Part of restoration also involves the genetic preservation of species threatened by a pest or disease. For example, a statewide effort was made to collect wiliwili seed from as many populations as possible when the gall wasp was introduced, and it became apparent that the species could become endangered. As the gall wasp population has become suppressed by the introduced biocontrol agent, restoration efforts will utilize this seedbank for reestablishing 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.

### Priority Issues and Areas for Forest Health

Management of invasive species in Hawaii involves working in diverse areas. Many species are initially detected in urban areas through the efforts of the island invasive species committees around harbors and ports, along roadways, and in people's yards. If eradication is not initially possible they can quickly spread to adjacent forested watersheds. Much of Hawaii's low elevation forests, and where control of incipient populations frequently occurs, are predominantly made up of non-native species. The focus of the ISC's early detection and rapid response actions shown in Maps 2.1 and 2.2 fall into two broad categories; roadside surveys in urban areas, and aerial surveys of priority upland forest areas where native ecosystems remain largely intact, primarily at higher elevations (*see Issue 6: Conservation of Native Biodiversity*). The aerial surveys conducted by the ISC's put a high priority on locating and eradicating miconia before it begins to produce seeds. Maintenance of these priority forest areas requires ongoing monitoring and control of invasive species (*see Issue 1: Water Quality and Quantity*).

Therefore, priority landscapes for invasive species include high-risk areas such as ports 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 in other Issue sections in this document. This does not preclude working in any area that becomes infested with a high-priority species utilizing a species-led strategy as described above.





Map 2.3. The map shows how one invasive plant, strawberry guava, threatens remaining native forests on the island of Hawai'i. It is already widely established in the lower elevation mixed and alien dominated forest types.



Currently many long-established insect pests and disease damage native Hawaiian forest trees, but little work has been done on describing their environmental range or mapping their risk. This is in part due to the extreme variation and heterogeneity in Hawaiian ecosystems. Therefore maps are not included for most of these pests, nor are specific priority landscapes given because the pests range and sometimes that of the host is neither well known nor mapped. Map 2.3 shows the potential distribution for one of our well-established and highly invasive forest species, strawberry guava (*Psidium cattleianum*) for which a biocontrol agent has been identified and will soon be released in hopes of controlling the spread of this species.

Priority areas from highest to lowest are those with intact native ecosystems (*see Map 6.4 in Issue 6: Conservation of Native Biodiversity*), valued native species outside of intact ecosystems (such as wiliwili), urban areas, commercial forests, and non-native forested watershed. In reality, most pests heavily overlap these various areas.

### Data Gaps & Opportunities

Currently few maps exist for the statewide distribution of widespread invasive species because of the lack of the data and the technology to acquire it. Monitoring of forest health conditions occurs throughout the state on all land ownerships; 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, but the data is not standardized throughout the state to communicate statewide species-specific information in the same manner as the data from the invasive species committees. Progress has been made in developing remote sensing tools for monitoring the presence of invasive plants and in determining plant mortality and damage from insects and disease in Hawaii's forests. Since many of the most habitat-modifying invasive plants live in the understory, the technology to "see beneath the canopy" is in its infancy, but proof-of-concept research has proven that it can be done using a combination of LiDAR and multi-spectral imaging. Research and development of these new technologies must be supported if they are to become practical tools for resource managers.

The diverse and well-established urban forests in Hawaii are an extraordinary resource for local communities (*See Issue 4: Urban & Community Forestry*). However, these forests link ports with the native forests and could provide a bridge for the spread of introduced pests and pathogens into native forests. Establishing closer links between forest health, agriculture staff, and urban forest professionals will lead to the detection of these pests and diseases and analyze their impact. It will also promote the development of appropriate control measures and inform arborists and other interested parties on how to recognize and contend with these pests and pathogens.

A thorough risk assessment of pathways and pests that threaten Hawaii's native forests is required to provide important information for managers and quarantine agencies. A similar risk assessment that focuses on agriculture commodities has been made and an inspection 'blitz' at

the Kahului airport on the island of Maui several years ago pointed to several high-risk pathways and commodities. A forest pest risk assessment would build on these previous efforts and contribute greatly to the protection of Hawaii's native forests.

For invasive species monitoring, another data need is for close coordination between shippers and federal and local quarantine agencies. Creating the capacity for electronic, advance manifests for all incoming cargo will assist inspectors in targeting their inspections to the highest risk products.

There is also a gap of information to support candidates for 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. Information on plant pests that are entering the state would be used to compile the necessary risk assessments to 'list' plants by the state agriculture agency. This information could also be used to get high risk species on USDA APHIS's "Not Approved Pending Risk Assessment" (NAPRA) list for plants for planting.

## Strategy Matrix for Issue 2: Forest Health: Invasive Species, Insects & Disease

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

Although Hawaii is one of the most isolated island chains in the world, it is the center for travel and transport of goods to the Pacific and far west. As such, many non-native and invasive species and have been brought to these islands that threatened those that are native or endemic to Hawaii. Management of invasive species in the Pacific 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 total eradication is not possible, invasive species can quickly spread to adjacent areas and eventually impact entire watersheds and/or ecological hydraulic functions. Much of Hawaii's low elevation forests are fractured into patches that are dominated by non-native incipient populations; whereas upland priority forested areas are more intact and encompass more native species. Maintenance & protection of these priority 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
1) Prevent harm from new invasive species by improving biosecurity policies.	Ports and harbors, urban areas, targeted upland areas, wildland urban interface.	Improved protection of T&E spp., improved hydraulic functions, coral reef protection.	HISC, HDOA, USDA APHIS, DHS CBP, Invasive Species Program (Wildlife), Forest Health, UCF, WPP, HTA, DOD, EQIP, FSCG,	Private landowners, NPS, TNC, HI Counties, public, DOD, HAWP, USFWS	Cargo fees, conveyance tax, state general funds, HDOA, CGAPS, HISC, FHP, PBIN, LICH, TNC, SPC, SPREP, HCA, USDA APHIS CAPS, USGS-BRD	Interceptions of forest weeds and pests by quarantine officials; Risk assessments.
2) Establish early detection networks & support island-wide eradication and containment of incipient species.	Ports, urban areas, wildland urban interface, degraded ecosystems.	Same as above	Same as above	Same as above	Same as above	Species eradicated; New state or island records; Acres surveyed/ treated for incipient invasive species.
3) Restore areas where invasive plants, insects, and disease have harmed forests.	Intact native forests; threatened ecosystems; watershed partnership lands.	Same as above	Watershed Partnerships, NARS, Wildlife, FRS, FHP, Stewardship,	Public, private landowners, TNC, DOD, HAWP, USFWS	State general, Natural Area Reserve Fund, FHP, USFWS, Stewardship	Acres forest restored.
4) Develop new tools to increase effectiveness of invasive plant, insect, and disease management, including biological control.	Intact native forests; threatened ecosystems; watershed partnership lands; commercial plantations.	Share new knowledge with the rest of the Pacific & Caribbean, T&E spp. Protection.	Invasive Species Program (Wildlife), Forest Health, Special Tech. Development Program, FSCG, NRCS	UH, USFWS, USDA APHIS WS, NWR, HDOA, TNC, HARC, WPP, USGS-BRD	HISC, STDP IPIF, PSWRS, HDOA staff and facility, UH scientists, CGPS	Increased capacity to suppress invasive species, insects, and disease, improved Best Management Practices.

*Strategies for Issue 2: Forest Health: Invasive Species, Insects & Disease*  
Forest Health: Outreach & Education

Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Implementing Partners	Measures of Success	Supports National Objectives
1) Increase public support and involvement in invasive species prevention and control.	Statewide	Increased funding, improved coral reef health.	Conservation Education, HISC, Invasive Species Program (Wildlife), FSCG, Forest Health, WPP, UCF, HCA	Public at large, agricultural & horticultural industries, urban forest users & workers, land management agencies	HISC, State special funds, CGAPS, LICH, AAA, DOFAW staff	More effective invasive spp. control messages to the public; combined funding.	1.2 2.2 3.1 3.4 3.5 3.6
2) Monitor invasive plants and damage or mortality caused by forest pests for trends to inform management activities.	Native and non-native forests; urban forests.	Utilize a variety of new technologies already available.	HISC, Invasive Species Program (Wildlife), Forest Health Protection, Forest Health Monitoring, UCF, WPP competitive grants	Public, agricultural industry, horticultural industry, urban forest users and workers, land management agencies	Conveyance Tax, state funds, HISC, CGAPS, Forest Health Monitoring Lab facilities	More informed decision making; appropriate funding levels for the profundity of problems we have.	1.2 2.2 3.1 3.4 3.5 3.6
3) Work with other programs ensuring integrative approaches to management of invasive species.	Statewide		Forest Health, UCF, FSP, Wildfire Conservation Education, FSCG	UCF, FSP Council, HAWP, HISC	DOFAW and US Forest Service personnel, CGAPS	Improvement in sharing resources.	1.2 2.2 3.1 3.4 3.5 3.6

**Acronyms Used:**

1. CZM – Coastal Zone Management
2. OHA – Office of Hawaiian Affairs
3. C&C – City & County of Government of Hawaii
4. AAA – Aloha Arborists Association
5. NARF – Natural Area Reserve Fund
6. Friends – Friends of Urban Forests
7. FRS – Forest Reserve System
8. DOFAW – EE – Environmental Educational
9. HARC – Hawaii Agriculture Research Center
10. LLCF – Legacy Land Conservation Program
11. FLP – Forest Legacy Program – Forest Service

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

24. STDP – Special Technology Development Program
25. PSWRS – Pacific Southwest Research Station
26. HFIA – Hawaii Forest Industry Association
27. SPC – The Secretariat of the Pacific Community
28. SPREP – South Pacific Regional Environmental Program
29. FAO UN – Food and Agriculture Organization of the United Nation
12. FSCG – Forest Service Competitive Grants
13. DAR – Division of Aquatic Resources
14. Na Ala Hele – State Na Ala Hele Trails & Access Program
15. HISC – Hawaii Invasive Species Council
16. FSP – Forest Stewardship Program
17. CGAPS – Committee Group on Alien Pest Species
18. HCA – Hawaii Conservation Alliance
19. IPIF – Institute of Pacific Island Forestry
20. UCF – Urban & Community Forestry (Kaulunani)
21. NOAA – National Oceanographic and Atmospheric Administration
22. USGS – US Geological Service
23. YCC – Youth Conservation Corps
30. SOPAC – Secretariat of the Pacific Applied Geoscience Commission
31. HFIA – Hawaii Forest Industry Association
32. SAF – Society of American Foresters
33. LICH – Landscape Industry Council of Hawaii
34. PBIN – Pacific Biodiversity Information Node

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### Internet Resources

Hawaii's Invasive Species Partnerships – reports and strategic plans

<http://www.hawaiiinvasivespecies.org/>

Statewide Partnerships annual report for 2009:

<http://www.hawaiiinvasivespecies.org/cgaps/whitepapersreports.html>

Control of Rats:

<http://removeratsrestorehawaii.org/>

Kahalui Airport Risk Assessment:

<http://hawaii.gov/hdoa/pi/pq/KARA>

Hawaii Pacific Weed Risk Assessment

<http://www.botany.hawaii.edu/faculty/daehler/wra/default2.htm>

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## Issue 3: Wildfire

### Overview

Native ecosystems in Hawaii are not adaptive 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.<sup>1</sup> Two-thirds of Hawaii's threatened and endangered species are in fire hazard areas. Wildfires in Hawaii place communities at risk, destroy irreplaceable cultural resources, cost taxpayers money, negatively impact drinking water supplies and human health, increase soil erosion, impact near shore and marine resources, and destroy native species and native ecosystems.



Wildfires like this one on Maui are occurring with increasing frequency due in large part to the introduction of non-native fire-adapted grass species. They threaten human lives and property, impact watershed function, destroy habitat for native species and contribute to non-point source pollution. Photocredit Pacific Disaster Center.

### *Brief History of Fire Management in Hawaii*

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 1980's 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, the need for mutual aid between agencies became increasingly important. County fire departments improved their capabilities by increasing the number of stations and personnel. Mutual Aid Agreements (MAA) with DOFAW and Federal land management agencies, such as the National Park Service, and the U.S. military were strengthened. These MAA's are now the cornerstones of DOFAW's Fire Management Program. With the number of wildfires increasing and funding levels diminishing, these Mutual Aid Agreements are crucial to providing rapid multi-agency response to wildfires. Mutual Aid Agreements with Hawaii's four county fire departments, and other statewide fire response agencies, ensure coordinated efforts in successfully suppressing wildfires.

#### *Division of Forestry & Wildlife Fire Management Program*

The State's Fire Management Program is part of the Watershed Protection and Management Section of DOFAW. The principle function of the Watershed Protection and Management Section is to ensure viable water yields by institutionalizing statewide protection and enhancement of Hawaii's forested watersheds commensurate with their social, economic and environmental values. The mission of the Fire Management Program is to provide fire protection of State Forest Reserves, public hunting areas, wildlife and plant sanctuaries, and Natural Area Reserves.

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. Approximately 90% of DOFAW's personnel 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 and the National Park Service.

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 mainland/fire adapted ecosystems, fire plays a vital role in forest successional patterns and other ecological functions; however in Hawaii and many Pacific islands this is not part of or positive for the native ecosystems.

## Trends

### *Causes of Fires*

An overwhelming majority of wildfires in the state of Hawaii are caused by arson or human error. Human error includes errant fireworks, trash, cooking accidents, vehicle-caused wildfires, and agricultural fires that get out of control in the wildland-urban interface. The Wildland Urban Interface (WUI) is the zone where structures and other human development meet and intermingle with underdeveloped wildland or vegetative fuels. Human error combined with the spread of non-native invasive fire-adapted grasses, shrubs, and trees, has led to an increase in wildfires across the islands. The leeward portions of the main Hawaiian Islands, 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.

### *Wildfire & Fuel Loading Cycle*

Wildfires are increasing in areas where non-native fire-adapted grasses, shrubs and trees are increasing in range and abundance. Fountain grass (*Pennisetum setaceum*) is perhaps the best example of this cycle. Introduced to Hawaii 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 Hawaii's rainy winter season. The ash from the fire nourishes the existing 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.

## Threats & Harmful Effects of Wildfire in Hawaii

**Table 3.1. Wildfire Threats & National Themes**

Wildfire Threats	National Themes
Wildfires threaten homes and lives.	2.1, 3.3
Wildfires destroy native Hawaiian plants and forests and deprive native animals of their habitat.	1.1, 1.2, 2.2
Wildfires cause soil erosion that pollutes and impacts the ocean and reefs.	3.1, 3.5
Wildfires increase the spread of invasive plants that are highly flammable.	2.1, 2.2
Wildfires impact the health of Hawaii's watersheds.	3.1



### *Threats to Communities and the Wildland Urban Interface (WUI)*

In 2005, DOFAW began identifying Communities at Risk from wildfire (CAR's) in the WUI on a statewide basis.<sup>2</sup> Criteria used to identify CAR's include current vegetation type, climate regimes, and fire history. The threat of wildfire in the WUI is of great concern in Hawaii. Map 3.1 depicts the Communities at Risk (CAR's) and the WUI. The WUI for Hawaii is currently defined as areas identified as a one-mile buffer around any CAR's designated as High Risk, Medium Risk or Low Risk.. Vast tracts of land, once used and maintained for agricultural purposes, are now fallow and are used for cattle grazing or developed for residential housing. Today, where there was previously little or no wildfire risk, now there is an increased incidence with more people living in close proximity to wildland areas. Wildfires can also start in these residential areas and spread to the wildland, putting threatened and endangered plant and animal species at risk.

### *Threats to Native Biodiversity*

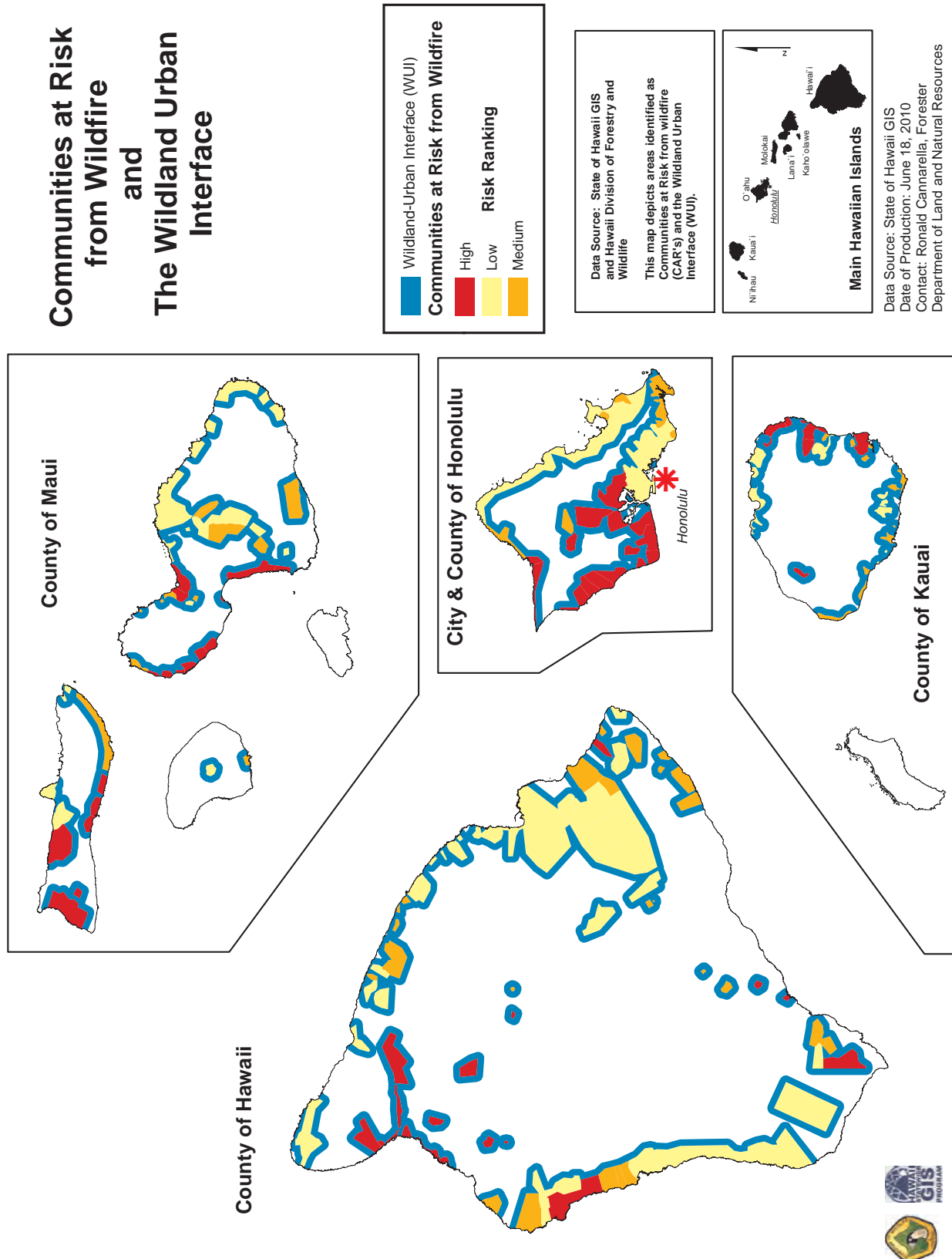
The State of Hawaii is the most geographically isolated island chain on earth, home to plants and animals found nowhere else in the world. Approximately 90 percent of Hawaii's 10,000 native species are endemic, which makes them even less capable of regenerating populations after large-scale fires.<sup>3</sup> Wildfires in Hawaii have caused many native plants to go extinct, and some have such narrow ranges that even if seed stock were still available, the necessary habitat many not be. According to local biologists, many native plant and animal species are only a wildfire away from extinction.<sup>4</sup>

### *Impacts to Watersheds & Groundwater*

Virtually all of Hawaii's public water systems are supplied by artesian wells, which rely on groundwater aquifers. Wildfires destroy vegetation in watersheds, and diminish capacity to absorb rainfall and fog drip that replenishes groundwater resources. Watersheds on all islands are subject to frequent tropical downpours and these brief but intense events can quickly cause erosion and landslides in areas impacted by wildfire. Without vegetation that is resilient to fire and/or does not carry heavy fuel loads, terrestrial plants & animals, fresh & marine water species, and the quality of streams and wetland ecosystems will diminish and their capacity to function properly will degrade.

### *Soil Erosion & Coral Reef Impacts*

Wildfires destroy vegetation in Hawaii's coastal watersheds. Frequent tropical downpours cause soil erosion in fire-damaged areas, leading to increased sediment deposits in the near shore zone. This sedimentation damages coral reef ecosystems that are vital economic, cultural, and subsistence resources for local residents. For example, between 1988 and 1998, the island of Molokai experienced three wildfires that damaged more than 10,000 acres on the island. All three wildfires took place on mountain slopes where run off is channeled directly to the longest



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

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 impacted residents that rely on near shore fishing for sustenance.

#### *Spread of Invasive Fire-adapted Species*

The dry, dense biomass of fire-adapted non-native grass species is an easily combustible fuel that carries fire quickly over large areas, particularly in windy conditions. As wildfires destroy native plants, soil moisture is reduced, making it more difficult for native plants (in sub-surface seed banks) to germinate and re-colonize these ‘arid’ areas. This wildfire/invasive plant cycle perpetuates opportunistic grasses.

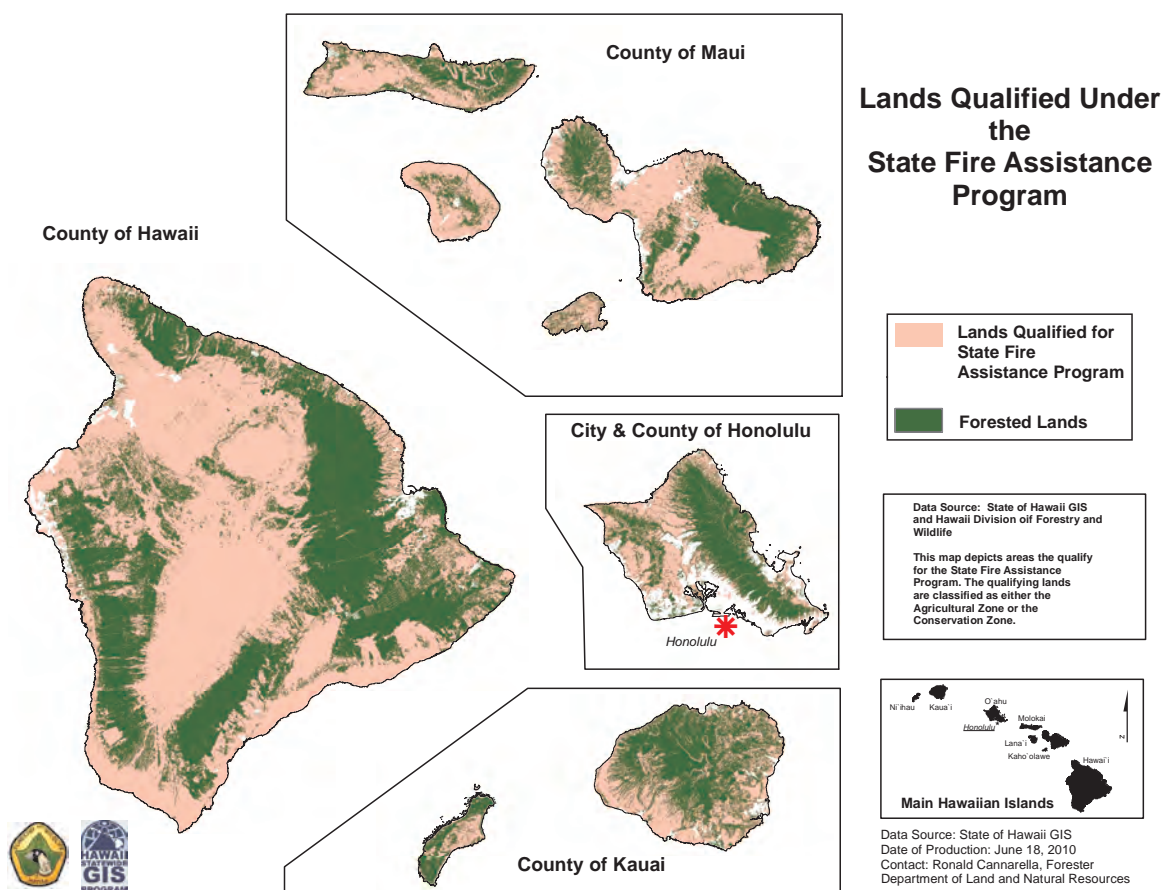
#### *Climate Change*

Changes in climatic conditions could cause more negative impacts such as the fire/grass cycle described above, and have serious impacts on the coast zones due to sea level rise. Some modeling research has been conducted to predict these scenarios but still more is needed. It is important to factor in fire as a possible ramification of upland land use changes, such as been done in some areas in South Kona. Upland land use practices, for example deforestation to support cattle grazing above 4000 feet, can have dramatic affects on lowland area water quantity and quality and native plant animal habitat needs.

#### *Present Conditions*

The Hawaiian Islands are approximately 4.1 million acres in size. Of this land, 48% is zoned Conservation, 47% Agriculture, and 5% is zoned Urban. Combined, the Conservation and Agriculture zones constitute approximately 3.3 million acres. Map 3.2 depicts these lands. This represents the area qualified under the State Fire Assistance Program, as well as many other landowner assistance programs (*See Appendix C Forestry Related Assistance Programs*).

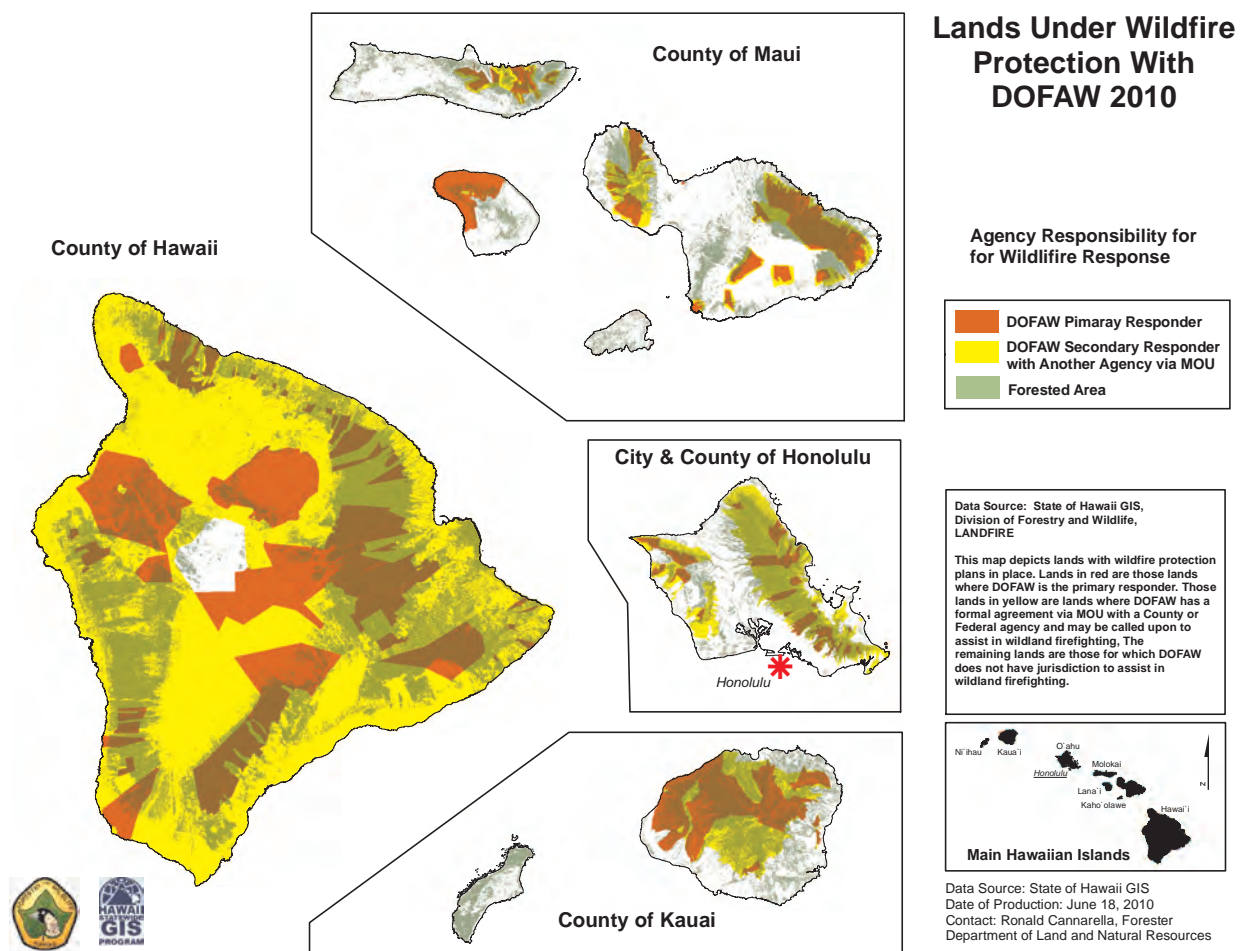
*Fire Response Zones:* DOFAW has established formal agreements with all county and federal land management agencies for responding to wildland fires. DOFAW is the primary response agency for 3,360,000 acres of combined cooperative zones (81% of the State). Map 3.3 depicts areas where DOFAW is the designated first responder, areas where DOFAW may assist federal and county agencies according to the terms of the agreements with those agencies, and areas where no formal agreement exists and are generally out of the DOFAW’s jurisdiction. DOFAW is authorized to respond to fires in extraordinary circumstances in areas without formal agreements only under specific conditions. For example, extreme threats to public safety, local resources are fully committed, and extreme fire behavior. In addition, the request for DOFAW’s assistance must go through the appropriate channels before DOFAW can respond. For example, if state resources are available.



Map 3.2 Lands which qualify for the State Fire Assistance Program.

**Funding:** State and federal budget constraints on funding fire pre-suppression and suppression activities impact the response time needed for effective suppression efforts. DOFAW depends heavily on the Federal Excess Personal Property program for fire equipment. This is supplemented by State Fire Assistance grants to purchase slip-on units, communication equipment, and personal protective equipment. The funds also provide for all-risk management training, including ICS. The Volunteer Fire Assistance Program plays a key component in engaging the county fire departments in providing continued fire protection to rural communities. Funds from this program supplement the county's efforts in equipping, training, and organizing their personnel to meet agency policy and objectives in rural community fire protection. Federal Emergency Management Agency (FEMA) Fire Management Assistance Grants provide financial support when firefighting resources are critically low due to budgetary or personnel constraints.

**Establishment of a Land Fire Protection Law:** A Firefighter's Contingency Fund was established by Hawaii State Law HRS Chapter 1-85, the Land Fire Protection Law. The funds provided under this law are used for fire prevention, preparedness, and suppression activities.



Map 3.3 Lands Under Wildfire Protection by DOFAW and other federal and county agencies.

The Land Fire Protection Law, provides the authority for DOFAW to "...take measures for the prevention, control, and extinguishment of forest fires on state owned lands within forest reserves, public hunting areas, wildlife and plant sanctuaries and natural area reserves; and shall cooperate with established fire control agencies from the counties and the Federal Government in developing plans and programs and mutual aid agreements for assistance for the prevention, control, and extinguishment of forest, grassland brush fires, and watershed lands not within the department's fire protection responsibilities described above."<sup>5</sup>

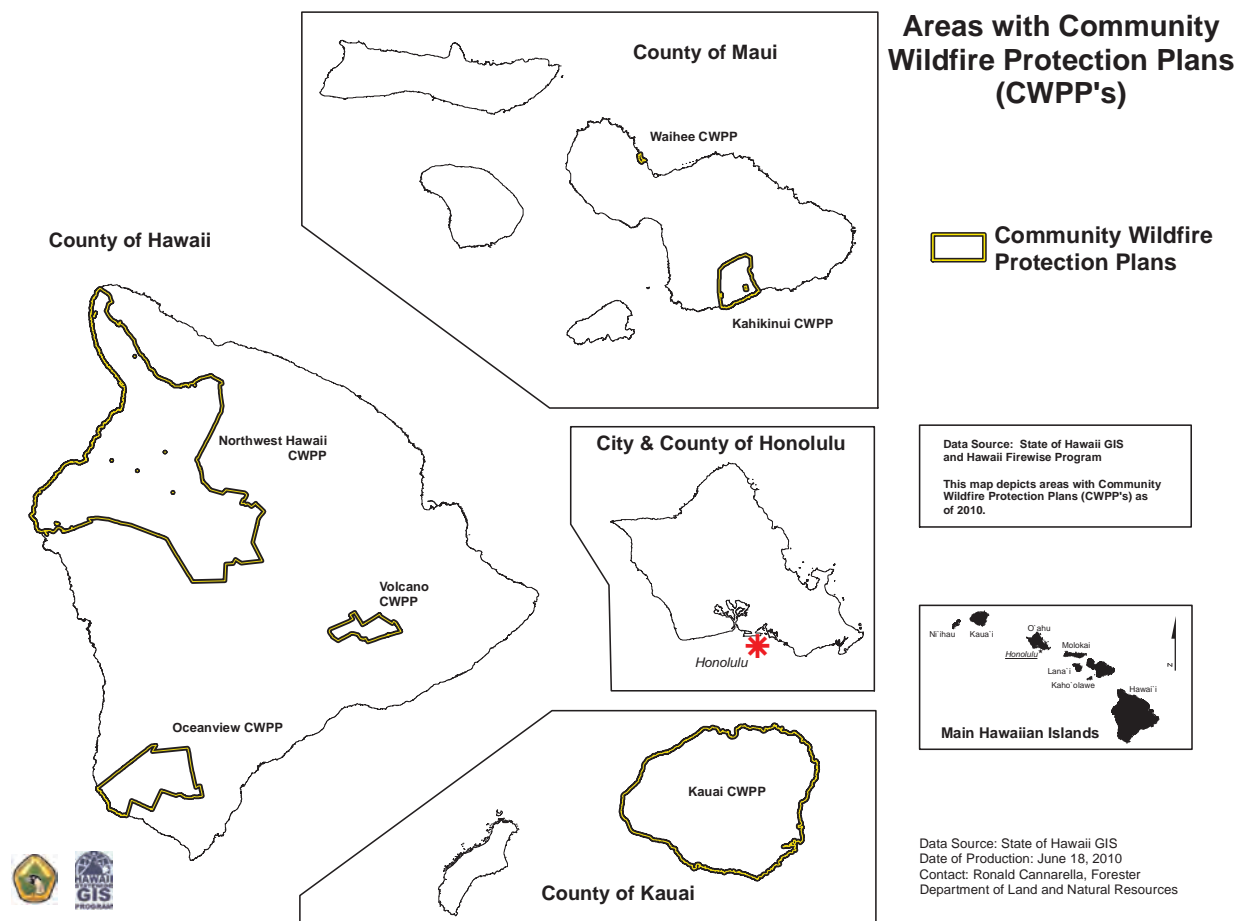
### Community Wildfire Protection Plans

The requirement for developing Community Wildfire Protection Plans (CWPP) was a result of the Healthy Forest Restoration Act of 2003 (HFRA). Wildfires within wildland urban interface pose a tremendous risk to life, property, and infrastructure. Recognizing this risk, the National Fire Plan and the Ten-Year Comprehensive Strategy for Reducing Wildland Fire Risks to Communities and the Environment, made it a priority to work collaboratively with communities



to reduce their wildfire risks. The Healthy Forest Restoration Act provided statutory incentives for federal agencies, such as the U.S. Forest Service and the Bureau of Land Management, to implement fuel mitigation projects deemed a priority by a community. CWPP's allow community members to prioritize fuel mitigation projects.

Currently, six areas on three of the main Hawaiian Islands have Community Wildfire Protection Plans. See Map 3.4.



Map 3.4 Areas with Community Wildfire Protection Plans.

*Community Wildfire Protection Plans offer multiple benefits including:*

- Provide a comprehensive look at the wildfire problems facing a community
- Identify a community's wildfire risk
- Prioritize fuel mitigation projects and
- Are required for a community to be eligible for Federal National Fire Plan grant funding

CWPP stakeholders vary by island and community; however, each CWPP includes participation from the County Fire Department, DOFAW, and the Civil Defense Agency. Other agencies that participate in the CWPP process include: the National Park Service, the U.S Army, Natural

Resource Conservation Service, the U.S. Fish & Wildlife Service, and the Department of Hawaiian Home Lands. While the communities in Hawaii with CWPP's differ dramatically, they also have similar concerns and recommended actions, some of which are described below.

*Recommended actions 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 utilization of current reservoirs and/or installation of pre-staged static water tanks. Development of wells or damming of narrow gulches to increase water reservoir resources.
- Creation of dedicated landing zones for helicopters for fire suppression purposes. Creation of a contingency fund to hire private government-certified helicopters during wildfires.
- Implementation of pre-incident planning meetings between community members and county Fire Department officials to make fire officials aware 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 homesteaders. 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 (CERT) 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.

There are no CWPP's in development at this time and no CWPP's have been officially finalized on Oahu, the island with the highest population. With the current economic climate, it is becoming more difficult for groups and agencies to find funding for CWPP's. This is unfortunate because there are community groups in high-risk areas that want to initiate wildfire mitigation projects but are unable to receive grant funding because they do not have a CWPP. Several

communities on Oahu and in South Maui are examples of this problem. South Maui, including Wailea, Kihei, and Maalaea, are in high-risk fire hazard areas that have a history of wildfires that cause damage to homes, disrupt traffic, and negatively impact the community.

### *Firewise Hawaii Program*

DOFAW engages homeowners who live in Wildland Urban Interface areas via the Hawaii Firewise Communities program, which has been very active statewide since 2002. This program was borne 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. 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 Federal National Fire Plan funding for fuel reduction projects. Kohala By The Sea, a community on the leeward side of Hawaii Island received National Fire Plan grants, achieving national Firewise Communities USA recognition status for six consecutive years. The national Firewise Communities organization, <http://www.firewise.org>, serves as a valuable resource for information about reducing the threat of wildfires in rural communities

### Priority Areas for Wildfire:

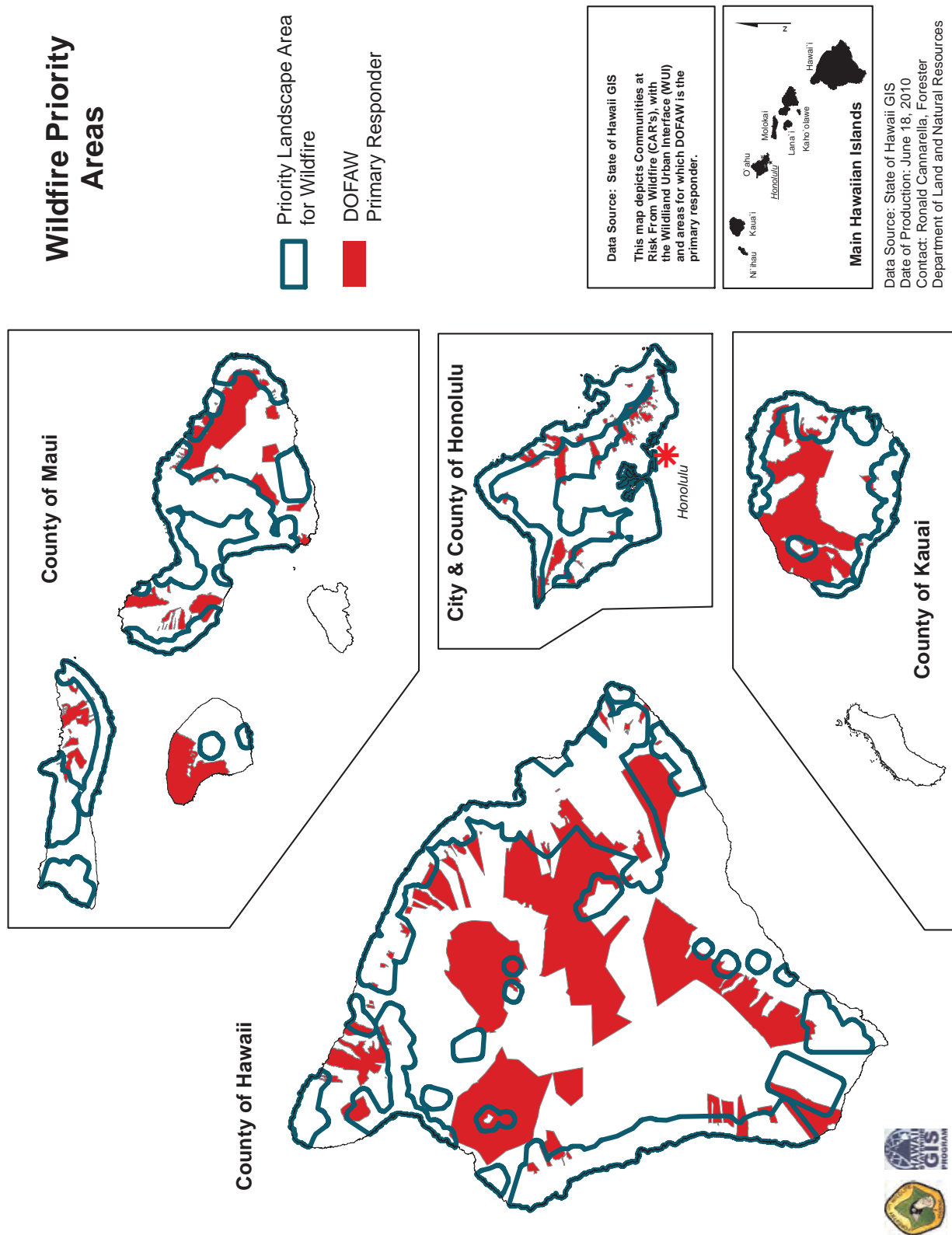
Wildfire Priority Landscapes consist of any land that include

- Communities at Risk from Wildfire and the WUI
- Lands where DOFAW is the primary responder

Please refer to [Map 3.5](#) for the map of DOFAW's Priority Landscape Areas for Wildfire

### Data and Opportunity Gaps

- Modeling for climate change potential impacts on fire adapted invasive species.
- More imagery is needed at a fine scale to ascertain the movement and rates of recruitment of many invasive species.
- Clearly more concise and irrefutable information is needed to inform the public at-large as well as decision makers (funding and policy).



Map 3.5 Wildfire Priority Areas.

## Strategy Matrix for Issue 3: Wildfire

## Strategies for Issue 3: Wildfire

Unlike ecosystems and forests in most of the continental states, Hawaii's ecosystems 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 a fire. Wildfires in Hawaii place communities at risk, destroy irreplaceable cultural landmarks, native species, and complex ecosystems linking the mountains to the sea.

Wildfire						
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/required	Measure of Success
1) Reduce the impacts of wildfires on native ecosystems and watersheds	forest reserves, public hunting areas, wildlife and plant sanctuaries and natural area reserves	Reduced erosion; coral reef health improved	Cooperative Fire Assistance, Forest Stewardship, Environmental Quality Incentive Program (EQIP), Forest Health	State Civil Defense; County Civil Defense; County Fire Departments; Volunteer Fire Departments; National Park Service; U.S. Forest Service; U.S. Army Garrison Hawaii; U.S. Fish & Wildlife Service	Dept. Firefighter Contingency Fund; State Fire Assistance; Volunteer Fire Assistance; Wildland Urban Interface competitive grants	Number of acres protected; Number of homes & structures protected; Number of populations of T&E species protected 1.2 2.1 2.2 3.1 3.3 3.5
2) Reduce the impacts of wildfires on communities and threatened rare habitats near them.	Communities at Risk from Wildfire and the Wildland Urban Interface	Stronger message to private landowners about Fire-wise practices	Cooperative Fire Assistance, Forest Stewardship, EQIP	HI Wildfire Mgmt. Organization; County Fire Departments; Community Associations; County Civil Defense	State Fire Assistance; Wildland Urban Interface competitive grants	Number of homes protected; increase acres of dryland forests; reduced acres of invasive grasses and fire that cycle together 2.1 2.2 3.3 3.6



Section References

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- <sup>1</sup> Gon, Sam quoted in Naomi Sodetani, "Be Fire-Smart Wildfires Threaten Island Ecology, Economy", The Nature Conservancy <http://www.nature.org/wherewework/northamerica/states/hawaii/projectprofiles/art21976.html>. (accessed February 2010).
- <sup>2</sup> SILVIS Lab, Forest & w\Wildfire Ecology University of Wisconsin - Madison. , "The Wildland-Urban Interface", Northern Research Station, the Pacific Northwest Forest Inventory and Analysis Program, and the Northern Global Change Program of the USDA Forest Service under the National Fire Plan. [http://silvis.forest.wisc.edu/projects/WUI\\_Main.asp](http://silvis.forest.wisc.edu/projects/WUI_Main.asp) (accessed February 2010).
- <sup>3</sup> Gagne and Cudahy, (1999) quoted in LaRosa, Anne Marie, et.al. "Chapter 11: Fire and Nonnative Invasive Plants in the Hawaiian Islands Bioregion." In *Wildland Fire in Ecosystems: Fire and Nonnative Invasive Plants*. Gen. Tech. Rep. Rmrs-Gtr-42, 6, 225-242. Ogden: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- <sup>4</sup> Gon, Sam quoted in Naomi Sodetani, "Be Fire-Smart Wildfires Threaten Island Ecology, Economy", The Nature Conservancy <http://www.nature.org/wherewework/northamerica/states/hawaii/projectprofiles/art21976.html>. (accessed February 2010).
- <sup>5</sup> Land Fire Protection Law Chapter 185, Hawaii Revised Statutes, C185hrs ", <http://hawaii.gov/dlnr/dofaw/forestry/forest-and-wildland-fire/c185hrs> (accessed March 2010).

## **Issue 4: Urban & Community Forestry**

### Overview

Tropical urban forests are complex ecosystems that provide a wide range of important functions that are invaluable to humans and native & non-native species in Hawaii. Urban forests provide essential green infrastructure for diverse lowland and coastal plant and animal communities. They are the first line of defense from catastrophic storms and inland water runoff that can deleteriously impact coral reefs and near shore marine ecosystems. These forests also reduce city temperatures by providing shade, provide temporary refuge for migrating birds and reduce air pollutants. Urban forests also play a contributing role to carbon storage and sequestration as they are home to the majority of parks in the state and they minimize the effects of climate change occurrences such as sea level rise and coastal erosion. These essential areas provide environmental, psychological and social benefits; as well as a dramatic and visual backdrop for Hawaii's greatest economic engine--tourism.

During November 4-5, 2009, the “Tropical Urban and Community Forestry Summit” was held. The purpose of the summit was to clarify urban forestry conditions, threats, trends, visions and strategies. The collaboration included “Kaulunani”, an urban forestry program of the Division of Forestry and Wildlife, the USDA Forest Service, the Friends of Hawaii's Urban Forest, and The Outdoor Circle. Forty-two participants from across the state and the Pacific shared insights on key urban forestry issues and priorities in Pacific urban and community forests. Their findings contribute to the outcomes reflected in this statewide Assessment and Strategies Report.



Figure 4.1 Kaulunani Council members convene with other urban forestry leaders at the Summit at the East-West Center in Honolulu. Photo courtesy of Heidi Bornhorst.



Hawaii's Kaulunani Urban and Community Forestry Program is funded by the USDA Forest Service and the Division of Forestry & Wildlife in Hawaii. Goals of this program are: to improve the understanding of the benefits of trees in urban areas and communities, increase tree canopy cover, reduce carbon emissions, conserve energy, improve air quality and increase other environmental benefits, support community tree planting and tree demonstration projects, support Arbor Day activities, enhance the technical skills and knowledge of the urban forest industry, and expand research and educational efforts. Kaulunani's Mission is:

*Balance the urban and natural environment by encouraging, empowering and equipping the people of Hawaii to Malama the trees in our aina.<sup>1</sup>*

Since its inception in 1991, Kaulunani has awarded \$2.1 million to more than 400 organizations across the state in the form of cost-share grants, which were matched with \$6.1 million in cash and in-kind contributions. The key to the success of this program is the blend of partners, people, and projects. Project elements such as environmental change, advanced planning, leadership, volunteer commitment, community involvement, interagency partnerships, appropriate plant selection, proper horticultural procedures and maintenance are important indicators of successful urban forestry projects.<sup>2</sup>

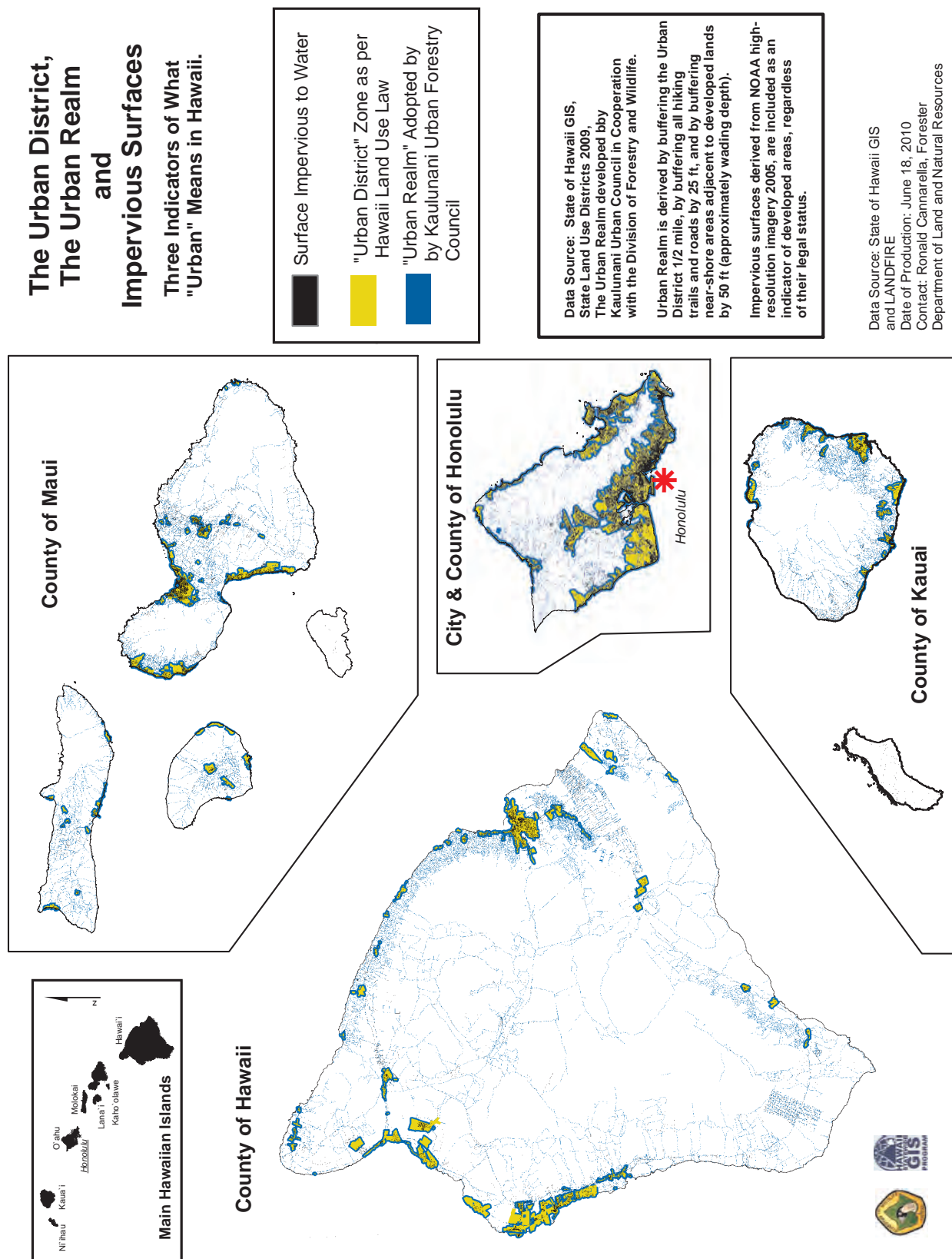
Kaulunani has grown from a program focusing primarily on tree planting projects and education, to one that engages in challenging topics such as invasive species control, the role of trees in shoreline protection and restoration practices, measuring the environmental benefits of street trees, and supporting chemical trials to control of the erythrina gall wasp.

#### **Invasive Species Weed Risk Assessment Development Project**

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 Hawaii-Pacific Weed Risk Assessment (HP-WRA) was developed with the intent of identifying plants that pose a high weed risk in Hawaii 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 one of the primary measurement systems predicting invasive plant probability across all ecosystems in Hawaii. (See Issue 2: Forest Health: Invasive Species, Insects and Disease for additional information.)

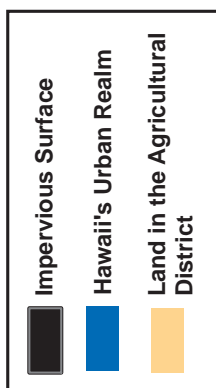
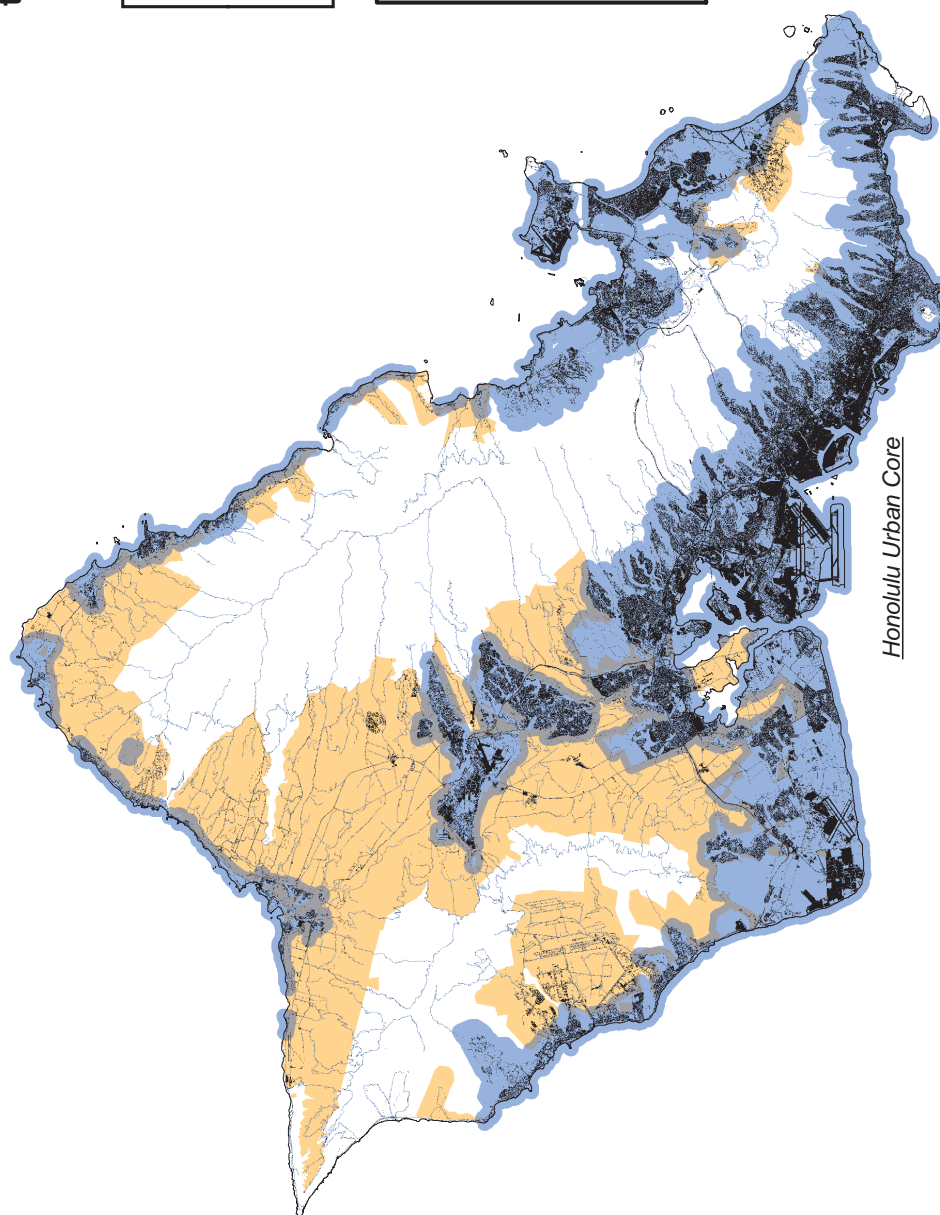
#### Hawaii's Urban Realm/Priority Areas

Urban forestry is about tree management in any area influenced and utilized by the urban population.<sup>3</sup> Islands ecosystems are more dramatically and intricately connected than those on



Map 4.1. The Urban Realm in Hawaii.

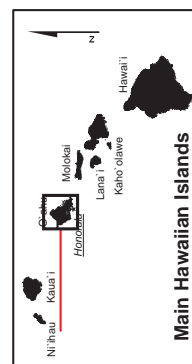
# Urbanized Areas and the Agricultural District Island of Oahu



Data Source: State of Hawaii GIS, State Land Use Districts 2009, The Urban Realm developed by Kaulanani Urban Council in Cooperation with the Division of Forestry and Wildlife.

Urban Realm is derived by buffering the Urban District 1/2 mile, by buffering all hiking trails and roads by 25 ft, and by buffering near-shore areas adjacent to developed lands by 50 ft (approximately wading depth).

Impervious surfaces derived from NOAA high-resolution imagery 2005, are included as an indicator of developed areas, regardless of their legal status.



Data Source: State of Hawaii GIS  
Date of Production: June 18, 2010  
Contact: Ronald Cannarella, Forester  
Department of Land and Natural Resources

Map 4.2. Map of the island of Oahu showing impervious surfaces including roads and buildings; the urban realm where people live, work and play; and the Agricultural District.



continents. Because of these tight connections, integrating urban forest issues into landscape and island-wide management efforts are necessary. The importance of the urban environment was echoed by partners and stakeholders stating that “*urban forest stewardship is critical to our forests and reefs*”.<sup>4</sup> Map 4.1 depicts the Hawaii Urban Realm; that area that urban forestry will focus. Map 4.2 depicts the urbanized areas and the agriculture lands on Oahu. These close proximity areas are one of the many reasons that urban forestry must be considered when prioritizing land management on other parts (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, a shady place to shelter from the sun, food, soil stabilization, increase property values, conservation and cultural benefits.



Figure 4.2, Monkey Pods, *Samanea saman*, are a staple in urban forests & provide significant

In 2006, Kaulunani funded an assessment of Hawaii’s urban trees utilizing the Street Tree Resource Analysis Tool for Managers (STRATUM) to gather baseline data on benefits of urban trees in tropical settings. Using STRATUM in The City & County of Honolulu Municipal Forest Resource Inventory, data from 43,817 street trees were analyzed by the Center for Urban Forest

Research, Pacific Southwest Research Station. Hawaii's urban trees were found to provide extensive environmental benefits. For example the annual environmental benefits were calculated at \$90 per tree, and provide \$2.98 in benefits for every \$1 spent on tree care. The replacement value of urban trees was calculated at \$1,665 per tree.<sup>5</sup> The report identified benefits such as electricity savings and climate effects, carbon storage, air pollution removal, and rain interception. A summary of the environmental benefits of trees in Honolulu are found in Table 4.1.

**Table 4.1: A summary of the environmental benefits of trees in Honolulu**

<b>Benefit</b>	<b>Value</b>
Electricity saved from shading & climate effects	\$343,356 or \$8/tree
Carbon storage	25,529 tons
Air pollution removal (ozone & sulfur dioxide)	21,441 lbs. or \$32,175
Rain interception – reduce runoff by 35 million gallons per year	\$350,104
Annual total benefit	\$3.9 million or \$90/tree
Based on 43,817 street trees	

### Present Conditions of Hawaii's Urban Forest

#### *Human Population and Urbanization*

Hawaii is approximately 4.1 million acres in size distributed over the main islands of Kauai, Oahu, Maui, Hawaii, and several smaller islands; Lanai, Molokai, Niihau, and the unpopulated Northwestern Hawaiian Islands. According to the July 1, 2009 census data, the State of Hawaii had a total resident population of 1,295,178 people and an average daily de facto population of 1,388,605 people. 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.<sup>6</sup>

Hawaii's population is concentrated in the Honolulu Urban Core on the island of Oahu, and the other Counties are primarily composed of small towns and rural communities. Table 4.2 shows the average daily de facto population in the State in 2008.

**Table 4.2 shows the average daily de facto population in the State in 2008**

<b>Year</b>	<b>State total</b>	<b>City &amp; County of Honolulu</b>	<b>County of Hawaii</b>	<b>County of Kauai</b>	<b>County of Maui</b>
2008	1,388,605	934,262	192,691	80,054	181,598

## Land Use

In Hawaii 48% of all land is zoned for conservation, 47% is zoned agriculture, and 5% is zoned urban. However, urbanization is occurring at a rapid pace on non-urban zoned lands across the State. Development and urbanization without conserving and planting trees contributes to many environmental issues including a decline in the quality and quantity of water, increases in erosion, pollution and sedimentation of coastal watersheds and damage to the near shore reefs. Poor development practices have resulted in the increases of impervious surfaces, which added to waste management issues. De-vegetation, top soil erosion and soil compaction has lead to more frequent flooding. Population growth and increased housing demands heavily impact existing resources resulting in pressure to change current zoning. In fact, the percentage of population (53%) living in coastal areas and the rising number of predicted high intensity storms has created highly vulnerable coastal areas.

### Coastal Readiness Project

Effects from the devastating tsunamis in the Indian Ocean showed that coastal communities with high tree density and appropriate species selection were not only more defensible to intense storms, but also more resilient. The disaster resulted not only from these tsunamis but also from the lack of coastal area preparedness for storm events. This prompted Kaulunani to assemble a committee of experts to investigate the issue in Hawaii. The committee included



Figure 4.3 Ironwood Trees, *Casuarina equisetifolia*, line Hawaii's shoreline on many beaches. Photo courtesy of Teresa Truman-Madriaga.

the Pacific Disaster Center, the University of Hawaii Civil Engineering and Tropical Plant and Soil Sciences Departments, arborists, landscape architects, Louisiana State University Department of the Coast and Environment, and the University of Florida. Phase One of this project was a global literature review of the role of vegetation and engineered defenses in coastal areas for the protection of people against tsunamis, hurricanes, cyclones and typhoons. This lead to a comprehensive report and database entitled, "The Protective Role of Natural and Engineered Defense Systems in Coastal Hazards:

Effectiveness of Vegetation for Mitigating the Coastal Impact Due to Storm Surges, Hurricanes and Tsunami," completed by Spatial Information Group LLC.<sup>7</sup> Phase Two focused on the investigation of the existence and arrangement of vegetation in several coastal areas in Hawaii and in Samoa after their recent tsunami in 2009. This information will be used to gain an understanding of the effects of vegetation on the reduction of ocean wave run-up, inundation and overall coastal vegetation resiliency.



**Impervious Surfaces of Maunaloa**

Map showing the distribution of impervious surfaces (red) across Maunaloa, overlaid on a topographic background. The map is divided into Ahupua'a boundaries (yellow lines). Key areas labeled include Wai'ala'e Nui, Wailupe, Niu, Kuli'ou'ou, Hahaione, Kamilo Nui, Ka'alakei, Kamilo Iki, Portlock, Kawaihoa, and Kūpikipikī'ō. The map also shows Maunaloa Bay and the coastline. A legend in the bottom right corner defines the symbols: Outlet to Ocean (red dot), Storm Drains, Streets & Impervious Surface (red line), Ahupua'a (yellow line), and Streams (blue line). An inset map shows the location of Maunaloa on the island of O'ahu. Data Sources: NOAA Impervious Cover, State of Hawaii GIS, Ahupua'a boundary layer defined by Mālama Maunaloa.

Figure 4.4 Impervious cover in the urbanized region of Maunaloa located in East Oahu. These surfaces, including streets, drainage canals, parking lots, driveways and rooftops cause excessive overland water flow into nearshore aquatic ecosystems. This decreases vegetation and groundwater percolation areas where water uptake and filtration occurrence restores hydrologic function of the urban watersheds of Maunaloa. Map courtesy of University of Hawaii, Sea Grant Extension Program.

### Invasive Species

The Hawaiian Islands are at risk from imported plants, insects and diseases. It is estimated that 10,000 plant species have been introduced in Hawaii, 200 of which have become environmentally harmful. Many more species worldwide could potentially become harmful if they are allowed to be introduced. Ninety-one percent of the invasive species found in the forest were intentional introductions to Hawaii.<sup>9</sup> (See Issue 2: Forest Health: Invasive Species, Insects and Disease for additional information.) Introduced pests and disease can cause devastating effects on upland/rural and urban trees. Recently, widespread death of *Erythrina* spp. (Wiliwili) trees was caused by the Erythrina gall wasp, a tiny insect that was only recently discovered. The wasps have created one of the most serious epidemics ever caused by an invasive species in Hawaii, and thousands of trees throughout Hawaiian forest have been victims of these tiny insects.<sup>10</sup>

#### Chemical Trials for Erythrina Gall Wasp Management Project



**Figure 4.5 Erythrina gall wasp damage**

The erythrina gall wasp was first detected in Hawaii on Oahu in April 2005. The insect quickly spread throughout the state infesting *Erythrina variegata*, *E. sandwicensis* and *E. cristagalli*. Extensive damage occurred throughout the state, including in urban and natural forests. Little was known about controlling this pest. The University of Hawaii (2007)<sup>11</sup> along with collaborative partners from the Department of Agriculture, the Department of Land and Natural Resources, and the USDA Forest Service conducted trials using different cultural and chemical treatments to control the gall wasp. Figure 4.5 shows damage from the erythrina gall wasp. The study found that there was not one perfect solution and all of them have advantages

and drawbacks. Injecting trees to inoculate them successfully required practice and was difficult to duplicate from tree to tree. Trenching showed little or no effects. The work to determine longevity of treatments and to improve reliability of treatment results following trunk injections is ongoing.

### Urban Forestry Tree Health & Best Management Practices

Hawaii's urban forest has a mixture of young and mature canopies. Like most cities there is a mixture of established new community developments. Some newer urban areas have a limited number or are devoid of trees. Frequent tree damage problems include topping, trimming, poisoning of street trees, charcoal damage to park trees, and asphalt or concrete proximity damage to root systems. Tree maintenance does not always follow the American National Standards Institute (ANSI) standards.<sup>11</sup> On a positive note federal and state contracts have



adopted the City and County of Honolulu's tree specifications that require qualified arborists to supervise tree work on military bases, along state highways, and on state property.<sup>12</sup>

#### *Tree Inventories*

There are no active inventories, other than at Schofield Army Base, in any Hawaiian county to measure or monitor tree health, form, structure and public safety.

#### *Tree Assessment*

There is no active assessment of the urban forestry canopy and there is an over dependence on a limited tree palette.

#### *Tree Best Management Practices*

Generally, some Best Management Practices have been implemented but are inconsistent with poor application in both the public and private sector.

#### *Public Relations and Education*

There is no overall marketing initiative regarding increasing an awareness of trees and the benefits that they provide. Urban forestry activities are celebrated on Earth Day and Arbor Day, are well received, and include public, private and nonprofit partners.

#### *Cultural Respect for Trees*

The cultural respect for trees is an important social norm in tropical areas. In many tropical areas forests provide not only food and shelter but also form an integral part of cultural and spiritual traditions<sup>13</sup> The use of native trees and culturally important trees in urban areas has not been promoted, although state legislation is in place that requires the planting of natives around public buildings whenever possible. There is also a lack of integration of tribal knowledge relating to urban trees and a need to develop a culturally appropriate strategy for restoring balance.

#### *Threats & Concerns in the Urban Forest*

The threats to the urban forest are extensive. Table 4.3 highlights threats and concerns from Council and stakeholder discussions and ties them to the Forest Service National Themes.



Figure 4.6. Winning poster representing Hawaii in the 2009 National Arbor Day Poster Contest. Artist 5<sup>th</sup> grade student from Mililani Mauka Elementary School.

**Table 4.3 Threats and Concerns to Urban & Community Forestry Linked to National Themes**

<b>Threats &amp; Concerns</b> ( Multi-state issues are identified with ** )	<b>Forest Service National Themes</b>
<b>Best Management Practices - Tropical Urban Forestry</b>	
• Overdependence on limited plant palette - monocultures**	1.2
• Treeless communities = reduced ecosystems benefits**	2.2
• Poor tree trimming = increased accidents or failure**	3.4
• Increased impervious surfaces = more heat islands**	
• Lack of knowledge about the urban forest canopy**	
• Lack of research on best tree species for tropical urban areas**	
• No working inventory used by any county to measure or monitor tree health, form, structure and public safety**	
• Inadequate tree replacement policies**	
• Low staffing & funding	
• Staff qualifications	
• Tree protection	
<b>Climate Change</b>	
• Increase in number and intensity of tropical storms **	1.1
• Decrease in water quality and quantity**	3.1
• Salt water intrusion in drinking water supplies**	3.5
• Inundation of wastewater treatment infrastructure	3.7
• Coastal sea level changes**	
• Increases in temperature = tree line changes, mosquito range increases, hyper evolution of species adapted, fecundity changes, etc.	
• Other as yet unknown impacts	
<b>Coastal Zone</b>	
• Shoreline erosion**	1.1
• Development and urbanization has increased in coastal areas, escalating the potential for significant shoreline damage and loss of life should storms occur	1.2
• Impacts of hazards on social groups such as homeless when storms occur as well as the ability to recover	2.2
<b>Economics</b>	
• Decline in tourism	
• Increase in fuel costs	
• Inadequate funding sources and rely too heavily on federal funds**	

<b>Table 4.3 Threats and Concerns to Urban &amp; Community Forestry Linked to National Themes</b>	
<b>Threats &amp; Concerns</b> ( Multi-state issues are identified with ** )	<b>Forest Service National Themes</b>
Education and Culture	
• Lack of awareness of the value of urban trees**	3.6
• Loss of indigenous knowledge**	
• Trees as source of food	
Funding	
• Lack of funding results in inadequate tree care, planning and missed opportunities at state and county levels	
Human Health	
• Concerns with food security including marine productivity	3.1
• Population increases	3.2
• Poverty**	3.3
• Oil Scarcity	3.7
• Genetically Modified Organisms	
Invasive Species	
• Continued use of invasive species in the urban landscape	2.2
• Concerns of new urban forest pests and ability to quickly respond	
• Codes of Conduct not widely used or accepted	
• Lack of understanding regarding pathways for tropical invasive and exotic species**	
Policy & Planning	
• Legislation for parking lot trees needs to improve	
• Agency inconsistencies	
• Lack of planning relating to urbanization and population increase	
• Land use trends	
• Concerns with continued use of impervious surfaces	
• Need for local and regional ordinances to implement comprehensive land use plans **	
• Need for GIS tree inventories, assessments, and mapping to reflect composition and baseline values**	
• Need for more tree planting or demonstration projects	
Urban Sprawl	
• Demands for urban sprawl influence land use policy and degrade ecosystem services	

<b>Table 4.3 Threats and Concerns to Urban &amp; Community Forestry Linked to National Themes</b>	
<b>Threats &amp; Concerns</b> ( Multi-state issues are identified with ** )	<b>Forest Service National Themes</b>
• Loss of Agriculture lands	
• Land use trends	
Watershed/Water Issues	
• Urban is not an active partner in <i>ahupuaa</i> management	
• Dedicate resources to address priority watersheds	
• Need to address sediment and polluted runoff, work to increase pervious surfaces**	
• Poor water quality	
Wildfire	
• Wildfire Fuels - grasses	2.1
• Urban / wildland interface concern with fuels and fire	

### Trends & Opportunities

There is growing local and national support for increasing the urban forests efficiency in the infrastructure. Fortunately, the trend in Hawaii is towards adopting a 21<sup>st</sup> Century *ahupuaa*: A culturally appropriate and biophysical paradigm for restoring balance and sustainability to our communities. The wisdom of our native Hawaiian ancestors, coupled with technological innovations of today, will make our islands sustainable for the future.

#### *IslandAbility—Living Pono*

The need for Hawaii to be more sustainable and the urban forestry industry to be more proactive has been echoed throughout the industry. The subcommittee of the Urban & Community Forestry Council that was established to focus on this Statewide Assessment labeled the effort “IslandAbility” which echoes Living *Pono*. *Pono* is one of the values that we have embraced from the native Hawaiians that stresses living right with the land and the sea, living in harmony with each other, being sustainable, having a good quality of life and having prosperity. The name “*Hawaii*” itself means breath, water and creative energy.

#### *Green Movement*

There is increased public interest in the green movement, ecotourism and awareness of the environment. This creates an opportunity for urban forestry to link to the visitor industry. Funding for urban forestry projects could be attained through federal, state and local sources such as Hawaii Tourism Authority, Livable Communities grants, U.S. Forest Service, Department of Transportation (DOT), Department of Housing and Urban Development (HUD), and Environmental Protection Agency (EPA) grants. Hawaii could consider incorporating biofuels, vertical landscaping, green roofs, use of permeable surfaces, and increased use of native



species and non invasive plants. New legislation could be considered such as Complete Streets and Sustainable Transportation. Construction ordinances with mandatory pervious surfaces, revised and updated landscape ordinances, and stormwater management legislation should be enacted. Urban development, and land use trends (changes in the use of agriculture lands) combined with the economic crisis and a heightened awareness of environmental issues could lead to more support for the effective use of trees and innovation in the landscape.

#### Water

Water is a primary factor in regards to aquifer and well recharge, smart channeling, reef health and other environmental concerns. Water quality and quantity are all affected by urbanization. Using trees in urban area can positively affect all of these factors.

***“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.”***

Quote from “A Model for Urban Forest Sustainability” Jim Clark, et.al.<sup>14</sup>



Figure 4.7. Hawaii stream, just above, or mauka of residential area.



### Priority Areas and Issues

The following represent priority landscapes and issues identified by the Kaulunani Council in collaboration with representatives from our Pacific Island colleagues, partners, and stakeholders at the Tropical Urban Forestry Summit held in Honolulu on November 4-5, 2010.

#### *Spatially Explicit Priority Issues*

1. Urban, rural and agriculture zoned lands
2. Buffer zones - including trails into uplands and marine areas
3. Canopy assessment data
4. Urban/coastal zone interface
5. Future urban development
6. Highly polluted bays overlapped with prime tourism destinations
7. Impermeable surfaces
8. Invasive species in the urban/wildland interface as a point of entry
9. Priority Watersheds: most impacted; most pristine; those within a certain area (not upland ones)
10. Stream channels that run through urban realm
11. The Wildland/Urban Interface (WUI)
12. Non geospatial priority issues
13. Improve best management practices for the tropics
14. Emphasize cultural aspects of urban trees
15. Improve economic stability & create green jobs
16. Focus on creating a sense of place such as the Lei of Green concept
17. Increase the emphasis on public awareness, education and outreach
18. Examine, revise and implement tree ordinances & guidelines
19. Improve policies and planning
20. Conduct exploratory and baseline tropical urban forestry research
21. Advance quality of life issues by demonstrating the benefits of green infrastructure

#### Needed Tropical Urban Forestry Research, Gaps & Opportunities

1. Tropical Urban Forestry Research
2. The need for research on tropical urban forests was noted not only in Hawaii, but also at the Tropical Urban Forestry Forum in Puerto Rico in 2008. The resulting report advised the Forest Service to support research and technology transfer by developing a tropical urban forestry strategic plan.
3. A model for island-wide land use plans.
4. Research at the local level.
5. Standardized tropical nursery standards and inclusion of all tropical islands in the Forest Service Inventory.
6. Strategies to share research across disciplines and networks.
7. Assess the urban canopy and identify the environmental benefits of trees.
8. Inventory the number and tree species in the tropical urban forests.

9. Identify examples of green infrastructure for island ecosystems.
10. Assess tropical root structures and benefits.
11. Assess environmental benefits of urban trees across the state.
12. Research important maintenance needs for tropical urban forests.
13. Develop alternatives to minimize risks associated with monocultural landscapes and buffering critical root zones.
14. Identify the entities in Hawaii working on sustainability and identify where there is an overlap with urban forestry.
15. Map the historic path of devastating hurricanes, floods, tsunamis, and storm surges and you will also find some of the fastest growing communities.
16. Identify the type of tropical urban forestry research needed. Such as: recommended tree species for the tropical urban forests; examples of good green infrastructure for island ecosystems; Roots structures and benefits for storm runoff; an Urban Forest Effects Model including assessment of the entire tree benefits across the state and a canopy assessment; information on trees; identification of a numerical target for forest cover; and a model for energy savings based on the cooling and shade that trees provide.
17. Map invasive species through the urban communities, and point of entry.
18. Examine and revise policies, ordinances, and best management practices across the state.
19. Create urban forest management plans at the county and state levels.
20. Create a better understanding of green infrastructure in tropical urban environments.

Maps to identify:

1. Invasive species in the urban/wildland interface
2. Urban/watershed impacts
3. Urban/coastal impacts
4. Canopy assessment
5. Exceptional trees
6. Historic path of devastating hurricanes, floods, tsunamis, and storm surges with communities especially the fastest growing communities.
7. Identify the true economic and social costs of not implementing green infrastructure practices (including the cost in pollution, lost visitor dollars, etc.).

Summary

Hawaii's trees are a dynamic resource. Tropical urban forests have a critical role to play in island communities. Using trees as green infrastructure in the watershed addresses water quality and quantity, reduces storm run-off, cools "heat islands" by providing shade, and improves human health. The need for Hawaii to be more sustainable and for the urban forest industry to be more proactive has been voiced. A number of issues that are of highest concern include: the importance of measuring the tree canopy; the need for tropical urban forestry research; the need to educate the community about trees and gain their support; the lack of the use of trees and vegetation to intercept and catch water; and, the need to update the infrastructure using tested tools such as green roofs, permeable paving, bioinfiltration and rain gardens, drainage swales, and naturalized detention basins. Coupled with these concerns are worries about loss of

agriculture lands and food security, the number of communities without trees, the lack of basic tree inventories and canopy assessments, and a lack of a plan to achieve these goals collaboratively. This assessment and the strategy provide the road map.



Figure 4.8. This Monkey Pod Tree (*Samanea saman*) is one of Hawaii’s nationally recognized “Exceptional Trees” at Moanalua Gardens. Photo courtesy of Kevin Eckhart

# Strategy Matrix for Issue 4: Urban & Community Forestry

## Strategies for Issue 4: Urban & Community Forestry

The Hawaii Urban & Community Forestry Program (Kaulunani) recently updated its Strategic Plan incorporating input from a number of stakeholder meetings, including the Urban Forestry Summit held in Honolulu in mid 2009. Representatives from various Hawaiian professional groups and agencies attended this summit; as well as number of people from the Federated States of Micronesia and the Commonwealth of Mariana Islands. The strategies and priority landscapes identified below strive not only to define issues and spatial priority areas related to urban forestry issues in Hawaii, but they also demonstrate those vulnerable areas that are also corridors for invasive species from many entry points in these islands. Urban areas simply cannot be held to the same standards that other areas are held to. Urban areas are the most vulnerable, and the most human populated, and the most impacted of any areas & ecosystems in Hawaii. It is important to note that many of the issues portrayed below are highlighted in most of the other US Pacific and US Caribbean Island Assessments and Strategies. Please see the Reference Section pertaining to the US Tropical Islands for more details.

Urban and Community Forestry: Improve Spatial & Vegetative Understanding of HI Urban Forests Through Technology						
Long Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success
1) Acquire the "Urban Canopy Assessment & Inventory" from UV/USFS; used with local existing satellite & LiDar imagery	See State-Wide Urban Realm Map	Partner on imagery & get it utilized more by urban groups; carbon credit programs; stimulate use of (UFORE, STRATUM), UH Blue Line	HI Counties, FSCG, U&CF grants, UH, City of Honolulu Arborists, C&C, AAA, CZM	Counties, State Utility Companies, private landowners, DOD, DOT, Na Ala Hele, DAR	TNC, State & National Parks, Non-profits, Friends of Urban Forests, HCA, HFIA, HISC, CGAPS, Friends, SOPAC, HARC, SAF, HFIA, FSCG	Define vegetation imagery at a micro & macro-scale; Impact growth of Kapolei?; Education efforts focus on city planners & policy makers; Impact how \$ is spent.
2) Establish a tropical urban & community forestry research center (virtual / internet based is a real potential)	Global tropical island impact potential.	Tropical island research, conservation technology & education integration; Children's Forest	FSCG, U&CF, SPREP, CZM, NOAA, F&WS, NRCS, HFIA, AAA, PSW, Forest Service, HARC	HI C&C Gov., UH, US & International Pacific Islands	PSWRS, UH, Arboretums, Botanical Gardens, Non profits, FHUF, FAO, SPREP, SPC, Friends, SPOAC, HFIA, SAF	Research strategic plan completed; protective mechanisms in place in more islands across Pacific; political impact/money, more biocontrols.
3) Take advantage of existing imagery / previous efforts to examine specific areas of interest	See State-Wide Urban Realm Map – likely a highly motivated community.	Partner on imagery & get it utilized more by urban groups; carbon credit programs; stimulate use of (UFORE, STRATUM), UH Blue Line	HI Counties, FSCG, U&CF grants, UH, CHA, Any county not included in #1, AAA	Counties, State Utility Companies, private landowners, DOD, DOT	TNC, State & Nat. Parks, Non-profits, Friends, HCA, HFIA, HISC, CGAPS	Define vegetation imagery at a micro scale; have a REAL impact on policy decisions at the local scale.
						Supports National Objectives 1.2 3.4 1.1 1.2 2.2 3.1 3.2 3.4 1.1 1.2 2.2 3.1 3.2 3.4

**Strategies for Issue 4: Urban & Community Forestry**

Urban and Community Forestry: Local, Regional, National and International Outreach							
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Implementing Partners	Measures of Success	Supports National Objectives
1) Develop, introduce, implement and integrate the HI State-wide Environmental Literacy Plan with other Pacific CE plans.	Industry, School Age Students, Public, and Tourists	Learn about climate change issues & mitigation technologies elsewhere in the Pacific.	UCF, CE, FSCG, HI Counties, FSCG, U&CF grants, UH, C&C, AAA	Practitioners, scientists, non profits, governments, Hawaii Tourism Authority	Use UCF grant for inventory. Private/stakeholder donations, SOPAC, YCC, DOFAW EE, HFIA, SAF, FSCG, HEEA	Execution, dissemination and or Implementation of the State ELP. Sink actions with the FSM Micronesian Challenge. Take any CE plan to the next level.	1.2
							2.2
2) U&CF management plans for all major cities in Hawaii.	All Hawaii counties	Identify plans, policies, ordinances, rules and laws impacting Hawaii's urban forest, sink actions with the Micronesian Challenge.	UCF, CE, FSCG, HI Counties, FSCG, U&CF grants, UH, C&C, AAA	Public, policy makers, county parks, county arborists county planning, practitioners	Counties, non-profits, UCF funds, University, SOPAC, HARC, HFIC, FSCG	UCF management plan template developed and implemented;	2.2
							3.4
3) Discuss new BMP's with EPA as they affect parks and public lands so they can- mitigate environmental impacts of urbanization.	Watersheds, areas with high impervious surfaces.	Base line research for tropical low impact development tools; Future plans, resource agency BMP updates.	Watershed, DOFAW, UCF, HI Counties, FSCG, U&CF grants, UH, City of Honolulu Arborists, C&C, AAA	Counties, watershed partnerships, University, USACE	Watershed partnerships, use UCF funds, University CTAHR, Counties, non profits, SOPAC, FSCG	New standards for low impact development developed; develop new BMP's for urban areas such as grating standards or 'green' LEED development.	2.2
							3.1
4) Children's Forest	Statewide	Invasive spp. control. Hunting vs. native spp. devastation.	UCF, CE/EE, FSP, FH	Private landowners, UCF, FSCG, HISC,	ELP, SAF, HFIA, HCA, TNC		3.1 2.1 3.4
5) Demonstration urban-watershed project	Id partners, project site and urban watershed.	Collaboration with watershed partners.	U&CF, watershed partners	UCF, watershed partners,	Watershed partners, UCF to fund trees	Template for urban-watershed projects.	3.1 3.4 3.6



# Strategies for Issue 4: Urban & Community Forestry

Urban and Community Forestry: Climate Change, Coastal Watersheds & Carbon Sequestration							
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success	Supports National Objectives
1) Mitigate impacts of invasive species from the urban forest on native ecosystems.	Urban invasive species outbreaks in the urban & upland areas, industrial areas, ports, nurseries & botanical gardens.	More native and non-invasive plants in trade; grower rewards.	State, U&CF, competitive grant	Private nurseries, UH, colleges, botanical gardens, ASLA, DLNR, DOFAW, HI Invasive Species Committee	State, federal, UH, CGAPS, Use UCF grant for inventory. Private/stakeholder donations, SOPAC, YCC, DOFAW EE, HFIA, SAF, FSCG	Mapped invasive species in urban/wildland interface.	2.2 3.6
2) Use trees as a tool to mitigate the effects of sea level rise.	Vulnerable urban forest areas based on sea level rise.	Tree species in coastal area, urban planning, research hypotheses development.	UCF, Coastal, western competitive grant	State, County, U&CF	State - Office of Conservation and Coastal Lands, UCF funds, FSCG	Vulnerable areas and appropriate coastal tree species.	3.4 3.6 3.7

## Acronyms Used:

1. CZM – Coastal Zone Management
2. OHA – Office of Hawaiian Affairs
3. C&C – City & County of Government of Hawaii
4. AAA – Aloha Arborists Association
5. NARF – Natural Area Reserve Fund
6. Friends – Friends of Urban Forests
7. FRS – Forest Reserve System
8. DOFAW – EE – Environmental Educational
9. HARC – Hawaii Agriculture Research Center
10. LLCF – Legacy Land Conservation Program
11. FLP – Forest Legacy Program – Forest Service
12. FSCG – Forest Service Competitive Grants
13. DAR – Division of Aquatic Resources
14. Na Ala Hele – State Na Ala Hele Trails & Access Program
15. HISC – Hawaii Invasive Species Council
16. FSP – Forest Stewardship Program
17. CGAPS – Committee Group on Alien Pest Species
19. HCA – Hawaii Conservation Alliance
20. IPIF – Institute of Pacific Island Forestry
21. UCF – Urban & Community Forestry (Kaulunani)
22. NOAA – National Oceanographic and Atmospheric Administration
23. USGS – US Geological Service
24. YCC – Youth Conservation Corps
25. STDP – Special Technology Development Program
26. PSWRS – Pacific Southwest Research Station
27. HFIA – Hawaii Forest Industry Association
28. SPC – The Secretariat of the Pacific Community
29. SPREP – South Pacific Regional Environmental Program
30. FAO UN – Food and Agriculture Organization of the United Nation
31. SOPAC – Secretariat of the Pacific Applied Geoscience Commission
32. HFIA – Hawaii Forest Industry Association
33. SAF – Society of American Foresters
34. HEEA – Hawaii Environmental Education Alliance
35. ELP – Environmental Literacy Plan
36. BMP – Best Management Practices

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## Issue 5: Climate Change/Sea Level Rise

### Overview: Hawaii's Changing Climate

According to the Intergovernmental Panel on Climate Change (hereafter, IPCC), global average temperatures have risen by 1.5°F since 1970 and can be expected to rise another 2-11°F by the end of the 21<sup>st</sup> 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.<sup>1</sup>

Mounting evidence indicates that Hawaii'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 a stronger warming at higher elevations (See Figure 5.1).<sup>2</sup> The increase in average annual temperature is largely due to an increase in minimum temperatures. This response to global climate change is consistent with similar trends observed in North America.<sup>3</sup>

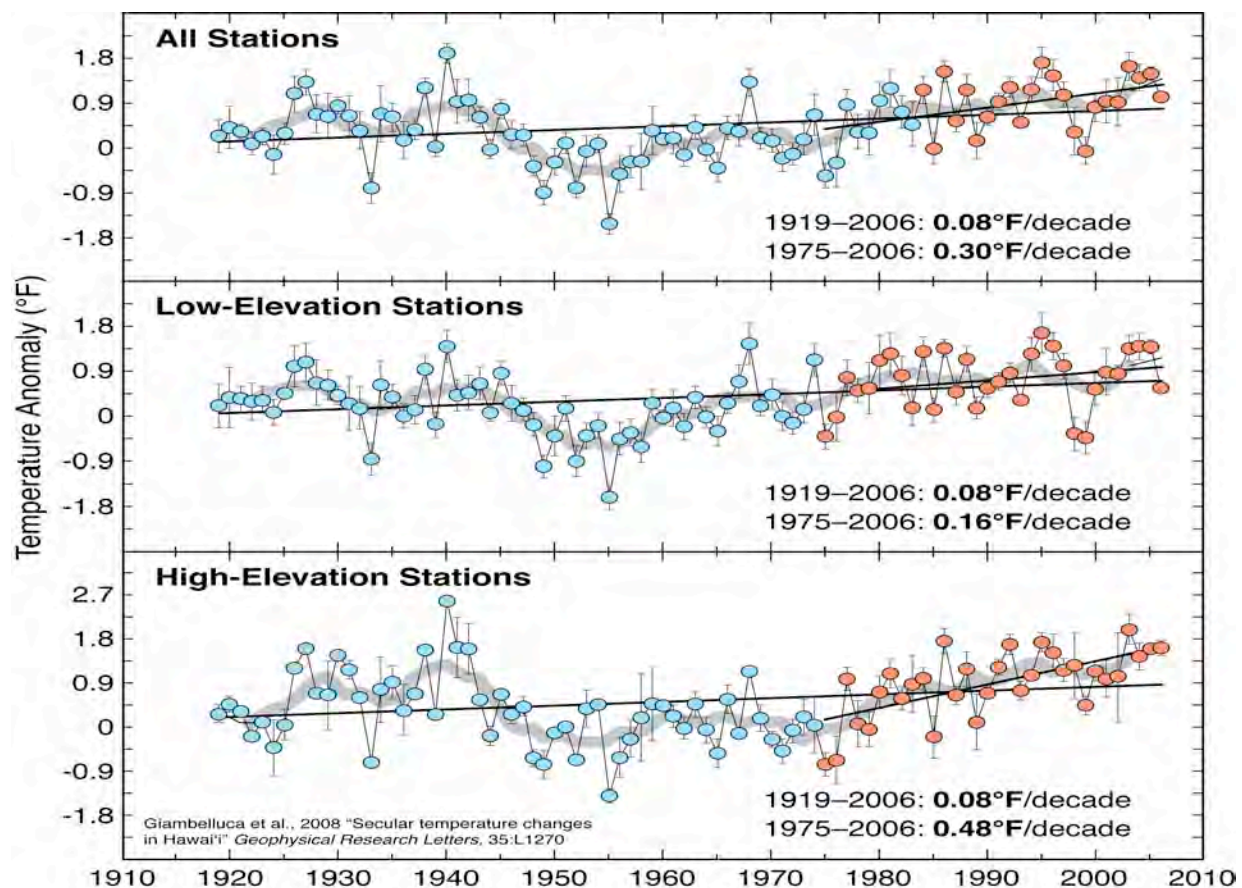


Figure.5.1: Data show a rapid rise in air temperature in the past 30 years (averaging 0.3°F per decade), with a stronger warming at higher elevations.

Along with an increase in surface air temperature, documented climate changes in Hawaii include:

1. decreased rainfall and stream flows,
2. increased rain intensity,
3. sea-level rise,
4. rising sea surface temperatures, and
5. ocean acidification.<sup>4</sup>

Because changes in Hawaii's climate will continue and intensify, scientists anticipate growing impacts to water resources, forests, marine systems, the economy, and coastal communities.

*In Hawaii, based on current data and trends, climate change will:*

- Reduce the amount of fresh water available
- Decrease Hawaii's forest health and biodiversity
- Increase the frequency, size, and intensity of wildfires
- Increase flash flooding, land slides, agricultural losses, and infrastructure damage
- Negatively impact beaches, coral reefs and key marine resources on which the State's economy depends

Although climate change threatens forest health, Hawaii's forest resources, appropriately managed, have the potential to mitigate global climate change and promote resilience for 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.<sup>5</sup> 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. Though mitigation is essential to promote a productive global future, climate change is already impacting Hawaii. 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.<sup>6</sup> Presently, Hawaii's forests offer many benefits that will help safeguard Hawaii'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 Hawaii, 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 Hawaii'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 requires a high level of collaboration and cooperation among state and local agencies, federal and community partners. It is critical to engage stakeholders, the public, educators and learners, and policy decision-makers because of the interconnections between human and natural systems.

### Threats & Trends

*Decreased rainfall has reduced the quantity of freshwater resources.* Perhaps nothing is more critical to life in the islands than rain, and in Hawaii, shallow cumulus clouds formed by trade winds are the most reliable and abundant source of rainfall.

Atmospheric circulation in the tropical Pacific has decreased due to global warming, and while 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 rainfall has steadily declined (about 15%) over the past two decades.<sup>7</sup> 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).<sup>8</sup>



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

Rain recharges groundwater aquifers, which are the principal sources of municipal water supplies in Hawaii. Groundwater also feeds Hawaii's streams and provides water for agriculture and aquaculture systems. Base flow of streams supplied by groundwater discharge has declined around the state since the early 1940's likely due to decreased rainfall.<sup>9</sup>

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 impact water resources already being affected by reduced rainfall.<sup>10</sup>



*Rising air temperatures and decreased rainfall threaten forest health and biodiversity.*

In Hawaii, 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 to the state's biodiversity are of particular concern considering many of Hawaii's endemic species are specialists, and many are restricted to small geographic areas with limited populations.

In Hawaii, temperature increases are not consistent at all elevations. For example, at elevations below 2600 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 2600 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 forest occurs 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, which have devastated the Hawaiian avifauna at lower elevations. Finally, this pattern will likely result in lower 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. The second will result in a reduction in disease-free forest and the latter will prevent the establishment of forest above the current tree line<sup>11</sup>. Thus, only those 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.

*A warmer, drier climate puts Hawaii at risk for larger and more frequent wildfires.*

Although it remains unclear how wildfire behavior and frequency will change in Hawaii 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.<sup>12</sup> Warmer, dryer weather causes fires to spread more quickly, particularly when associated with high winds. In Hawaii, rainfall is expected to decrease during the winter and early spring months (historically, the rainy season), a change which may lead to a longer wildfire season. Such an increase in the duration of wildfire season has already been observed in western states.<sup>13</sup> In addition to the increased suppression costs and potential economic damages, changes in fire severity would affect vegetation distribution and forest condition, and increase the risk to property, natural resources, and human life.



Figure 5.3. Healthy coral reefs are vital to our economy, our environment and our culture. Photo Chip Fletcher.

*More severe tropical storms and increasing rain intensity pose challenges for disaster mitigation and management.*

While global climate change will result in a reduction in freshwater, rain and storm intensity will likely increase. Typhoons and hurricanes will become more forceful, with larger peak wind speeds and greater precipitation.<sup>14</sup> Warming will cause the global averaged intensity of tropical cyclones to increase by 2–11% by 2100. Modeling consistently projects decreases in the global averaged frequency of tropical cyclones, by 6–34%, although the frequency of the most intense cyclones is predicted to increase.<sup>15</sup> Such storms can devastate forests, as well as threaten Hawaii'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.<sup>16</sup> In 1992, Hurricane Iniki forceful demonstrated the destructive force of cyclones on Hawaii when it struck the island of Kauai with sustained winds of 130 mph and caused over \$2.3 billion in property damage.<sup>17</sup>

Rain intensity is also increasing. Between 1958 and 2007, the amount of precipitation in the heaviest 1% of all rainstorm events in Hawaii has increased approximately 12%.<sup>18</sup> Intense rains result in flash flooding, mudslides and debris flows, road and business closure, infrastructure damage, and loss of public services especially to isolated communities. In March 2006, 41 straight days torrential rains caused over \$80 million dollars of damage in Manoa Valley and Laie on Oahu, cut off town of the town of Hana from the rest of Maui for weeks, and swept houses off their foundations in Hilo, Hawaii. While these events cannot be directly tied to global warming, they illustrate the severe impacts associated with intense rains.<sup>19</sup>

*Sea-level is rising, impacting beaches, coastal forests, and human communities.*

Long-term sea-level rise will exacerbate coastal erosion, coastal flooding, and drainage problems, all of which are occurring in Hawaii. Sea level in Hawaii has risen at approximately 0.6 inches per decade over the past century<sup>20</sup> and probably longer.<sup>21</sup> 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.<sup>22</sup> Shoreline retreat, larger storm surges, and water-table salinization will likely diminish the health and integrity of forests and wetlands close to sea level.<sup>23</sup>



Figure 5.3 Unusually high tides, like this one in Waikiki Beach will become more frequent as sea level rises. Photo Chip Fletcher.

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.<sup>24</sup> Approximately 25% of beaches on Oahu 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 one foot per year.<sup>25</sup> On Kauai for instance, 72% of beaches are chronically eroding and 24% of these are 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 three feet above the 1990 level by the end of the 21<sup>st</sup> century.<sup>26</sup> 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. While extreme tides already cause drainage problems in developed areas, Hawaii's communities located at the confluence of intensifying storm runoff and rising ocean waters will endure increased flooding.<sup>27</sup>

*Combined, the effects of climate change add to 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. Higher sea levels, as well as accelerated beach erosion, greater damage from sea surges and storms, and reduced water supply will likely impact coastal tourism.<sup>28</sup> Two additional climate-related factors, increasing sea surface temperature and ocean acidification, are likely to affect marine ecosystems and, thus, the economy.

Marine researchers at the University of Hawaii 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.<sup>29</sup>

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 Hawaii has grown more acidic.<sup>30</sup> 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 impact coastal communities, tourism, fisheries, and overall marine biodiversity.

### Benefits of Forestry

If managed properly, Hawaii's forests will help to mitigate the effects of climate change and promote adaptation and resilience for Hawaii's communities.<sup>31</sup>

### *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, under-story vegetation, and soil. Globally, forests contain 1.2 trillion tons of carbon, just over half the total in all terrestrial vegetation and soils.<sup>32</sup> 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 could be achieved by reducing deforestation.<sup>33</sup> Although deforestation is not a major source of greenhouse gas emissions in Hawaii, 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: Multi-State Issues for additional information.*).

### *Climate Change Adaptation*

Healthy forests and sustainable forest management can decrease the vulnerability of Hawaii'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 reports 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.<sup>34</sup> The leaf litter helps maintain high infiltration rates in the soil, preventing runoff and soil erosion, 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.<sup>35</sup>

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 reduce land-based sources of marine pollution, which are the primary causes of coral reef ecosystem degradation. Coral reefs are a source of subsistence fishing and harvesting, as well as vital tourist income for island destinations, and are frequently essential in protecting low-lying islands, such as those in the Pacific and Indian Oceans, from storm surges even where man-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 Hawaii'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 freshwater availability in forests, as well as

prevent the spread of avian diseases.<sup>36</sup> (See Issue 2: Forest Health: Invasive Species, Insects and Disease and Issue 6: Conservation of Native Biodiversity for additional information.)

### Priority Areas and Issues for Climate Change/Sea Level Rise

The large-scale nature of climate change, combined with the importance of coordinating management at an ecologically meaningful scale, indicates that coordination within and between state and federal agencies will need to improve. Although growing evidence of a changing climate has catalyzed new discussions among state and local agencies, non government organizations (NGOs), scientists, universities, and federal partners regarding the need to collaborate to develop workable solutions to climate change, adaptation and mitigation planning is still in the earliest stages in Hawaii.

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; Waikiki Beach is by far the most important source of employment and revenue in the state; the commercial shipping facilities and Honolulu International Airport are all located on the coast; and some of the nation's most strategically important assets including Kaneohe Bay Marine Corps Base, Pearl Harbor Naval Station and Pearl Harbor Naval Shipyard. The emerging consensus in Hawaii and the Pacific islands is that we will face a suite of challenges due to climate change; but the most immediate threat, and the one that we can most directly address is sea level rise.

The State of Hawaii's Ocean Resources Management Plan (ORMP) Working group, an interdisciplinary group established by the Office of Planning and the Coastal Zone Management Program, has recently directed efforts to climate change adaptation. Though ORMP is ocean-focused, its members include a range of stakeholder groups, including county planning departments, some state departments and offices, federal partners, and the Hawaii Conservation Alliance. The Center for Island Climate Adaptation and Policy at the University of Hawaii works in partnership with the ORMP working group to support their efforts. In November 2009, the Group released a collaborative document, A Framework for Climate Adaptation in Hawaii,<sup>37</sup> to encourage and facilitate the adaptation planning process. The document initially identifies planning areas relevant to climate change and describes some potential climate change impacts and considerations for each area. The ORMP working group is innovative and represents the kind of partnerships essential to a coordinated approach to climate change adaptation and mitigation. However, the group does not encompass all sectors and program areas vulnerable to climate change. It also lacks adequate resources to complete a comprehensive vulnerability assessment and implement a statewide adaptation plan.

Another example of collaboration that will enhance Hawaii's capacity to adapt to climate change is a partnership between the Hawaii Conservation Alliance (HCA), and the newly formed Pacific Islands Climate Change Cooperative (PICCC). See Map 5.1 for the PICCC region. Together, HCA and PICCC are developing scientific assessments of climate change impacts on physical and ecological systems at a scale relevant to conservation planning.<sup>38</sup>



With additional support and collaboration, state and local entities, federal and community partners, can develop statewide adaptation strategies and adjust management practices to ensure a productive future for Hawaii. As 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, the process 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 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.<sup>39</sup>

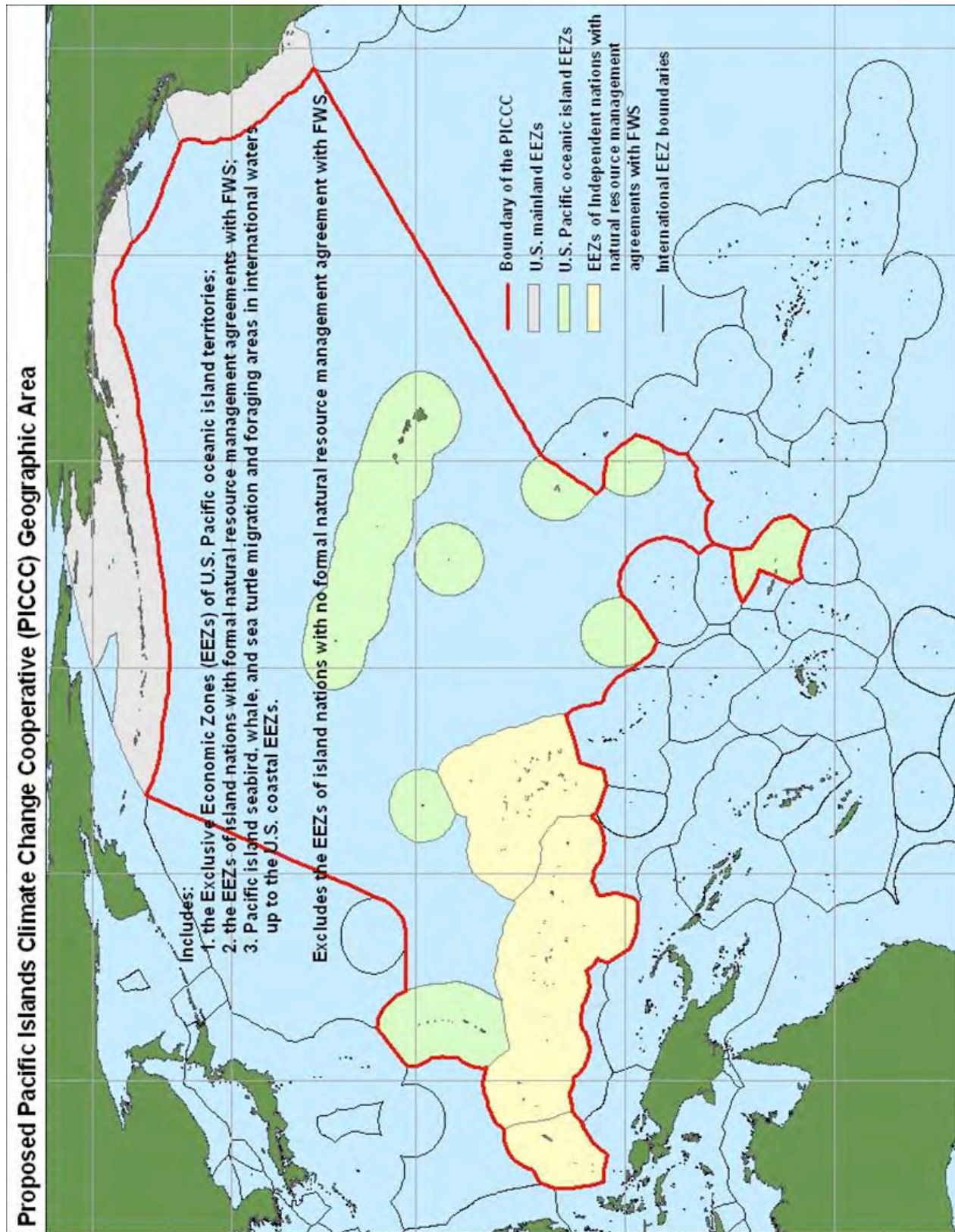
Since the potential for uncertainty and controversy associated with climate change could be high, state agencies should consider public participation planning and strive to improve the public’s understanding of the impacts of climate change. Gaining public support or acceptance is prerequisite for making successful adjustments in management plans and policies as a result of observed or anticipated climate changes.

#### Data Gaps

Despite the certainty that climate change is currently 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. Successful adaptation strategies in Hawaii will require intimate knowledge of the local economies, culture and ecosystems and attention to less obvious changes such as carrying capacities, wildfire, climate-driven immigration, disease-vectors and invasive species. 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. Observing trends and modeling the future impacts of climate change on forest systems and resources requires localized data collection. It is imperative to set up instrumentation to fill existing climate and biodiversity data gaps and monitor climate and ecosystem variables in the future.

Though some climate models exist for the Pacific region, the diversity of microclimates in Hawaii 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 over multiple climate scenarios.



Map 5.1 Proposed PICCC Geographic Area

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 Hawaii. 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.<sup>40</sup>

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 Hawaii's residents and communities depend. It is necessary to: (1) determine the degree to which natural and built systems are directly or indirectly affected by changes in climate conditions; and (2) assess their ability to accommodate changes in climate with minimum disruption or minimum 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.

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 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.

## Strategy Matrix for Issue 5: Climate Change/Sea Level Rise.

## Strategy for Issue 5: Climate Change/Sea Level Rise

To effectively understand and respond to climate change, Pacific Islands need climate modeling and ecological knowledge in order to identify how climate change impacts are affecting natural systems, encourage community and environmental infrastructure operations across planning sectors, and utilize key resources that enable change at many levels. Because no one agency can collect the variety and amount of data necessary to monitor climate and ecosystem changes, sharing information among partners and the public is mandatory in planning for climate change adaptation and coordinating landscape-scale conservation.

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
1) Develop and implement a coordinated Statewide Instrumentation Improvement Strategy (SIIS) to identify data gaps and enhance data collection and monitoring systems.	Statewide	Affect future policy pertaining use practices in upland, coastal and marine areas. Focus broad environmental education messages.	Fire & Aviation, Forest Health Protection, UCF, Conservation Education, schools, volunteer groups, FSCG	HCA, Pacific Islands Climate Change Cooperative (PICCC), USFWS, NPS, USDA, HDOA, DOT, TNC, NOAA Office of Ocean & Coastal Resource Management, DOD, CWRM, UHSOG, USGS, NWHL, EPA, USACE	USFWS (on NWHL), USGS, UHSOG, NOAA and National Weather Service, NASA, USDA Forest Service, IPIF, USACE, CAO, DAR	New instrumentation 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.
2) Assess the vulnerabilities, risks, and opportunities for important resources, infrastructure, and ecosystems using knowledge of trends and future scenarios of climate change.	Urban and coastal zones; targeted upland areas.	Affect future policy pertaining use practices in upland, coastal and marine areas. Material for better grant applications.	UCF, Forest Health Protection, Watershed Partnerships, Fire & Aviation, EQUIP, WHIP, FLP, FSP, FSCG	HCA, NOAA Pacific Services Center, OHA, DOD, HTA, USFWS, NPS, DOT, HDOA, TNC, DPCM, DPCM, DPCK, BWS, C&CH, DOH, MCZAC US Army Corps of Engineers, UHSG	PICCC, IPIF, Center for Island Climate Adaptation and Policy (ICAP) at UH, DOFAW staff, DAR	Describe exposure, sensitivity, and capacity to adapt to climate change scenarios for ecosystems, resources, and landscapes; Prioritize actions among program areas with the most beneficial outcomes based on assessments of and management activities.
						3.7 3.6



Strategy for Issue 5: Climate Change/Sea Level Rise

Climate Change: Develop Adaptation Strategies & Outreach Activities						
Long Term Strategy	Priority Landscape Areas	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Partners	Measures of Success
1) Develop and implement facilitated adaptation strategies for forest and resource conservation management; monitor effectiveness; continually incorporate new information; and, adjust actions as needed.	Urban and coastal zones; targeted upland areas.	Development of Best Management Practices for Climate Change Remediation.	UCF, Forest Health Protection, Watershed Partnerships, Fire & Aviation, EQIP, WHIP, FSP, FLP, HAWP, FSCG	HCA, NOAA Office of Ocean & Coastal Resource Management, NOAA Pacific Services Center, OHA, DOD, HTA, USFWS, NPS, DOT, HDOA, TNC, MCZAC, DOH, US Army Corps of Engineers, UH Sea Grant Program, DPCH, DPCM, DPCK, BWS, C&CH	ICAP, PICCC, FWS, UHSG, IPIF, HCA, IPIF,	Adoption of a Statewide climate change adaptation plan; Implement actions intended to prevent serious disruptions in forests and ecosystem services due to changing climate; Implement actions that take advantage of man-made or natural disturbance events to facilitate adaptation to future climate; Re-iterative processes, continual monitoring and the use of new science into planning, policies and decisions.
2) Help landowners, conservation managers, and the public understand changing conditions; and, establish strong alliances and partnerships with other programs, agencies, and stakeholders to ensure a coordinated and collaborative approach to climate change adaptation.	Statewide	New and creative incentive programs for private landowners.	Conservation Education, Forest Health Protection, Urban & Community Forestry, Fire & Aviation, EQIP, WHIP, FSP, FSCG, UCF	Coastal industries, landowners, schools, HTA, HCA, NOAA Office of Ocean & Coastal Resource Management, NOAA Pacific Services Center, USFWS, NPS, US Army Corps of Engineers, TNC, UHSG	FSP, Conservation Education, PICCC, UH, NRCS, FWS, HCA, HFIA, ELP	Number of trained individuals specializing in climate change adaptation and mitigation; increased, # of educated landowners; More public support for implementation of innovative approaches for adaptation; Strategies, policies, and actions for addressing climate change are integrated across all programs areas.

#### Acronyms Used:

1. UCF – Urban & Community Forestry
2. HCA – Hawaii Conservation Alliance
3. PICCC -Pacific Islands Climate Change Cooperative

4. UHSG - University of Hawai'i School of Ocean & Earth Sciences
5. HTA - Hawai'i Tourism Authority
6. TNC - The Nature Conservancy



*Strategy for Issue 5: Climate Change/Sea Level Rise*

7. MCZAC - Marine & Coastal Zone Advocacy Council
8. BWS - Board of Water Supply
9. C&CH - City and County of Honolulu
10. DPCH - Department of Planning for County of Hawai'i
11. DPCM - Department of Planning for County of Maui
12. DPCCK - Department of Planning for County of Kauai
13. CAO - Carnegie Airborne Observatory
14. FWS - Fish & Wildlife Service
15. EQIP - Environmental Quality Program
16. WHIP - Wildlife Enhancement Program
17. FSP - Forest Stewardship Program
18. FSCG - Forest Service Competitive Grants
19. IPIF - Institute of Pacific Island Forestry
20. HFIA - Hawaii Forest Industry Association
21. DAR - Department of Aquatic Resources
22. ELP - Environmental Literacy Plan
23. UHSG - Seagrass

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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 3,200 kilometers (2,000 miles) from the nearest continent. Due to its extreme isolation and climactic conditions, Hawaii 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. Yet 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 were ever described.

Because of this extreme isolation, relatively few species have colonized the archipelago and only a subset of these successfully establish populations over the islands' 70 million year history. Those that did, however, found a diversity of habitat types because of 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 that were isolated from one another on an island and between islands. Hawaii provides a text-book example of adaptive radiation, the process by which many new species evolved from a single common ancestor in a relatively short time span.

Although comprising less than 0.2 percent of the land area of the United States, the Hawaiian Islands hold more than 30 percent of the nation's federally listed species, including 317 taxa of plants and animals listed by the U.S. Fish and Wildlife Service (USFWS) as endangered or threatened, 12 taxa proposed as endangered and 105 taxa as candidates for listing. Unique and varied habitats are also found across the islands. As a result, Hawaii presents both an opportunity and a challenge for conservation.

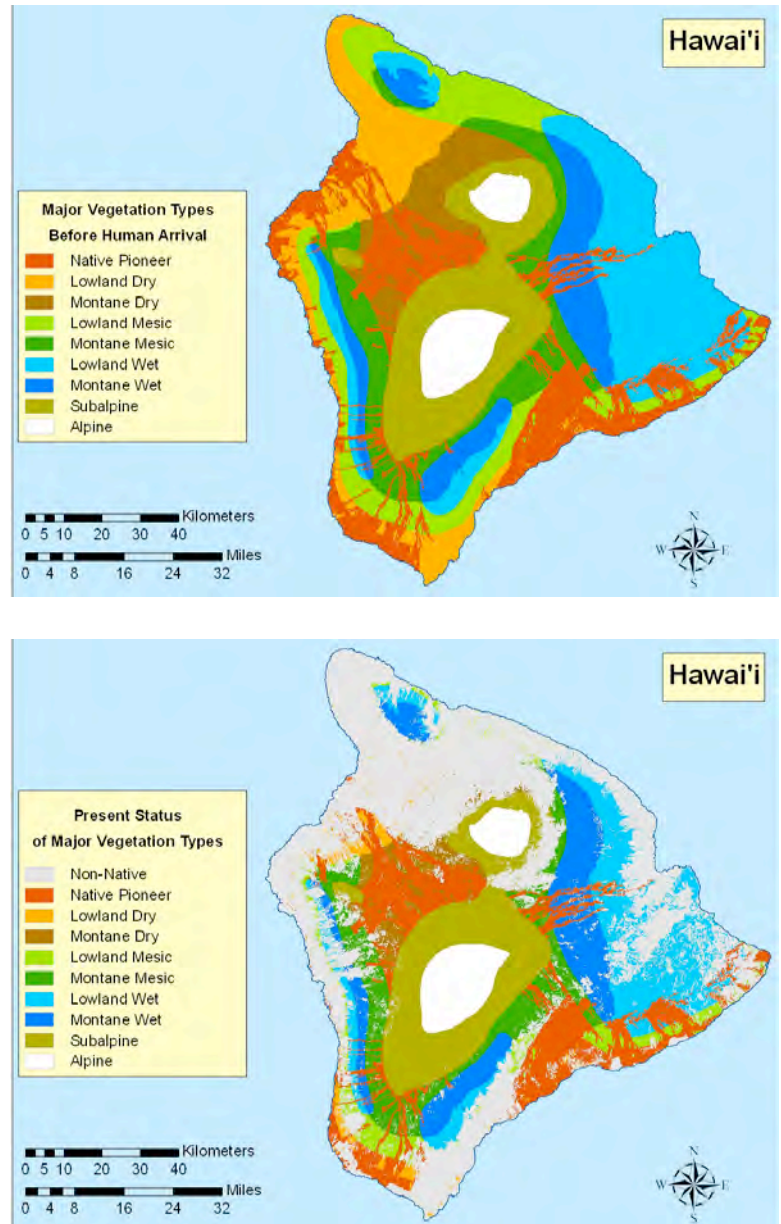
In 2005, Congress required all states to develop a Comprehensive Wildlife Conservation Strategy (CWCS).<sup>1</sup> The CWCS's are to be updated every five years. In Hawaii, this provides the opportunity for resource managers to develop and modify a comprehensive planning process to help manage all of Hawaii's unique native wildlife. The CWCS 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. On the ecological level, the CWCS 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. This plan builds on and synthesizes information gathered from existing conservation

partnerships and cooperative efforts. Additionally, it highlights partnerships and their efforts in Hawaii with a goal to enhance and expand existing and to create new partnerships, ultimately increasing support for implementing Hawaii's wildlife strategy.

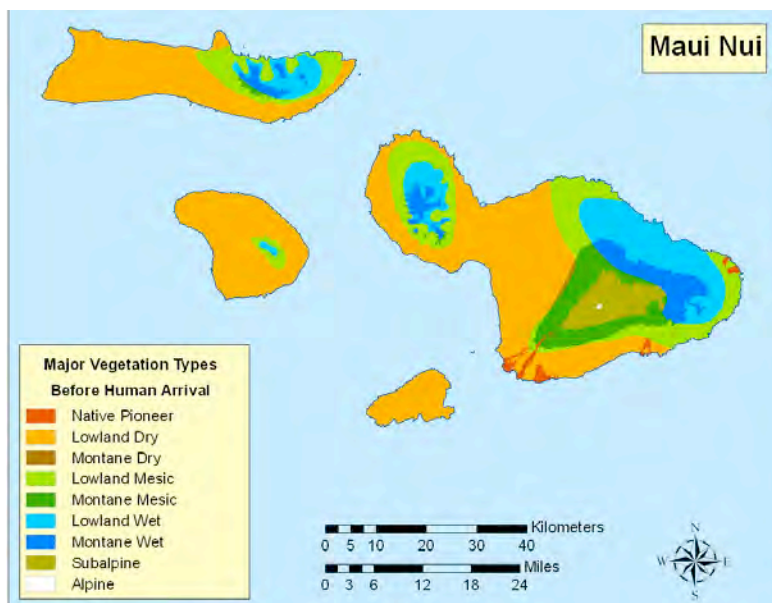
The DLNR coordinated the development of Hawaii's CWCS, with joint cooperation by the Division of Forestry and Wildlife (DOFAW) and the Division of Aquatic Resources (DAR), the divisions primarily charged with protecting the State's terrestrial and aquatic resources. The foundation for this assessment of Hawaii's Biodiversity was derived from the CWCS with up-to-date data on Hawaii's habitats and species contributed collaboratively by DOFAW staff, The Nature Conservancy and other Hawaii biodiversity and wildlife experts. The assessment provides an overview of the range of species found in Hawaii and offers a number of strategies that could positively impact the conservation of biodiversity in these islands.

### Benefits & Services

In present day Hawaii, the link between native Hawaiian culture and native species continues to be practiced 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 native Hawaiians, the relationship with the land and native ecosystems is integral to their identity and sense of well-being. The special role and relationship native Hawaiians have with some native species and ecosystems in the islands is perhaps best reflected in their increasing role in natural resource management in places such as the island of Kahoolawe; Limahuli and Lumahai valleys on Kauai; Moomomi, Molokai; and Keauhou, Hawaii where traditional management practices such as *kapu* (taboo) and *ahupuaa* (watershed)-scale thinking predominate.

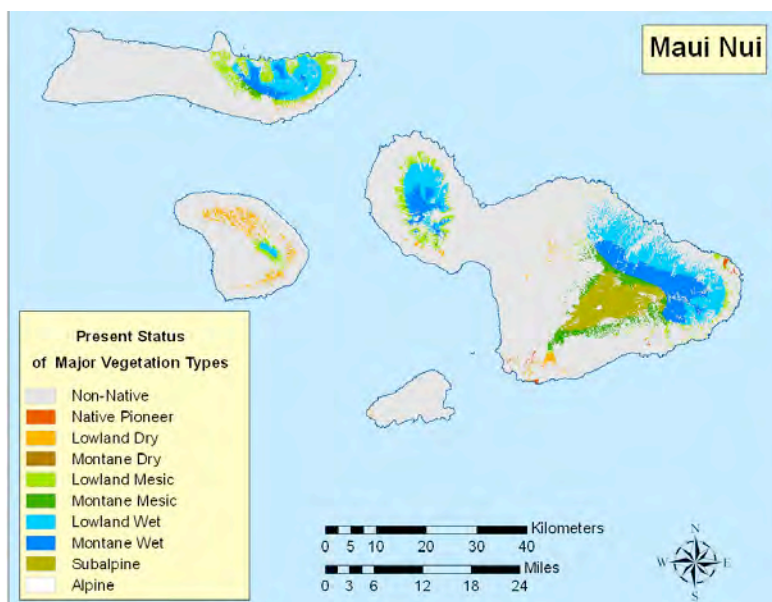


Map 6.1 Major vegetation types for the Island of Hawaii before the arrival of humans and at present time. Map by Page Else, Hawaii Conservation Alliance.



Native biodiversity is not only important to native Hawaiians, but also to many non-Hawaiian residents and to many outside of the islands. Active local lifestyles may include activities such as hiking, backpacking, snorkeling, boating, fishing, and hunting and are enhanced when interacting with native wildlife and ecosystems unique to the Hawaiian islands. Based on a 2004 survey “Wildlife Values in the West”, a large majority of Hawaii’s residents (71.4%) strongly agree that it is important to take steps to prevent the extinction of endangered species.<sup>2</sup>

Economically, wildlife viewing opportunities have become an important part of the State’s \$10 billion a year tourism industry.<sup>3</sup> Hawaii’s native wildlife 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 Hawaii study of the economic value of these services estimated between \$7.4 to \$14 billion in the Koolau Mountains on Oahu alone.<sup>4</sup> Other examples of ecological services provided by native habitats include coral reefs that protect beaches, homes, and businesses from erosion, storms, and tsunami waves; wetland habitats that filter the water supply, mitigate pollution, and slow storm runoff; and other natural areas that provide social and human health benefits through recreation, beauty and a spiritual



Map 6.2 Major vegetation types for the Maui Nui (Maui, Lanai, Molokai and Kahoolawe ) before the arrival of humans and at present time. Map by Page Else, Hawaii Conservation Alliance.

connection to nature.

Forest conservation plays a critical role in maintaining the health of makai (ocean) resources such as coral reef ecosystems and limu (seaweed) beds. Local wisdom passed on by kupuna (elders) cautions that unless we take care of mauka resources, makai resources will suffer.

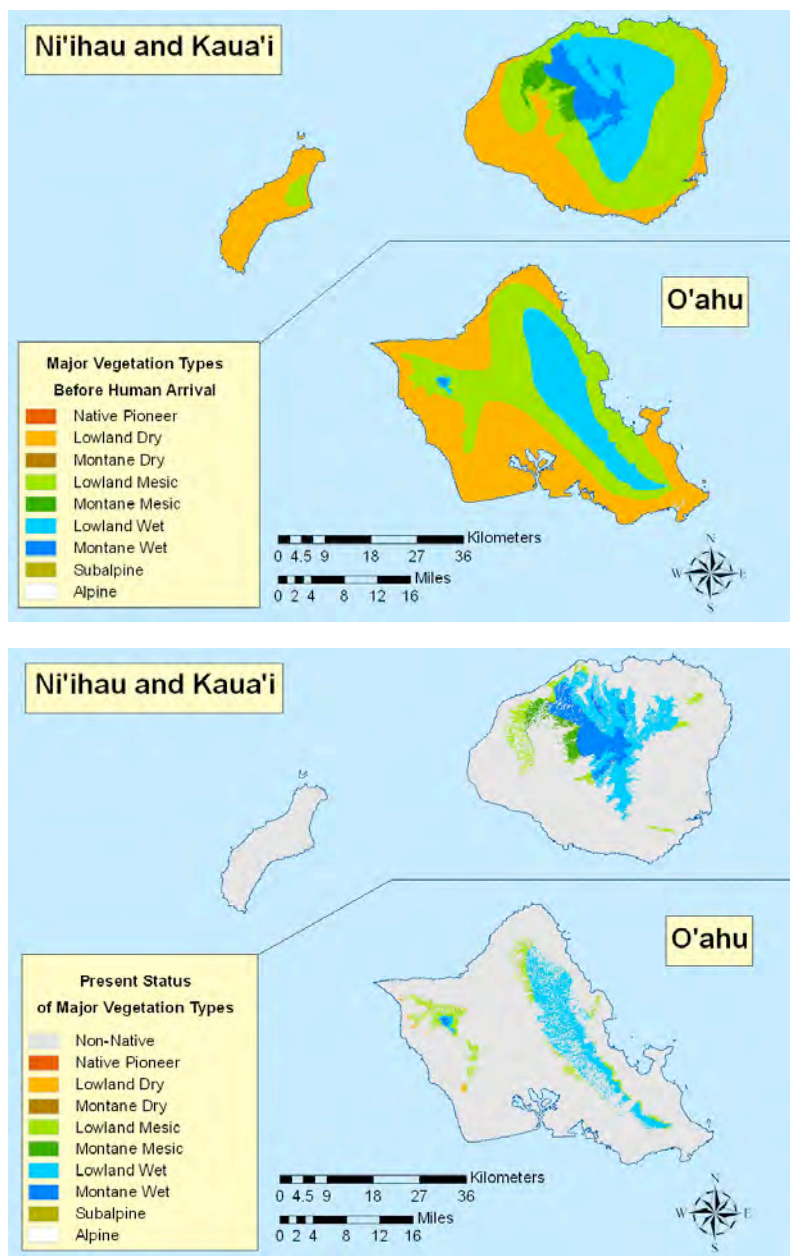


### Current Conditions

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 major vegetation types before human arrival and their current extent. For example, an estimated 90 percent of Hawaii's dryland habitat, 61 percent of the mesic habitat, and 42 percent of wetlands habitats have been lost. Today, native vegetation occurs over less than 40 percent of the islands' land area. Similarly, much of the habitat for freshwater species has declined, with 58 percent of the perennial streams in the State having been altered in some way.

### Terrestrial Habitats

The distribution of terrestrial habitats in Hawaii is influenced by elevation, climate, and substrate. Using elevation zones and moisture gradients, Hawaii 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 Hawaii<sup>5</sup> 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.



Map 6.3 Major vegetation types for the Kauai, Niihau and Oahu before the arrival of humans and at present time. Map by Page Else, Hawaii Conservation Alliance.

### *Aquatic Habitats*

Aquatic habitats link together most of Hawaii'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 forested and shrubland areas into estuaries and wetlands at low elevations and then finally into the ocean. Many of Hawaii's native freshwater aquatic animals migrate between the ocean, estuaries, and upper reaches of streams as part of their life cycle.

This interconnected network of streams and the adjacent land areas collectively is referred to as a watershed, similar to the traditional Hawaiian land division *ahupuaa*. Activities or threats that affect one part of this interconnected system will affect some other part, thus affecting the whole of the system. To effectively protect watersheds, the entire *ahupuaa* must be maintained or allowed to restore itself. Equally important are marine ecosystems, which are affected by pollution and/or onshore activities. Therefore, effective conservation of terrestrial habitats has direct relevance to the health of marine ecosystems.

### *Native Taxa*

Seventy-five percent of plant and animal extinctions documented in the United States have occurred in Hawaii. Today, Hawaii has the highest number of threatened and endangered species in the United States accounting for more than 30 percent of all federally listed taxa. The decline in native species is also mirrored by the loss of native habitat, with less than 40 percent of the land surface covered with native-dominated vegetation today.

The Hawaii CWCS<sup>6</sup> selected a large cohort as Species of Greatest Conservation Need including: one terrestrial mammal, 77 birds, over 5,000 known terrestrial invertebrates, over 500 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, 154 marine fishes, 197 marine invertebrates, and 79 species of endemic marine plants or algae.

### Threats

The current, most pervasive threats to Hawaiian biodiversity in Hawaii are non-native invasive, habitat-modifying plants, animal and disease. For many endangered species, small populations make recovery difficult. Fire, residential development, and military training are also important at specific locations. Threats include some that are pervasive across all conservation areas in the archipelago and some that are specific to particular places (See Table 6.1 Terrestrial Habitats and Principal Threats to Native Ecosystems).

*Invasive alien species:* The continuing invasion of alien weeds, predators, herbivores, pathogens, and competitors into native ecosystems is the engine that currently drives the Hawaiian



**Table 6.1. Terrestrial Habitats & Principal Threats to Native Ecosystems**

<b>Terrestrial Habitat</b>	<b>Principal Threats</b>
Alpine	Alien Insects (ex. Argentine Ant)
Subalpine	Introduced ungulates: sheep & mouflon, pigs, goats & cattle browse native vegetation & disperse invasive plants
Montane wet	Rooting pigs (pigs also spread habitat modifying invasive plants); logging; conversion to pastureland
Montane mesic	Conversion to pastureland; invasive grasses; feral goats, sheep & pigs, wildfire, clearing for commercial tree planting
Montane dry	Invasive plants and grazing by feral goats, sheep & mouflon
Lowland wet	Establishment & spread of invasive plants, especially kahili ginger & strawberry guava and degradation of the understory by feral pigs
Lowland mesic	Most converted to agriculture, ranching or logging, remaining threatened by a number of invasive plant species, wildfire, feral ungulates and introduced game animals, particularly goats, pigs and axis deer
Lowland dry	Most converted to urban & residential use; degraded by fire, grazing, and invasive grasses, particularly fountain grass, beard grass and natal red top - these grasses constitute a major fire threat
Coastal	Conversion to residential development, introduced plant species, off road vehicles and arson
Subterranean	Degradation of habitat, habitat loss to development, invasive invertebrates

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.

Hawaii is extraordinarily vulnerable to human-accelerated alien species invasions due to: (1) its geographic isolation as the hub of Pacific travel and trade, and (2) an exceptional range of hospitable habitats for invaders to occupy. 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 Hawaii at the rate of once every 18 days. The existing complement of established invasive aliens has the capacity to overwhelm most remaining native habitat if left unchecked.

*Over human history in the islands, several major groups of alien species have emerged as the most damaging to native ecosystems and species:*

*Ungulates* – Lacking any large native herbivorous mammals, the Hawaiian flora is not adapted to ungulate browsing or trampling. Feral pigs, goats, sheep, deer, and cattle were responsible for destruction of lowland ecosystems, and continue to degrade remaining native ecosystems.

*Invasive weeds* – Through a history of increasing introduction of alien plants, there are now more species of naturalized alien vascular plants in the wilds of Hawaii than there are native species. An estimated 200 of these are extremely aggressive, habitat-modifying weeds.

*Predators* – Small mammals such as rats, mongoose, and feral cats prey on native birds. Rats are implicated as wholesale vegetation modifiers via selective seed predation. Predatory invertebrates such as ants and other social Hymenoptera have greatly disrupted invertebrate communities at all elevations, particularly in the lowlands.

For these reasons, successful conservation in Hawaii requires keeping 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 species. Table 6.1 reveals that alien species such as ungulates and weeds are prominent and ubiquitous, with other threats active in specific locations.

*Climate Change:* Rising sea levels, increased climate variability, and increased flooding threaten native biodiversity through the change in baseline moisture and temperature conditions. Climate change has invariably played a role in the frequency of fires on the leeward sides of many of the Hawaiian Islands, as well as the nearly total loss of the dryland forests.

*Development:* Widespread conversion and development of the lowlands in Hawaii took place from prehistoric times to present day. Following statehood, the implementation of strong conservation zoning laws has largely limited development of natural areas and forest reserves. However, incremental conversion of lowland native areas continues on the most densely populated island (Oahu), as well as the largest island (Hawaii), particularly in Windward Mauna Loa and Kailua Kona. Development also impacts important agricultural areas that render the human populations more dependent on imports for daily needs.

*Grazing:* Clearing of forest for production of cattle has a 200 year history in Hawaii. Cattle have the same damaging effects on native vegetation as other ungulates, and the devastating effects of cattle in Hawaii are well documented. Today, there are still a number of very large private ranches, several of which occur within native ecological systems. Ranching-related loss of native ecosystems is active in the Kona 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 (feral) into forested areas.

*Logging:* Although logging and other high-intensity harvesting is not practiced widely in Hawaii (most high timber value areas were cleared in the last century), these and other clearing practices are important concerns in some conservation areas on Hawaii Island. Commercial logging of native koa (*Acacia koa*), ohia (*Metrosideros* spp.), sandalwood (*Santalum* spp.), and hapuu tree ferns (*Cibotium* spp.) are approaching the limits of available resources, and the forest products industry supports planting programs to restore former forest lands. On the Hamakua Coast on Windward Hawaii Island, vast mesic and lowland areas, formerly dominated by sugar cane, have

been planted with eucalyptus species and are awaiting a viable logging industry for harvest. This could stimulate the harvest of more adult hardwood stands and strike the need for aggressive replanting and sustainable harvest practices. (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 Oahu and Hawaii 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 Hawaii also have acquisition buffer programs that have played important roles in acquiring important threatened and endangered species habitat. (Please refer to Appendix C: Forestry Related Assistance Programs for more information).

*Overharvesting:* Most minor forest and stream “commodities” (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. These activities are not sustainable at the commercial scale, however, and are restricted by permit systems. Similar issues prevail in the seaweed and fishing industries.

*Pathogens (including invertebrate pests):* Diseases and pests can play an important role in reduction of viability of native species, and indirectly, the natural communities and ecological systems comprised of these species. Pathogens and pests related to declines in native species include mosquitoes and mosquito-borne diseases (avian malaria and pox), ants (various species), Erythrina Gall Wasp (*Quadrastichus erythrinae*), Two-Spotted Leafhopper (*Sophonia rufofascia*), slugs (various species), and Black Twig Borer (*Xylosandrus compactus*). Often the role of pathogens is tied to other threats. For example, avian diseases affecting native forest bird concentrations are spread by mosquitoes, and spread of mosquitoes into forest bird habitat is tied to wallows of feral pigs that create mosquito breeding sites where none otherwise existed. Proliferation of diseases across taxa can be common in Hawaii due to the fragility and vulnerability of these ecosystems.

*Recreational use:* Typical recreational uses of native ecosystems include hiking, camping, hunting and off-road vehicle touring. Restrictions on damaging activities in the state conservation district somewhat limits the impacts of recreational use, although indirect effects of recreational activities such as hiking, e.g., spread of invasive weeds, has been documented. Hunting is also a very important sport and source of food for many people in Hawaii. There is much disagreement on how to manage feral ungulates in such a way that they do not devastate native forests, but also continue to maintain a viable hunting capacity.

*Small Mammals:* There are no native small mammals (e.g., rodents, cats, dogs, rabbits, mongooses) in Hawaii. The long term ecological effects of herbivorous, omnivorous and

predatory small mammals has drastically reduced populations of native species, sometimes to extinction. Rodents damage lowland forests via seed predation, as well as on both ground-nesting seabirds and forest birds. Feral cats and dogs impose similar impacts. Rodents seem particularly damaging in the Waianae conservation area of Oahu, where they affect endangered tree snails, rare native plants, and an endangered forest bird, the elepaio (*Chasiempis sandwichensis gayi*).

*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 of harvesting. The new Hawaii State Water Code<sup>7</sup> provides mechanisms for protecting stream flow, but these mechanisms await their first test cases.

*Wildfire:* Wildfire is an uncommon natural occurrence in Hawaii, where ground-strike lightning is rare and wet plant communities cover large areas. Fire-adapted aliens (especially grasses and short-lived shrubs) are established in lower, leeward slopes and some subalpine areas. 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.

Other non-biological factors that threaten conservation of biodiversity in Hawaii include: limited information and insufficient information management; uneven compliance with existing conservation laws, rules and regulations; constraints in management capacity; and inadequate funding.

In addition to geographic specificity, threats are also specific to certain terrestrial habitats, freshwater habitats and individual species or groups of species. Tables 6.2, 6.3, and 6.4 summarize threats by habitat and species.

### Trends

While the threats to Hawaii's native species persist, recent years have seen greater awareness of the need to take action to conserve biodiversity through more assertive political will to address these problems, and wider community involvement in project implementation. These changes have resulted in positive steps towards the recovery of many of Hawaii's endangered species and in the protection of species that remain common so that they do not become endangered. Success stories include recovering the nēnē (*Branta sandvicensis* [Hawaiian goose and state bird]) from the edge of extinction, increasing populations of honu (*Chelonia mydas agassizi* [green sea turtle]), protection of numerous important habitats and community-led restoration efforts such as in Waimanalo streams encouraging the return of the endangered aeo (*Himantopus mexicanus knudseni* [Hawaiian stilt]). However, despite these success stories, Hawaii continues to face

major conservation challenges in protecting its over 10,000 native wildlife species, as well as some critically endangered such as the Hawaiian Monk seal (*Monachus schauinslandi*).

**Table 6.2. Threat Assessment Summary by Geographic Landscape<sup>11</sup>**

Threat	Kauai	Waianae (Oahu)	Koolau (Oahu)	East Molokai	West Maui	East Maui	Kohala (Hawaii)	Mauna Kea (Hawaii)	Windward Mauna Loa	Kau/Kapapala (Hawaii)	Kona (West Hawaii)	Pohakuloa/Puuwaawaa
Ungulates	H	H	H	H	H	H	H	H	H	H	H	H
Weeds	H	VH	VH	H	H	H	H	H	VH	H	H	H
Fire	L	H	M	H	M	L	L	M	L	L	H	VH
Small Mammals	M	H	M	L	L	M	L	M	M	M	M	L
Pathogens	M	L	L	L	L	M	L	M	M	M	M	L
Development	L	M	M	L	L	L	L	L	H	L	H	L
Military Training	L	H	M	L	L	L	L	L	L	L	L	H
Recreational Use	L	L	L	L	L	L	L	L	L	L	L	L
Stream Diversion	L	NA	L	L	M	M	L	M	NA	NA	NA	NA
Overharvesting	L	L	L	L	L	L	L	L	L	L	L	L
Logging	L	L	L	L	L	L	L	M	L	L	H	L
Grazing	L	L	L	L	L	L	M	M	L	L	H	M
Overall rank:	M	H	H	M	M	M	M	H	H	M	H	H

VH=Very High Threat, H = High, M = Medium, L = Low, NA = Not Applicable, no perennial streams.



### *Collaborative Working Groups*

Conservation of Hawaii's unique habitats and species requires cooperation across land ownerships and organizations. Examples of successful collaborative partnerships protecting and conserving habitats and species are:

- The Hawaiian Bat Research Cooperative, a partnership composed of government agencies, nonprofit 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 nonprofit organizations guide forest bird conservation work, including the development of the Draft Revised Recovery Plan for Hawaiian Forest Birds<sup>8</sup> and five-year implementation plans for identified critical species, captive propagation, annual forest bird surveys, as well as other identified research and management projects.
- Dryland Forest Working Group (DFWG) is an ad hoc partnership formed in the early 1990's. It was the driving force behind restoration science at Kaupulehu dryland forest. In 1993, the DFWG began to advise and participate in a cooperative restoration project and agreement between the Hawaii Forest Industry Association (HFIA) and the USFWS.

**Table 6.3. Principal Threats to Native Aquatic Habitats**

Aquatic Habitat	Principal Threats
Streams	Sedimentation caused by grazing animals, development, water diversions: dams, channelizing/concreting stream bottom & 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.
Estuaries	Similar to streams: sedimentation, development, & invasive species boat harbors & other sources of human disturbance.
Sandy Bottom	Pollution, human impacts.
Coral reefs	Human impacts, non-point source pollution from terrestrial land use practices, excessive inundation with freshwater during storm events which can inhibit successful establishment of coral larvae, invasive species of algae, disease and global climate change.
Bathypelagic, Mesopelagic, and Pelagic	Offshore aquaculture is a potential new threat to these areas.
Additional Marine Habitats	Direct and indirect human impacts due to proximity to the coast.

Table 6.4 Native Species, Principal Threats and Conservation Needs	
Species	Principal Threats
Hawaiian hoary bat	Habitat loss, roost disturbance, pesticides, collision with structures in the built environment.
<p>Forest birds</p> <p>There are only 33 extant species of native Hawaiian forest birds in the main Hawaiian islands-less than half the number known from historic and fossil records-and one third of those remaining are extremely rare or possibly extinct. 21 are Federally listed as Endangered Species.</p>	Conversion of land from forests to agricultural & other use. Degradation by ungulates & invasive plant species, introduction of the avian malaria virus and avian pox. Rats, feral cats, & mongooses prey on bird nests, nestlings, and incubating adults. Alien bird & arthropod species may compete for food or nest resources.
<p>Raptors</p> <p>The <i>io</i> (Hawaiian hawk) &amp; <i>pueo</i> (Hawaiian short-eared owl) are the only extant native raptors in Hawaii. Historically there were at least two additional species of hawks/eagles and four owls.</p>	Primary threats include predation by introduced rodents and cats (particularly for the ground-nesting pueo) and habitat loss.
<p>Waterbirds</p> <p>Six species of extant, endemic waterbirds occur in Hawaii: the endemic Laysan duck (<i>Anas laysanensis</i>), <i>nene</i> (Hawaiian goose), <i>koloa maoli</i> (<i>Anas wyvilliana</i> [Hawaiian duck]), and the native <i>alae ula</i> (<i>Gallinula chloropus sandvicensis</i> [Hawaiian moorhen]), <i>alae keokeo</i> (<i>Fulica alai</i> [Hawaiian coot]), and <i>aeo</i> (Hawaiian stilt). At least eight species of duck/geese, three species of ibis, and 12 species of rails have been lost.</p>	Loss and degradation of wetland habitats. Predation (primarily by feral cats, also by mongooses and feral dogs ( <i>Canis familiaris</i> ), hybridization between non-native mallards and the <i>koloa maoli</i> (Hawaiian duck), and disease.

Table 6.4 Native Species, Principal Threats and Conservation Needs	
Species	Principal Threats
<p>Seabirds</p> <p>40 species observed, at least 20 known to breed in Hawaii. 2 are endemic: <i>uau</i> (<i>Pterodroma sandwichensis</i> [Hawaiian petrel]) and <i>ao</i> (<i>Puffinus auricularis newelli</i> [Newell's shearwater]). Many are of global or national importance: over 95 percent of the world's <i>moli</i> (<i>Phoebastria immutabilis</i> [Laysan albatross]) and <i>kaupu</i> (<i>Phoebastria nigripes</i> [black-footed albatross]) populations nest in the Hawaiian Archipelago.</p>	<p>Primary threats on the main islands includes predation by feral cats, rodents, &amp; mongooses, loss or degradation of habitat due to habitat-modifying invasive plants or animals, &amp; human disturbance including coastal lighting. Threats at sea include fisheries by catch and pollution (including oil spills).</p>
<p>Migratory shorebirds and waterfowl</p> <p>Many species of migratory shorebirds and waterfowl winter in Hawaii. <i>kolea</i> (<i>Pluvialis fulva</i> [Pacific golden plover]), <i>akekeke</i> (<i>Arenaria interpres</i> [ruddy turnstone]), <i>lili</i> (<i>Heteroscelus incanus</i> [wandering tattler]), <i>kioea</i> (<i>Numenius tahitiensis</i> [bristle-thighed curlew]) are regular migrants that have been identified as important (by the U.S. Shorebird Conservation Plan) because the populations in Hawaii are hemispherically significant or relatively large.</p>	<p>Primary threats include loss or degradation of habitat and predation by feral cats and dogs.</p>

### *Innovative Management Techniques*

Select innovative biodiversity management techniques are under pilot testing for potential adoption in Hawaii. One example, use of predator-proof fencing to protect seabird nests and Monk seals, will be demonstrated at Kaena Point on Oahu. These fences, developed in New Zealand, prevent the ingress of all mammals and once constructed the mammals inside the fence can be eradicated. The Kaena Point fence will protect nesting seabirds and Monk seal, and equally important will exemplify to visitors the impact that predators have on Hawaii's wildlife and habitats. Other trials include implementation of consistent aerial shooting techniques and timing and landscape-scale mapping of specific weeds through aerial imagery.

### *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, 31 are federally listed under the U.S. Endangered

Species Act and 17 have populations of less than 1,000 individuals. 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 to improve Hawaiian bird conservation, DOFAW staff 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 nine year period totaled \$752,779,924. Hawaiian birds comprise a third of the listed bird taxa (n = 31), yet dedicated recovery expenditures was only \$30,592,692 or 4.1% of the total spent on all listed birds. Despite similar priority ranks assigned by the U.S. Fish and Wildlife Service, listed mainland birds received over 15 times the funding of Hawaiian birds. In general, the threats to island taxa are unlike those of mainland taxa (e.g., non-native predators), management actions are expensive, and in many cases they 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.<sup>9</sup>

Hawaii ranks near the bottom (48th) in the nation for state spending on fisheries and wildlife, though 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 2006, the State Department of Land and Natural Resources was allocated approximately \$76.8 million of the State's \$8.9 billion dollar executive budget. With less than one percent (0.86%) of the state's budget, the 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 parks/recreation), manage statewide ocean recreation and coastal areas 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 the Department'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 \$23 million dollars for Fiscal Year 2006. Though no comprehensive cost estimates exist for the protection and recovery of wildlife in Hawaii, the inadequacy of current funding levels is obvious based on costs included in recovery plans for endangered species. For example, the recently published Draft Revised Recovery Plan for Hawaiian Forest Birds (2003) estimates the cost of recovering 21 species of forest birds at nearly \$2.5 billion dollars over the next 30 years – an annual cost (\$83 million) that exceeds the budget for the entire DLNR. Costs associated with the recovery for endangered whales, sea turtles, seabirds, waterbirds, invertebrates and plants would add tens of millions more per year.

Funding levels from federal sources are also inadequate and inequitably apportioned. With more than 30 percent of the nation's imperiled species, Hawaii receives less than 15 percent of the national appropriation under the Endangered Species Act, the traditional Section 6 Program and only one percent of the national appropriation under the State Wildlife Grants Program. In recent years, 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 Hawaii 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 extinction and rarity of native bird species and are suspected to play an important role in the decline of native invertebrate populations. Historically, logging, agriculture, grazing, military use, fire, and urban and residential development have claimed more than half of Hawaii's native habitats. At low elevations where development pressures are highest, less than ten percent of native vegetation remains. Alterations of streams, non-point source pollution, sedimentation, and storm water 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 impacts 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, 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 plants and animal species or require restoration to support native wildlife. In addition, zoning does not protect the entire remaining quality habitat from being converted to another land use.

### Priority Areas and Issues for Conservation of Native Biodiversity

#### *Public Education*

There is a lack of awareness about Hawaii's avifauna. Mainland U.S. visitors and birdwatchers 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 Hawaiian residents have little connection to, or knowledge, of native taxa, and without this connection, there is little demand from the public for increased funding.



### *Improve Information Access & Management*

Huge gaps in knowledge exist for many native species. 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 or habitat, and allow management decisions to be made using the most up-to-date and accurate information.

### *Geospatial Data*

Through a grant from the LANDFIRE national organization to the The Nature Conservancy of Hawaii, a group of GIS technicians and ecologists developed a GIS layer depicting the condition of native ecosystems throughout the main Hawaiian Islands specifically for this Statewide Assessment. Based on extensive field inventories, ecological modeling and expert opinion all lands were classified in one of six categories which underlies Map 6.4: Priority Areas for Conservation of Native Biodiversity.

#### Category 1: Intact Native Ecosystems, Highest Biodiversity

These areas are important for maintaining native ecosystems and forest birds. These high-quality native-dominated areas (as designated by a habitat quality analysis developed from a combination of Hawaii Gap Analysis (HIGAP) and LANDFIRE datasets) have more intact structure and function and have historically documented high plant diversity and contain some of the most important areas 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 high priority areas for maintenance of biodiversity.

#### Category 2: Intact Native Ecosystems, High Natural Biodiversity

These areas 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 the U.S. Fish and Wildlife Service, and any areas containing high quality coastal vegetation, including islets.

#### Category 3: Rapidly Degrading Ecosystems

This category includes lands that have the highest potential for restoration. Although native plant species are no longer dominant, they are, by definition, 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 defragment and reduce threats to

adjacent areas. However, the user of this data set should bear in mind that some areas mapped in this category on Maui, Oahu, and Hawaii Island are the result of inaccuracies in the underlying HIGAP landcover data. Areas that should be included in this High Priority Restoration but were omitted include Puu o Kali, southern west Maui, back of Makaha Valley, and northern Koolaus. Areas that were inaccurately included in this class are Makena/Lower Olinda, any lowland dry natural community (especially the lowland dry shrubland on Lanai), and Hualalai/South Kohala. Based on the field experience of the ecologists on the mapping team, the consensus is that these aforementioned areas should be included in the next class; Threatened Native Ecosystems.

#### Category 4: Threatened Native Ecosystems

These areas have high potential and opportunity for habitat improvement. While dominated by natives, they also display the highest potential to increase species richness, representing opportunities to enhance species that have experienced a significant loss in historic range. Note that areas mapped in this class on the island of Lanai are actually much less extensive than map indicates because the lowland dry shrubland on Lanai is much less extensive than HIGAP maps it to be.

#### Category 5: Degraded Ecosystems

This class presents opportunities for localized native habitat restoration. Lands in the Degraded Ecosystems class are dominated by non-native species, and are 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 to 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 class of lands are areas where habitat conversion is severe enough to minimize chances of restoration of native biodiversity, due to paving over, contamination, and interruption of natural processes 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., developed areas, intensive current and former agriculture, and managed tree plantations).

#### Priority Areas for Conservation of Native Biodiversity

Priority Landscape Areas for the conservation of native biodiversity consist of all areas that are designated Critical Habitat by the U.S. Fish & Wildlife Service and/or are identified as Essential

Habitat in the current Recovery Plans for Hawaii's Forest Birds and Water Birds. Please refer to Map 6.4 for Priority Landscapes for the Conservation of Native Biodiversity.

### Summary

Hawaii is home to the greatest number of threatened and endangered species in the United States. The decline in native species is mirrored by the loss of native habitat, with less than 40% of the land surface covered with native-dominated vegetation today. Loss, fragmentation, and degradation of habitat are primary contributors to extinction and rarity of native species. Because many of the Hawaiian plant and animals co-evolved with one another, extinction of one species could lead to cascading extinctions of other species.

Alterations of streams, non-point source pollution, sedimentation, and storm water runoff have decreased, fragmented, or degraded freshwater habitats. At low elevations where development pressures are highest, less than ten percent of native vegetation remains. Forest conservation plays a critical role in maintaining the health of makai (ocean) resources like coral reef ecosystems and limu (seaweed) beds. The interconnected network of streams and the adjacent land areas collectively, is referred to as a watershed, similar to the traditional Hawaiian land division *ahupuaa*. Activities or threats that affect one part of this interconnected system will affect some other part, thus affecting the whole of the system. Effective conservation of terrestrial habitats has direct relevance to the health of marine ecosystems

Successful conservation in Hawaii requires keeping 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 species.

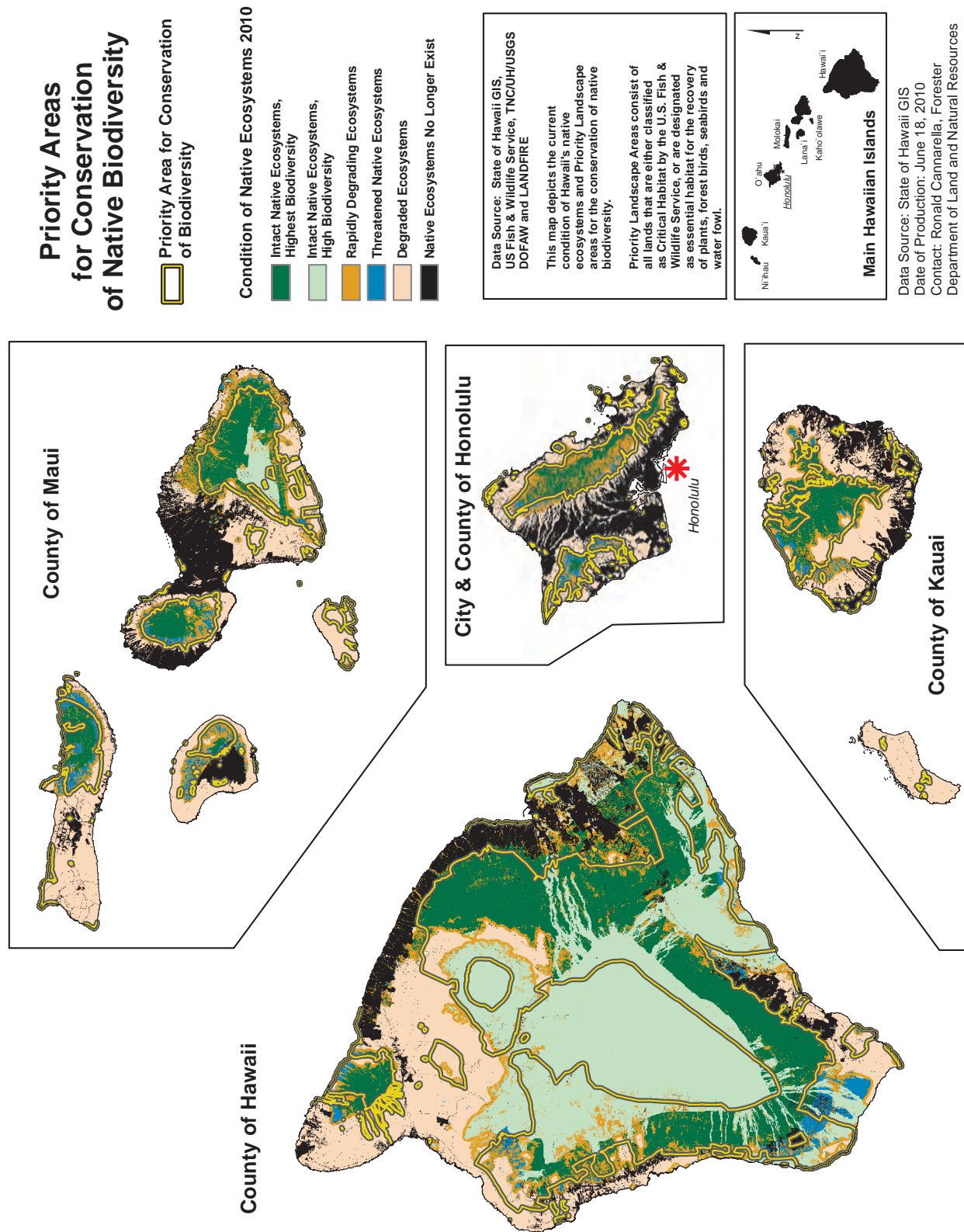
Hawaii continues to face major conservation challenges in protecting its over 10,000 native wildlife species.

### Data Gaps

#### *Limited Information & Insufficient Information 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, Hawaii's forest birds have been systematically surveyed for the past 25 years, yet current information on population size or distribution in certain areas remains poorly known for some species. Limited funds restrict surveys mainly to currently managed lands and may not



Map 6.4 Priority Landscape Areas for the Conservation of Native Biodiversity

accurately reflect a population's full distribution or abundance. Accurate population estimates for many Hawaiian waterbirds, seabirds, fishes, and for most non-threatened or endangered invertebrate populations 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 for many native species. Population censuses cannot provide data on basic demographic parameters or determine threats to specific species. Such information is often necessary to direct management, especially for those species persisting at low populations. For example, for many Hawaiian forest birds, 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 Hawaii 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.



# Strategy Matrix for Issue 6: Conservation of Native Biodiversity.

Strategy: Issue 6: Conservation of Native Biodiversity

The biodiversity described in this Assessment is meant to include all non-human living organisms in Hawaii. The link between native Hawaiian culture and native species continues to be practiced in belief systems; as well as traditional practices such as gathering of plants, animals for hula, medicines, food, structural materials, carving materials, and more products. Biodiversity conservation is also very important to many non-Hawaiian residents as well. Protection of the native species is very important, but critically important is the protection of the endemic endangered and threatened species in the upland and mesic forests, in the coastal areas, and among the coral reefs from the Northwestern Hawaiian Islands to South Big Island. To accomplish this, private landowners, resource specialists, Federal and non-federal Hawaiian Government agencies and policy makers must all understand the urgency & value the uniqueness of these species; as well as designate the appropriate resources to protect them for future generations.

Biodiversity Objective/Management Strategy for Lands with Intact Native Ecosystems (Map 6.1)						
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Implementing Partners	Measures of Success
I) Engage in conservation to maintain intact native ecosystems and species.	All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery Habitat.	Other ecosystem services including water quality and quantity, flood control, carbon storage & sequestration. Open space, ecotourism, information & education dissemination.	Forest Health Protection & Monitoring, Coop Fire, Forest Stewardship, Forest Legacy, Conservation Education, S&PF, Redesignated Competitive Grants	Public and private landowners, TNC, NAPP, NARS, FSP clients, Forest Legacy clients, USFWS, OHA, National Park Service, etc.	FSCG, NRCS, FWS, DAR, non-profits, NOAA, DOD Army, Watershed Partnerships, Forest Legacy Program (FLP), Bishop Museum, Duke Foundation, etc. Facilities and infrastructure including (e.g. captive breeding facilities, seed storage, nurseries); research and monitoring technologies and partnerships (e.g. aerial imagery, IPIF, PEP, PICCC, HAWP, Private Landowners; S&WCD	Invasive species removed; Acres of fenced, ungulate free habitat created and maintained; Acres of predator controlled habitat; Acres protected by fuel breaks created and/maintained; Native species re-introduced; Plant genetic materials secured in seed storage facilities; Long-term monitoring of 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 3.5

*Strategy: Issue 6: Conservation of Native Biodiversity*

2) Maintain native dominated ecosystems (50 to 100% native), including waterbird habitat & intact coastal sites.	All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery Habitat. Areas with FWS designated core waterbird; concentrations; Any coastal area designated by TNC as good to very good	See above	See above	See above	See 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 providing incentive programs for private landowners to engage in this type of land management.	1.1 1.2 2.2 3.1 3.5 3.6
<b>Biodiversity Objective/Management Strategy for Lands with Rapidly Degrading Ecosystems (Map 6.1)</b>							
<b>Long Term Strategy</b>	<b>Priority Landscape Area(s)</b>	<b>Secondary Issues Addressed</b>	<b>Program Areas that Contribute</b>	<b>Key Stakeholders</b>	<b>Resources Available &amp; Implementing Partners</b>	<b>Measures of Success</b>	<b>Supports National Objectives</b>
1) Enhance native dominated habitat with formerly wide-spread plant species that are now limited in range.	All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery Habitat.	See above	See above	See above	See above & CREP	See # 1 above; Establishment of two or more rare plant nurseries on each of the main Hawaiian Islands, more seed storage facilities and fully operational Plant Extinction Protection programs.	1.1 1.2 3.1 3.4 3.5
<b>Biodiversity Objective/Management Strategy for Threatened Native Ecosystems (Map 6.1)</b>							
<b>Long Term Strategy</b>	<b>Priority Landscape Area(s)</b>	<b>Secondary Issues Addressed</b>	<b>Program Areas that Contribute</b>	<b>Key Stakeholders</b>	<b>Resources Available &amp; Implementing Partners</b>	<b>Measures of Success</b>	<b>Supports National Objectives</b>
1) Restoration of landscapes with high potential for successful restoration due to their proximity	All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery	See above	See above	See above	See above & CREP	Invasives removed; Natural native plant regeneration; Length of barriers created to control the introduction of habitat modifying weeds and predators; Miles of fuel break created and/maintained; Native species re-introductions; Rare plants cultivated in nurseries for	1.1 1.2 2.2 3.5

*Strategy: Issue 6: Conservation of Native Biodiversity*

1) Restoration of landscapes with high potential for successful restoration due to their proximity (within 1km) of substantial areas of native-dominated vegetation.	All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery Habitat. Focus on high quality restoration sites 1km from a native-dominated landscape	See above	See above	See above	See above & CREP	Invasives removed; Natural native plant regeneration; Length of barriers created to control the introduction of habitat modifying weeds and predators; Miles of fuel break created and/maintained; Native species re-introductions; Rare plants cultivated in nurseries for outplanting; Rare plants regularly monitored.	1.1 1.2 2.2 3.5
2) Localized restoration in non-native dominated areas with localized potential for restoration.	All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery Habitat. Focus on sites with high value post restoration potential: wetlands, coastlines, etc.	Information & education	See above	Public & private landowners, OHA, non-profits, etc.	CREP, non-profits, HFIA, S&WCD	Number of common native plant populations established; Number of constituent native plants genetically and historically appropriate to location; Soil testing and soil improvement if necessary.	1.2 2.2 3.5
<b>Biodiversity Objective/Management Strategy for Lands Where Native Ecosystems No Longer Exist</b>							
<b>Long Term Strategy</b>	<b>Priority Landscape Area(s)</b>	<b>Secondary Issues Addressed</b>	<b>Program Areas that Contribute</b>	<b>Key Stakeholders</b>	<b>Resources Available &amp; Implementing Partners</b>	<b>Measures of Success</b>	<b>Supports National Objectives</b>

**Acronyms Used:**

1. CZM – Coastal Zone Management
2. PICCC – Pacific Island Climate Change Cooperative
3. PEP – Plant Extinction Program
4. AAA – Aloha Arborists Association
5. NARF – Natural Area Reserve Fund
6. DAR – Division of Aquatics (DLNR)
7. FRS – Forest Reserve System
8. DOFAW – EE – Environmental Educational
9. HARC – Hawaii Agriculture Research Center
10. LLCF - Legacy Land Conservation Program
11. FLP – Forest Legacy Program – Forest Service
12. FSCG - Forest Service Competitive Grants
13. CREP – Conservation Reserve Enhancement Program
14. DOD – Department of Defense
15. HISC – Hawaii Invasive Species Council
16. FSP – Forest Stewardship Program
17. CGAPS – Committee Group on Alien Pest Species
19. HCA – Hawaii Conservation Alliance
20. IPF – Institute of Pacific Island Forestry
21. UCF – Urban & Community Forestry (Kaulunani)

22. NOAA – National Oceanographic and Atmospheric Administration
23. USGS – US Geological Service
24. YCC – Youth Conservation Corps
25. STDP - Special Technology Development Program
26. PSWRS – Pacific Southwest Research Station
27. HFIA – Hawaii Forest Industry Association
28. SPC – Secretariat of the Pacific Consulate
29. SPREP – South Pacific Regional Environmental Program
30. FAO UN – Food and Agriculture Organization of the United Nation
31. SOPAC – Secretariat of the Pacific Applied Geoscience Commission
32. HFIA - Hawaii Forest Industry Association
33. SAF - Society of American Foresters
34. HEEA – Hawaii Environmental Education Alliance
35. ELP - Environmental Literacy Plan
36. SWCD - Soil & Water Conservation Districts

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- <sup>8</sup> U.S. Fish & Wildlife Service, Pacific Islands Fish and Wildlife, "Draft Revised Recovery Plan for Hawaiian Forest Birds " <http://www.fws.gov/pacificislands/recoveryplans.html>.
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## Issue 7: Hunting, Nature-Based Recreation and Tourism

### Overview

Protection of Hawaii's natural resources is essential for the quality of life of residents, the environment, and the future of Hawaii's visitor industry, which is the top revenue producing industry in the state. Hunting is a popular activity for residents and some visitors, and provides recreational opportunities, vital food source for many families, and helps to protect the environment by controlling the population of introduced feral ungulates. Table 7.1 illustrates the numbers of residents and visitors that participate in wildlife associated recreation.

**Table 7.1. Hawaii's Wildlife-Associated Recreation**

Activities	Resident	Non-resident	Total
<b>Fishing</b>			
Anglers	92,000	65,000	157,000
Days of fishing	1,300,000	171,000	1,471,000
Average days per angler	14	3	9
<b>Total Fishing expenditures*</b>	\$76,305,000	\$34,211,000	\$110,516,000
Average per angler	\$831	\$524	\$702
Average trip expenditure per day	\$33	\$177	\$49
<b>Hunting</b>			
Hunters	18,000	-	18,000
Days of hunting	418,000	-	420,000
Average days per hunter	23	-	23
<b>Total Hunting Expenditures*</b>	\$20,156,000	-	\$21,098,000
Average per hunter	\$1,110	-	\$1,136
Average trip expenditure per day	\$24		\$26
<b>Wildlife Watching</b>			
Wildlife-watching participant	155,000	107,000	262,000
Days of participating away from home	386,000	723,000	1,109,000
Average days of participation	8	7	7
<b>Total Wildlife Watching Expenditures*</b>	\$42,228,000	\$168,186,000	\$210,414,000
Average per participant	\$271	\$1,568	\$793
Average trip expenditure per day	\$49	\$230	\$167
Notes:			
* Includes trip-related, equipment, and other expenses			
- Sample size too small to report data reliably			

## Hunting

Public hunting is an essential tool in controlling game mammal populations on public and private lands, and well as a subsistence source of food for the last century. The Division of Forestry and Wildlife is the state agency responsible for managing native and non-native wildlife. Chapter 183D, Hawaii Revised Statutes (HRS), established The DLNR-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. Programs must facilitate hunting recreation by state wildlife agencies, within the constraints of other Division of Forestry and Wildlife goals and priorities.

Chapter 183D HRS also creates the Wildlife Revolving Fund, whereby monies collected from hunters, hunter education programs, and public shooting ranges are returned to those programs. Economic benefits of hunting have been relatively stable since 1985, with approximately \$20 million annually in direct expenditures, and over \$50 million in indirect benefits. Since World War II, hunting has become a major outdoor recreational activity in Hawaii, taking place on DOFAW managed lands, in Cooperative Game Management Areas (GMA's) managed by DOFAW, and on private lands, particularly on ranches. State-maintained trails and roads provide hunter access to some remote and pristine sites, thereby helping to control game mammal populations in those areas.<sup>1</sup> There are more than 60 separate public hunting areas in the state, constituting approximately 1.2 million acres of public hunting land.

## *Threats from Game Mammals*

Non-native feral ungulates introduced in the 18th century were largely responsible for the widespread deforestation and resulting water crisis of the 1860's. The Island of Kahoolawe provides us with an example of what would happen in Hawaii if populations of feral-ungulates were left unchecked.

Goats were introduced to Kahoolawe in the 1793. In 1858 the Hawaiian government issued the first of many leases for ranching on the island. From 1858-1941 the uncontrolled grazing of cattle, sheep and goats virtually denuded the island of all vegetation<sup>2</sup>. This lead to the complete erosion of the island's fertile topsoil. 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 impacted from sediment due to erosion.<sup>3</sup>

Beginning in World War II In Kahoolawe 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 Kahoolawe in 1990, and in 1993 the last feral ungulates were removed from the island. In 1994 the island was transferred to the State of Hawaii. Because of decades of bombing, the island was covered with unexploded ordinance (UXO) and public access to the island was prohibited because of possibility of someone unwittingly causing UXO to explode. An effort to remove all UXO from

the island has not been entirely successful, and today there are only a few main corridors that have been sufficiently cleared to allow public access.

Currently, there is a comprehensive program managed by the Kahoolawe Island Reserve Commission to revegetate the island. Management activities are hampered because of the restricted access to large portions of the island due to UXO, but progress is being made and the island is slowly coming back to life.

Hunting and game management involve a number of potentially contradictory and conflicting issues.

- Game animals hunted include axis deer, black-tailed deer, mouflon sheep, feral sheep, feral goat, and feral pigs, all of which may be problematic in large numbers or in sensitive habitats. Game birds hunted include pheasant, francolin, quail, dove, chukar, and wild turkey, which are much less problematic in terms of environmental or watershed impacts.
- Game mammals are managed not only through the hunting program, but also through endangered species projects, Natural Area Reserve projects, watershed partnership activities, and many other efforts aimed at reducing or eliminating game mammal populations. Nonetheless, hunting and hunters serve as the first effort to control game mammal populations in sensitive areas. This is done through normal hunting activities, and special control permits granted to individual hunters to reduce game mammal numbers where or when necessary
- A continuing series of efforts have been made to resolve conflicts between hunters and conservation and protection advocates including state agencies, and most have had limited success at best. Currently, a game management plan is being completed for the island of Hawaii in an attempt to at least sharply focus some of the issues and problems, and identify activities that might benefit hunting without creating other problems.

### *Benefits of Hunting*

- Game mammals seriously impact native vegetation, watersheds, and threatened and endangered species. Hunting helps manage populations of feral ungulates while providing recreation and food. (*See Issue 1: Water Quality & Quantity and Issue 6: Conservation of Native Biodiversity for additional information.*)
- Many of the 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* (*Branta sandvicensis*) in many areas.
- Public hunting provides direct and indirect economic benefits to state agencies and the state's economy: nature-based recreation.

### Priority Areas for Hunting in Public Hunting Areas

Priority areas for hunting in hunting areas managed by DOFAW are identified in DOFAW's Management Guidelines (Maps 7.1 and 7.2).

### Nature-Based Recreation and Tourism

Hawaii's favorable climate and environment offer year round opportunities for outdoor recreation for both residents and island visitors. With eight national parks/historic sites, ten national wildlife refuges, 55 state parks, 56 state forest reserves, 31 state harbors and boating facilities and hundreds of county park and recreation areas<sup>4</sup>, the opportunities for outdoor (terrestrial and marine) experiences can accommodate the young and old, as well as the thrill seeker or the sunbather. There are growing numbers of ocean recreation sports from windsurfing and para-surfing to paddleboarding and kayaking. Mountain and coastal trails are not only used for hiking, but have become popular venues for mountain-bikers, joggers, 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, federal, state, and county agencies.

The tourism industry continues to play a significant role in Hawaii's economy. Hawaii attracts over six million visitors each year, and in 2007 tourism generated more than \$12.8 billion in visitor spending.<sup>5</sup> In addition, tourism generates state taxes through accommodation taxes, sales tax, and auto rental taxes. According to a 2001 Visitor Satisfaction Survey conducted by the Department of Business, Economic Development and Tourism (DBEDT), for the majority of visitors, vacation is the primary purpose of their trip. While on vacation, nature-based sightseeing and outdoor recreation opportunities are two of the main visitor attractions.

Hawaii'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 and hunting. State recreation agencies most directly connected with mauka recreation include the Division of State Parks and the Division of Forestry and Wildlife, both under the Department of Land and Natural Resources. The following section primarily describes the benefits, threats and impacts in natural resources areas *mauka*, where recreation and tourism overlap; focusing on national, state, and county parks, and wildlife-associated recreation. The 2008 State Comprehensive Outdoor Recreation Plan and the Hawaii Tourism Authority Natural Resources Assessment provided much of this information.<sup>1,6</sup>

### *Benefits of Nature-Based Recreation and Tourism*

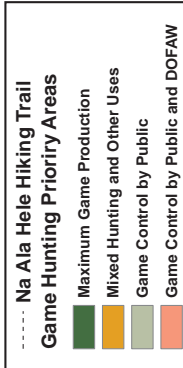
The greatest benefit of tourism in Hawaii is considered to be economic. The visitor population helps support maintenance of outdoor recreation programs and facilities through spending and taxes, with resultant tourism-related employment being quite high. A study by the National Parks Conservation Figure Association demonstrated that visitors to Hawaii's National Parks spent

# Priority Areas for Hunting on Public Land

Note: Priority areas on the island of Hawaii apply only to pigs. Please see note below.

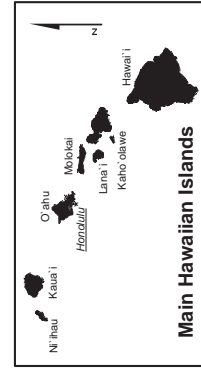
NOTE: This map shows priority areas for hunting all game mammals and game birds on all islands, with the exception of the island of Hawaii. For the island of Hawaii this map shows priority areas for hunting pigs only.

Please refer to Map 7.2 "Priority Areas for Hunting Sheep, Goats and Game Birds, Island of Hawaii" for hunting those species on that island.

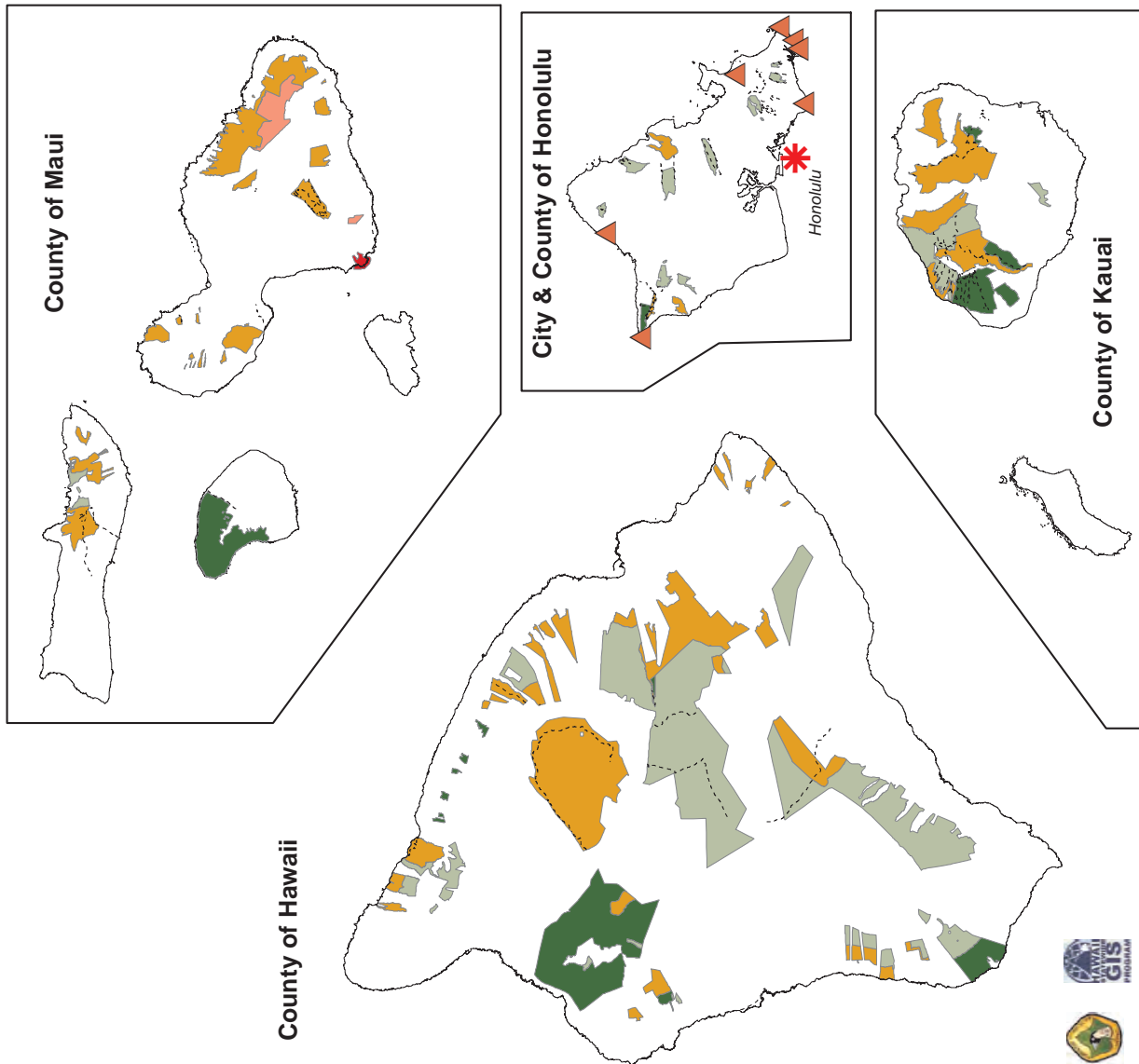


Data Source: State of Hawaii GIS, Division of Forestry and Wildlife Management Guidelines.

This map depicts priority areas hunting in public hunting areas only. Hunting is permitted on private lands at the discretion of the landowner.

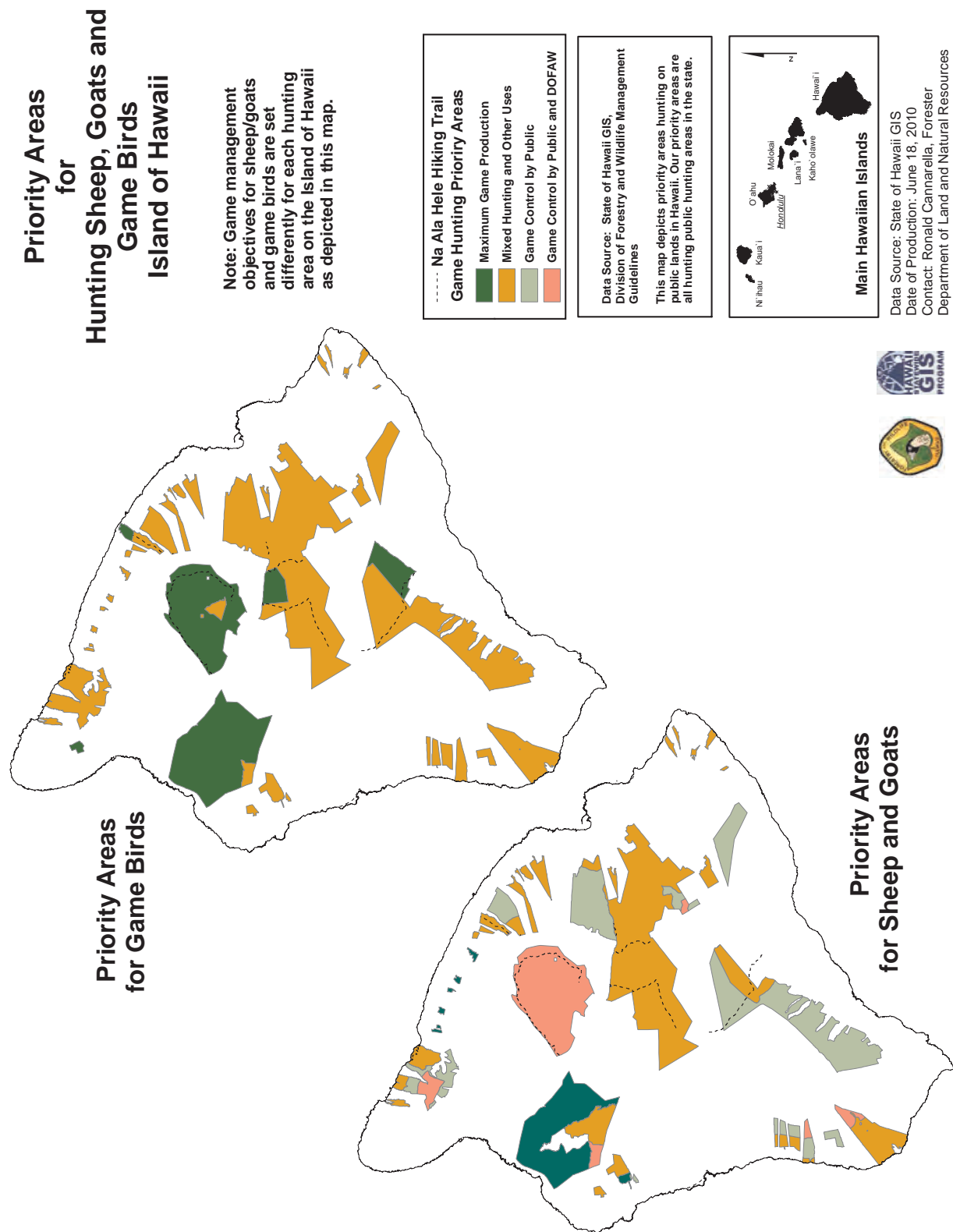


Data Source: State of Hawaii GIS  
Date of Production: June 18, 2010  
Contact: Ronald Cannarella, Forester  
Department of Land and Natural Resources



Map 7.1 Priority Areas for Hunting on Public Land.





Map 7.2 Priority Areas for Hunting Sheep, Goats and Game Birds on the Island of Hawaii.

nearly \$240 million in 2001, which directly support 4,844 jobs.<sup>7</sup> The Hawaii Coral Reef Initiative Research Program (HCRI-RP) has estimated that coral reefs in Hawaii have an overall economic value of \$363.71 million, \$304.16 million of which is directly related to recreation and tourism.<sup>3</sup> Surveys of visitors conducted by DBEDT and HCRI-RP reveal that although many factors play impact a visitor's decision to plan a vacation to Hawaii, 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, and in turn Hawaii's economic future, strongly depend on the sustainability of natural environments and resources. While economic gains are considered the greatest benefit, there are also other environmental and community benefits specific to recreational activities.

### *Trends*

In Hawaii, as well as nationally, trends in population age show that those 65 years and older rose by 12% between the years of 2000 to 2007.<sup>8</sup> Aging population is attributed to declining birth rates and longer life expectancies, which in turn impact the preference 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 include population growth projections contributing to overuse and overcrowding of recreational and nature areas, and an increase in sports tourism, cultural tourism and ecotourism.

### Cultural Tourism

The fundamental idea behind cultural tourism is to create activities, events and destinations that attract residents and visitors interested in learning about Hawaii's rich ethnic and cultural resources. Many believe cultural tourism will become a substantial part of the tourism industry.<sup>9</sup> In addition, cultural tourism fosters understanding, preservation, and appreciation for the history and heritage of the area.

The 2009 Hawaii Capital National Heritage Area Study (<http://www.hawaiicapitalculture.org>) examined the feasibility and suitability of National Heritage Area designation for central Honolulu and documented the areas cultural and heritage resources. This highly collaborative process involved the public, the support of state and city agencies, nonprofit and community organizations, educational institutions, and business owners. This study demonstrates that the proposed National Heritage Area meets all ten of the National Park Service criteria for evaluation of candidate areas, and that there is public support for such a designation.



Figure 7.1 Aeo, Hawaiian Stilt, one of six endemic waterbirds  
Photocredit: DOFAW Archives

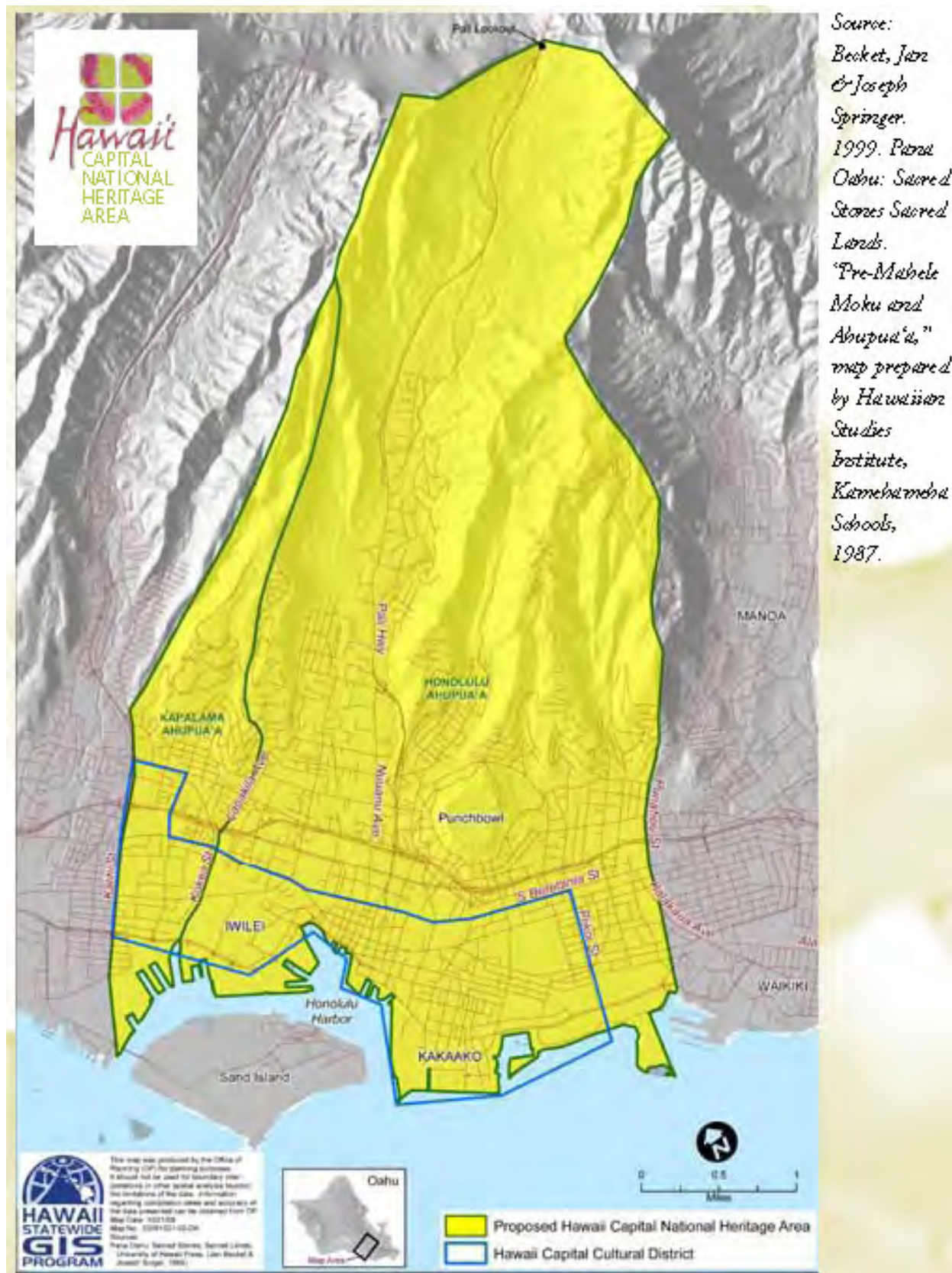


Figure 7.2. The entire *ahupuaa* of Honolulu is proposed for National Heritage Area designation.



The proposed boundaries are the ancient boundaries of the *ahupuaa* of Honolulu and Kapalama, covering the beautiful valley of Nuuanu, and adjacent coastal plains in the ancient and historic village of Kou, now the City of Honolulu, on the island of Oahu. According to the *moolelo*, 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 Koolau Mountains, to the welcoming seas of the Pacific (See Figure 7.2).<sup>10</sup>

### Ecotourism

Ecotourism is an emerging market in Hawaii. Many activities popular among visitors, such as enjoying scenic views, visiting museums, and photography are inherently “ecotourism” related, whether participants choose to label themselves as an “ecotourist” 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 include travelers who visit natural places easily accessible from a car or participate in a simple nature-based activity while on vacation, but may not consider themselves ecotourists or realize that they are participating in ecotourism activities.<sup>11</sup>

Ecotourist activities vary as widely as ecotourists themselves. In general, any nature-based outdoor activity in which visitors participate can be considered an ecotourist activity. The Ecotourism Society has

created a USA Ecotourism Statistical Factsheet, in which they rank the most popular nature-based activities.<sup>12</sup> Visiting parks and hiking were the most popular nature-based activities. (See Table 7.2)

### *Threats and Concerns*

The state’s largest industry depends on scenic beach parks, coral reefs, fisheries, and unique mountain and coastal ecosystems. While lack of funding and the subsequent inadequate

Table 7.2. Ecotourism Statistical Factsheet		
Rank	Activity	Incidence
1	Visiting Parks	55.8%
2	Hiking	55.0%
3	Exploring a Preserved Area	47.8%
4	Wildlife Viewing (non-birds)	45.8%
5	Visiting Nature Trails in Ecosystems	37.1%
6	Visiting Unique Natural Places (sinkhole, dunes)	27.5%
7	Environmental Education	20.3%
8	Bird Watching	19.5%
9	Biking	18.7%
10	Freshwater Fishing	17.9%
11	Snorkeling or Scuba Diving	14.7%
12	Exploring a Major Protected Swamp, Marsh	12.0%
13	Mountain or Rock Climbing	11.6%
14	Canoeing or Kayaking	9.2%

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 imported red fire ant have the potential to cause extensive economic and environmental harm in Hawaii.<sup>13</sup> Projected impacts from climate change include higher sea levels, accelerated beach erosion, greater damage from sea surges and storms, and reduced freshwater supply. (*See Issue 5: Climate Change/Sea Level Rise for additional information.*) All of these could negatively impact coastal tourism, a mainstay of Hawaii's economy. Table 7.3 provides an overview of threats and concerns to recreation and tourism in Hawaii.

**Table 7.3. Threats & Concerns: Recreation & Tourism**

Threats and Concerns	National Themes & Objectives
<b>Introduction of Invasive Species</b>	
Recreational hikers can unintentionally be vectors for invasive species.	2.2, 3.5
Overuse of trails and subsequent erosion can lead to opening 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 the park is a threat to native species.	2.2, 3.5
<b>Inadequate Funding</b>	
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
<b>User Conflicts</b>	
User conflicts can occur with over-crowding, poor regulations and conflicting uses (e.g., hunters and hikers).	1.2
Game animals can harm threatened and endangered species and/or habitat.	1.2, 2.2
<b>Beach and Coastal Erosion</b>	
Over the last half-century, nearly one-quarter of Hawaii's beaches have been significantly degraded. Typical erosion rates throughout the state range between 0.5 and 1.0 feet per year.	1.1, 1.2, 2.2, 3.7
There are considerable concerns about the future condition of Hawaii's coastal ecosystems, particularly erosion & 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
<b>Pollution</b>	



**Table 7.3. Threats & Concerns: Recreation & Tourism**

<b>Threats and Concerns</b>	<b>National Themes &amp; Objectives</b>
Visible pollution significantly damages the image of Hawaii as an unspoiled tropical destination.	1.1, 1.2, 2.2
Concentrated pollution in all forms from urbanization - air, water, and solid waste - particularly when the infrastructure necessary to accommodate growth is not in place.	1.1, 1.2, 2.2, 3.1, 3.2
<b>Overcrowding &amp; Population Growth</b>	
Overuse threatens resources. Projected growth in both resident and visitor population has the potential to negatively impact 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
<b>Aquatic Resources &amp; Marine Life</b>	
Numerous factors have the potential to negatively impact 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 agriculture 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

### Present Conditions

Much of Hawaii's popularity as a visitor destination is based on the range and extent of outdoor activities available. In 2002, the tourism sector provided one out of every five jobs and generated approximately 21 percent of total state and county tax revenues, as well as 16.5 percent of the Gross State Product.<sup>14</sup> It is for this reason that so much of the state's resources and planning efforts are directed toward sustaining and promoting the visitor industry. In contrast, funding for natural resource protection and management at all levels of government continues to be drastically reduced during the past decade. For example, the 2003 budget DLNR, the agency primarily in charge of statewide natural resource protection and management, accounted for less

than one percent of the state's total budget, despite the fact that DLNR manages over one-fourth of the total land mass, as well as many coastal areas.

## **Tourism & Natural Resources**

In 2003, Hawaii Tourism Authority (HTA) commissioned a study of the inter-relationships between the health of Hawaii's natural resources and the health of Hawaii'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. To accomplish this, the assessment included the 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; SLH 2002, was to provide a long-term planning for improving heavily visited natural resource sites. It 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 (NRAG), consultation with various agencies and organizations responsible for recreational and natural resource management, and public input. The final list of sites assessed included: 30 sites on Oahu, 19 sites on Maui, 5 sites on Molokai, 6 sites on Lanai, 27 sites on Kauai, and 23 sites on the island of Hawaii.

It was found that in many cases, the quality of the 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



Figure 7.3. Visitors come to experience Hawaii's unique flora and fauna such as this rainforest on the island of Hawaii.

natural resources as well. As such, an effort to improve important natural resource areas in general will in turn improve the visitor experience and the resources themselves.

There were, of course, exceptions where the quality of the site and its facilities served as an excellent visitor experience and protected the natural and/or cultural resources of the site. Sites were then prioritized for improvements based on a number of indicators, including estimated volume of use, safety concerns, threats to natural resources, and economic potential. Preliminary cost estimates and project descriptions were prepared for each of the 23 priority sites (five each on Kauai, Maui, and Hawaii, six on Oahu, and one each on Lanai and Molokai).

### *Hawaii's Parks*

Hawaii's parks are situated in forested, coastal, mountainous and urban landscapes. An estimated 10.1 million people visit Hawaii state parks in a year. Of this total, two thirds are out-of-state visitors and one third are residents.<sup>15</sup> 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.<sup>16</sup> Maintaining the natural beauty of the parks increases the likelihood that visiting state and national parks will continue to be a high priority for many Hawaii vacationers.

### **There are many benefits related to Hawaii's Parks:**

- By visiting state and national parks, residents and tourists develop an appreciation for Hawaii's natural and cultural resources, which in turn fosters respect and stewardship for these resources.
- Parks provide public access to natural areas for passive outdoor recreation and the enjoyment of nature.
- Parks preserve open space and scenic view corridors.
- Parks offer interpretation of cultural and historical sites increasing understanding and appreciation of Hawaii's unique culture and history.
- Parks conserve natural areas.



Figure 7.4. An ancient Hawaiian trail paved smooth stones helped travelers cross rough a'a lava.



### *National Parks*

The Hawaiian Islands are famous for their volcanoes, beautiful landscapes and complex ecosystems, which offer unusual hiking and camping opportunities. The State of Hawaii contains eight national parks established to preserve native Hawaiian activities, history and culture.<sup>2</sup> The National Park Service manages two parks in forested regions; Hawaii Volcanoes National Park and Haleakala National Park, one in the urban realm; the Arizona Memorial, one Historic Trail; Ala Kahakai National Historic Trail, and four parks that preserve and interpret Hawaiian culture and history; Kalaupapa National Historical Park, Kaloko-Honokohau National Historical Park, Puuhonua O Honaunau National Historical Park, and Puukohola Heiau National Historic Site. Three of the eight National Parks in Hawaii 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.<sup>17</sup>

### *State Parks*



Figure 7.5. Parks and trails provide important opportunities for education and recreation.

The Department of Land and Natural Resources 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”.<sup>18</sup> The hawaii state park system manages 53 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. Among repeat visitors from out-of-state, it has been reported that the nature and scenery of the area is what brings them back to Hawaii.<sup>19</sup>

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, resulting in facilities that are in need of major repair and renovation. Some of this renovation has been accomplished through required federal compliance with the Americans with Disabilities Act (ADA) and conversion to large capacity wastewater systems.

Due to the recent economic downturn, the Division of State Parks has shifted emphasis to public health and safety, and repair and maintenance, rather than developing new facilities. To generate revenues to support the 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:**

- Acquire new parks and expand 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. There are no full-time enforcement personnel in State parks.
- Provide visitor services and interpretive programs in the parks. In several parks, nonprofit organizations provide some of these services through management leases.

*City & County Parks*

Hawaii's residents and visitors enjoy the favorable year round climate and outdoor recreation activities that the islands have to offer. In addition to State Parks, there are hundreds of City and County parks, as well as recreational sites in Hawaii. For example, on the island of Kauai 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 city, has the greatest number of park facilities (See Table 7.3 for a summary of recreational facilities on the island of Oahu ).

*Na Ala Hele Trails & Access Program*

Na Ala Hele (NAH) is the State of Hawaii Trail and Access Program is administered through Department of Land and Natural Resources Division of Forestry and Wildlife (DOFAW). This program was established in 1988 (Chapter 198D, Hawaii Revised Statutes (HRS), in response to



**Table 7.3. Oahu Parks & Recreation Facilities Summary**

Facility	Description	Number	Area (acres)
Regional Parks	Serve entire island or region of island; include a variety of recreation types and facilities, natural and cultural sites.	11	2,054.69
Beach/Shoreline Parks	Areas/sites along shoreline; include facilities and support services for water activities, sunbathing, picnicking, and other passive activities.	69	1,078.66
Nature Parks/ Preserves	Areas maintained primarily to preserve or conserve unique natural features.	7	1,059.47
District Parks	Community-based park averaging 20 acres; intended to serve 25,000 people; includes playfields, playcourts, passive areas, gym/ recreation complex, swimming pool.	26	565.93
Community Parks	Community-based park averaging 10+ acres; intended to serve 10,000 people; includes playfields, playcourts, passive areas, recreation building.	52	444.09
Neighborhood Parks	Community-based parks averaging 6 acres; intended to serve 5,000 people; includes playfields, playcourts, passive areas, comfort station.	78	362.70
Mini-Parks	Small landscaped areas serving high-density neighborhoods as well as high-density business and industrial areas. Facilities may include benches, picnic tables, children's play area.	31	37.36
Urban Parks	Passive landscaped areas including squares and triangles usually located in residential or business areas.	17	45.09
Zoos	Honolulu Zoo	1	41.96
Botanical Gardens	Areas developed for the recreational and educational appreciation of specific types of plants and plant communities.	5	459.04
Public Golf Courses	Golf courses owned and managed by the City & County of Honolulu.	6	1,002.26
Malls	Any pedestrian promenade that is or has been established and is under the control, management, or ownership of the City.	7	4.84

public concern about the loss of public access to certain trails and the threat to historic trails from development pressure. The Program plans, develops, acquires land or rights for public use of land, 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 condition for specific hazards and executing

mitigation actions and applying warning signage along transit corridors.<sup>20</sup> NAH has become increasingly engaged in trail management and regulatory issues due to both public and commercial recreational activities and emerging legal issues.

Trails and unpaved access roads serve multiple functions. 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 as firebreaks and firefighter access routes.
- Experiencing, protecting and preserving Hawaiian culture.
- Recreating, hunting, hiking, bicycling, equestrian riding, off-highway vehicle riding.

The Commercial Trail Tour Activity (CTTA) program allows commercial tour operators to utilize NAH trails diversifying Hawaii's economy via management and monitoring of commercial trail and access road tours. Table 7.4 reflects revenue brought in by the CTTA program since its inception in 2002, totaling over \$600,000 in eight years.

**Table 7.4 Revenues from Commercial Trail Tour Activity (CTTA)**

<b>CTTA Revenue</b>	<b>FY09</b>	<b>FY08</b>	<b>FY07</b>	<b>FY06</b>	<b>FY05</b>	<b>FY04</b>	<b>FY03</b>	<b>FY02</b>
<b>Kauai</b>	\$19,574	\$41,792	\$35,973	\$ 37,332	\$ 34,273	\$11,114	\$33,232	\$36,145
<b>Oahu</b>	\$43,597	\$30,622	\$32,260	\$ 38,356	\$ 37,442	\$18,884	\$ 6,119	\$ 2,154
<b>Maui</b>	\$55	\$1,012	\$836	\$1,348	\$1,644	\$336	\$640	\$ 3,436
<b>Hawaii</b>	\$6967	\$5,989	\$22 844	\$37,368	\$38,723	\$10,172	\$25,752	\$4,028
<b>Total</b>	<b>\$70,193</b>	<b>\$79,415</b>	<b>\$91,913</b>	<b>\$114,404</b>	<b>\$112,082</b>	<b>\$40,506</b>	<b>\$65,743</b>	<b>\$45,763</b>

#### Priority Areas & Issues for Nature-Based Recreation

Three agencies in addition to DOFAW identified priority landscapes, issues and goals relating to nature-based recreation and tourism in Hawaii. Documents referenced include: the 2008 Statewide Comprehensive Outdoor Recreation Plan (SCORP); DLNR Recreational Renaissance Plan B, the Hawaii Tourism Assessment of Natural Resources and Strategic Plan and DOFAW's Management Guidelines. In addition, 10 areas were highlighted in "The Hawaii Watchable Wildlife Guide"<sup>21</sup>. The areas were carefully selected to help direct anyone interested in watching

wildlife find accessible locations for viewing wildlife. Our Priority Areas for nature-based recreation and tourism consist of all State and National Parks, the priority areas identified by these four agencies and the locations suggested in the “Hawaii Watchable Wildlife Guide”. Please refer to Map 7.3 for Hawaii’s Priority Areas for Hawaii’s Priority Areas for Nature Based Recreation.

The 2008 Statewide Comprehensive Outdoor Recreation Plan identified five priority issues:

- Protection of Natural and Cultural Resources
- Management of Recreation Resources and Facilities
- Meeting the Needs of Recreation Users
- Access to Recreation Resources
- Funding

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 Game Management Areas.

DLNR Recreational Renaissance Plan B<sup>22</sup> focuses on two goals:

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

The Hawaii Tourism Authority 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 to be addressed. The 23 sites are:

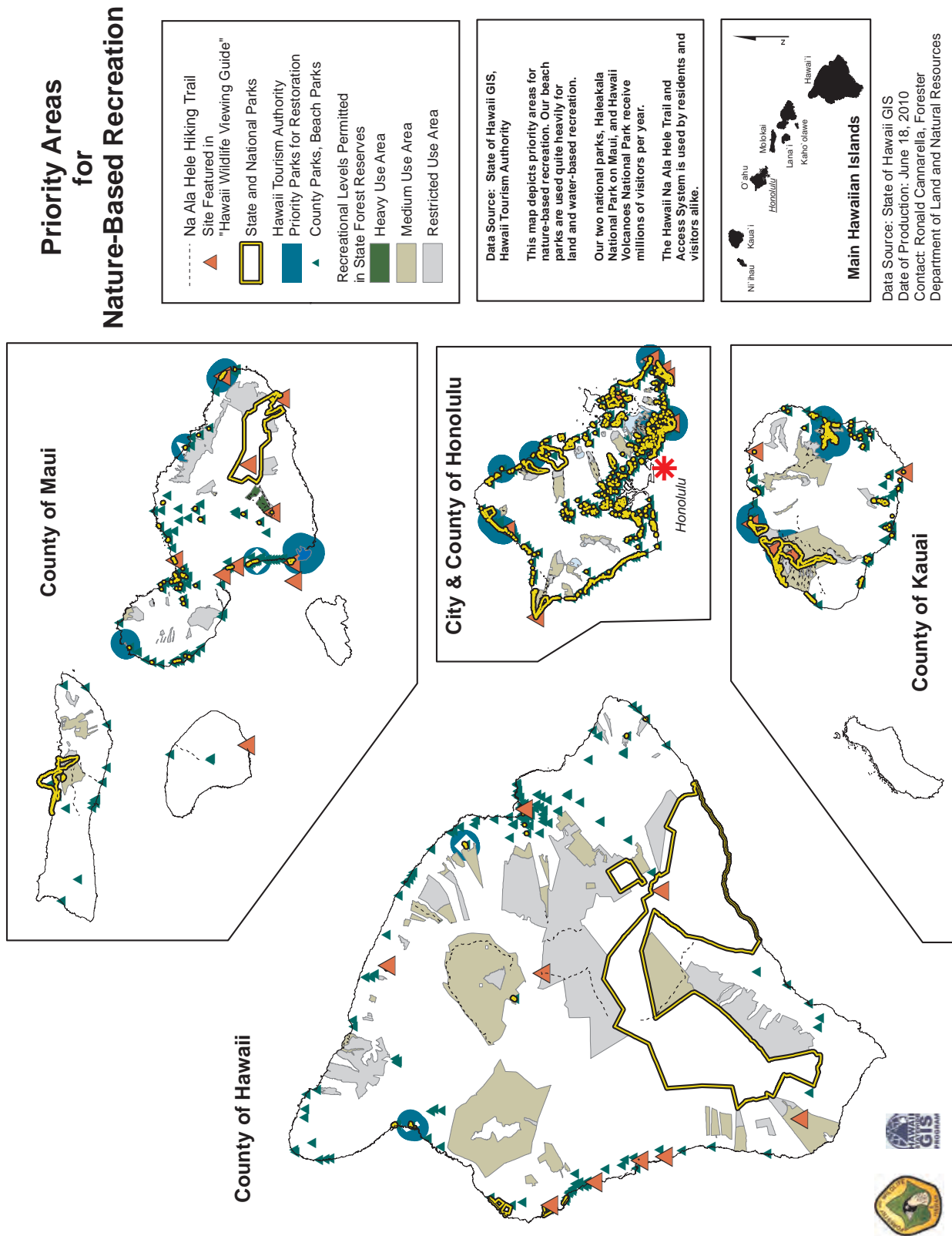
Kauai:

- Haena Beach County Park (and Maniniholo Dry Cave)
- Haena State Park
- Kalalau Lookout (Kokee State Park)
- Opaekaa Falls (Wailua River State Park)
- Puu Hinahina Lookout (Waimea Canyon State Park)

Oahu:

- Diamond Head Lighthouse Overlook
- Diamond Head State Monument
- Laie Point State Wayside
- Makapuu Point State Wayside
- Manoa Falls
- Pupukea Beach Park





Map 7.3: Priority Areas for Nature-Based Recreation

Maui County:

- Palaau State Park Lookout, Molokai
- Luahiwa Petroglyphs, Lanai
- Ahihi-Kinau Natural Area Reserve, Maui
- Honolua Bay and Mokuleia Bay (Marine Life Conservation District)
- Kamaole III Beach Park
- Kaumahina State Wayside
- Waianapanapa State Park

Hawaii Island:

- Akaka Falls State Park
- Hapuna Beach State Recreation Area
- Kealahakua Bay State Historical Park
- Punaluu Beach Park
- Waipio Lookout

Summary

According to the Hawaii State Parks Survey conducted in 2007, an estimated 10.1 million users visit State Parks each year, of which 67% are out-of-state visitors (6.7 million) and 33% are residents (3.4 million). While these statistics are for State Parks alone, a similar trend of increasing usage is also evident at other sites including less frequented resources such as Natural Area Reserves, Forest Reserves, botanic gardens and museums, difficult-to-access beaches, and hiking trails. In addition to usage, there are other factors such as signage, parking, accessibility and other amenities e.g., restrooms and concessions, that impact the overall quality and condition of each natural resource site in Hawaii. To continue to provide recreational areas for residents and visitors alike, natural resource sites need to be maintained, and in some cases, restored.

Interviews with recreation agencies and providers indicate that inadequate funding is one of the most critical problems. As departments struggle to maintain services and recreation programs in spite of staff reductions, natural resources will ultimately be negatively impacted. Potential problems include: not meeting the public's recreational needs, increased liability exposure if recreation areas are not maintained to assure public safety, park and trail closures, and resource degradation, all which will harm Hawaii's visitor industry.

In 2003, the Hawaii Tourism Authority commissioned a Natural Resources Assessment to focus on those natural resources important to tourism, particularly those vulnerable to tourism activity or overuse. The purpose of this study was to provide a long-term plan for the expenditure of monies set aside for improving natural resources. The study found that many physical improvements are required at nearly all of the various state and county natural resource sites. In many cases, the improvements recommended are needed to address either deferred maintenance and/or vandalism. Thus, while a restroom can be renovated, if maintenance is not performed regularly, or minor repairs made quickly, or if vandalism is frequent and destructive, then the improvements made are for naught. County, State, and Federal funding for outdoor recreation



and natural resource protection has remained drastically reduced throughout the 1990's and into this decade.

The majority of visitors choose Hawaii as a vacation destination based on the unique natural resources found here. The impact of a degraded environment in general would not only diminish Hawaii's attraction to visitors but also impact the lives of our resident population whose recreational, cultural, subsistence and physical health are often closely linked with the health of the land. Given the trend towards reducing State and County funding for natural resources and outdoor recreation, creative strategies must be implemented to ensure the proper maintenance of natural resource sites frequented by residents and visitors alike.



Figure Number One and Family. Visitors and residents alike enjoy Hawaii for its natural beauty, recreational opportunities, perfect weather and the *aloha* spirit of our people. Photo courtesy Associated Press.

### Data Gaps

Over the past few years, multiple mandates of the Na Ala Hele Trails have become particularly challenging due to the increased development actions affecting ancient and historic trails and responding at a rapid pace to development pressure, while also managing increased demand for

developing recreational trail opportunities such as managing the new off-highway vehicle riding. This challenge requires continuous evaluation and assessment.

*Trails & Access*

- There is a need for more research to be done on the impact of new and emerging recreational opportunities on trails and access lands, such as off-highway vehicle riding.
- Historic Trails require research, mapping and documentation.

*Wildlife Associated Recreation*

- Research on game mammal habitat areas

## Strategy Matrix for Issue 7: Hunting, Nature-Based Recreation and Tourism

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

Residents and visitors alike engage in recreational opportunities enhanced by Hawaii's unique natural resources. The impact of a degraded environment in general would not only diminish Hawaii's attraction to visitors but also impact the lives of our resident population whose recreational, cultural, subsistence and physical health are often closely linked with the health of the land.

Recreation and Tourism: Provide Public Access to Natural Areas							
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Implementing Partners	Measures of Success	Supports National Objectives
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 Hawaii Wildlife Viewing Guide, HTA Priority Parks for Restoration, and public-access easements through applicable private lands.	Reduced negative impact on sensitive resource areas, improved quality of life for residents, improved visitor experience.	Na Ala Hele, NARS, FRS, State & County Parks, DAR, NPS, FSP, FLP, LLCF, UCF, Hawaii Tourism Authority	All private residents/landowners and visitors, conservation organizations, advocates for nature-based recreation, visitor industry	NARF, various federal grants, TAT and HTA Natural Resources Grants 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
2) Preserve open space and natural settings through public & private acquisitions, conservation easements, MOU's, Access Agreements, Cooperative Agreements.	Public recreation areas, targeted private lands.	Management buffers, new conservation lands, more carbon, Multi-State involvement	State and County Planning offices, Federal - LWCF, CELCP, FLP, LLCF, RLA, FRPP, UCF, FSCG	All private residents/landowners and visitors	Land Trusts, TPL, TNC, County "open space" funds, Private donations, HCA, NOAA	Increased acreage under public ownership or control & managed for recreation; Expansion of park systems.	3.3 3.6 2.2

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

3) Promote responsible behavior and preservation of natural and cultural resources through understanding and stewardship of these resources.	Public & private recreation areas, coastal areas	Awareness of invasive species impact on natural areas.	Government & Community partnerships, Volunteer programs, Eco-tourism Co's, Various Park Rangers, UCF	All private residents/landowners and visitors	TAT, HTA, State special funds, HISC, HCA, NOAA	Increase in interpretive materials available to visitors; Increase in public support for stewardship projects.	3.6
<b>Recreation and Tourism: Priority – Provide Recreational Opportunities and Manage Game Mammals</b>							
<b>Long Term Strategy</b>	<b>Priority Landscape Area(s)</b>	<b>Secondary Issues Addressed</b>	<b>Program Areas that Contribute</b>	<b>Key Stakeholders</b>	<b>Resources Available &amp; Implementing Partners</b>	<b>Measures of Success</b>	<b>Supports National Objectives</b>
1) Comply with relevant State statutes (HRS 183D & 195D) and federal laws (Pitman-Robertson [PR] and Section 7 of the Endangered Species Act)	FRS, Private lands, Land locked State lands	Environmental Education, Enhancement, Incipient invasive species identification.	Na Ala Hele, Conservation Education, Forest Stewardship, FSP, CREP, UCF	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 the capacity to effectively manage game mammals through better research & monitoring.	Public hunting areas, private hunting lands, state leased lands	Env. Edu. enhancement, Incipient invasive species identification & control.	Wildlife Program, USGS-PIRG, UH-Manoa Dept. of Nat. Res. & Env. Mgmt., FLP, FSP, UCF, FSCG	Hunters, Rural communities, UH, Watershed Partnerships, Private Landowners	Fees from hunters, PR, Research capacity of State & Federal institutions, HCA	Number of areas & game spp. with population estimates; Number of plans & estimates of desirable game population #'s.	2.2 3.4 3.6
3) Increase effective communication between programs and the public, and among programs regarding resource problems, management and protection issues	Urban & Rural communities & institutions statewide	Env. Edu. enhancement, Incipient invasive spp. Id & control, targeted research.	HISC, Invasive Species Program (Wildlife), Forest Health, Watershed Partnerships, FRS, NARSFSP, CREP, UCF	Public & private landowners, Resource management agencies	HCA, Forestry & Wildlife Education & Outreach, HISC and CGAPS outreach staff, NOAA	Reduced conflict & increased cooperation in natural resource mgmt; Participation in management & protection initiatives,	2.2 3.4 3.6

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

Recreation and Tourism: Outreach and Education							Supports National Objectives
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Implementing Partners	Measures of Success	
1) Children's Forest	State Forests and the Hawaii Experimental Tropical Forest	Multi-State / Island participation.	Conservation Education, FSP, FRS, NAPP, UCF, FSCG	All private residents/landowners and visitors	HCA, TPL, TNC, IPIF, Dryland Forest Alliance, Outdoor Circle, Parks	Number of children engaged; Broad Pacific Island involvement; Demonstration sites.	3.6
2) Maintain a relationship with the Hawaii Environmental Education Alliance (HEEA)	Statewide	Invasive spp., coastal area protection, water quality & quantity.	Conservation Ed., UCF, FSP, FSCG, State & County Parks, FSP	Public & private landowners, resource management agencies	TNC, TPL, NOAA, NPS, Univ. Hawaii	More Coop. Agreements and MOU's; more research, political engagement in climate change issues.	3.3 3.6 3.7

**Acronyms Used:**

1. TAT = Transient Accommodation Tax administered by HTA; \$1m annually to State Parks and Trails.
2. HTA = Hawaii Tourism Authority
3. CELCP = Coastal Estuarine Land Conservation Program
4. PR - Pittman-Robertson Funds
5. NARF – Natural Area Reserve Fund
6. NARS – Natural Area Reserve System
7. FRS – Forest Reserve System
8. RLA – Recovery Land Acquisition Program – FWS
9. FRPP - Farm & Ranchland Program - NRCS
10. LLCF - Legacy Land Conservation Program
11. FLP – Forest Legacy Program – Forest Service
12. FSCG - Forest Service Competitive Grants
13. DAR - Division of Aquatic Resources
14. Na Ala Hele – State Na Ala Hele Trails & Access Program
15. HISC – Hawaii Invasive Species Council
16. FSP – Forest Stewardship Program
17. CGAPS – Committee Group on Alien Pest Species
18. NAPP - Natural Area Partnership Program
19. HCA – Hawaii Conservation Alliance
20. IPIF – Institute of Pacific Island Forestry
21. UCF – Urban & Community Forestry (Kaulunani)
22. NOAA – National Oceanographic and Atmospheric Administration



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- <sup>15</sup> State of Hawaii, Hawaii Tourism Authority, OmniTrak Group Inc. Hawaii State Parks Survey Honolulu, 2007. Page 7.
- <sup>16</sup> State of Hawaii, Hawaii Tourism Authority, OmniTrak Group Inc. Hawaii State Parks Survey Honolulu, 2007. Page 61.
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## Issue 8: Forest Products and Carbon Sequestration

### Overview

The history of forest product utilization in Hawaii is diverse and unique. Hawaii's forests have changed dramatically from the time the first Polynesians migrated to these islands in 400 AD to the present. The native Hawaiians inadvertently introduced the Polynesian Rat (*Rattus exulans*) which caused the near-extinction of the entire genus of our native palm *loulou*, (*Pritchardia spp.*) by feeding on the seeds produced by the palm. *Pritchardia* were once the dominant overstory tree species in the dry forests of Hawaii and formed a unique dry forest ecosystem dominated by a palm species. *Pritchardia*, which also dominated the forests of Rapa Nui (Easter Island), suffered the same fate. The Rapa Nui Polynesians did not develop a sustainable land stewardship system, and their society collapsed as a result. However, the Hawaiian civilization adapted to these rapid changes, and succeeded in developing the *ahupuaa* system in harmony with the natural resource base and unique geography of the high islands.

When the first Europeans encountered Hawaii, they noted that the dry lowlands had been mostly converted to grasslands which were periodically burned by the Hawaiians to stimulate the growth of *pili* (*Heteropogon contortus*) which was the primary thatching material used by the Hawaiians. *Loulu*, no longer the dominant dry forest species, had been replaced by the endemic *wiliwili* (*Erythrina sanwdicensis*).

For the most part, native Hawaiians did not use wood-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 our Wet and Mesic forests. A mature koa tree can reach 120 ft tall, and is capable of producing a straight trunk with no defects that the native Hawaiians found ideal for producing ocean voyaging canoes. In addition to its superior woodworking qualities, a mature koa can produce beautiful wood with a "curl" that rivals any fine craft wood in the world. Today, a koa rocking chair currently retails for \$3,000 to \$5,000 depending on the curl and skill of the craftsman. Thus, koa is highly prized for its ecological, cultural and economic value. Most of Hawaii's koa has already been harvested from private lands, and koa theft from the forest reserves has increased in the last several decades due to the high demand for the valuable heartwood.

The first commercial product extracted from Hawaii were the many endemic species of *iliah*, or sandalwood (*Santalum spp.*). Sandalwood is prized for its fragrant wood and was a valuable commodity for the international trade that immediately took hold in Hawaii after 1778. But *iliah* is a slow-growing species found generally in dry forests. Sandalwood harvesting boomed for 40 years, until the supply of fragrant old trees was exhausted and the genus was driven to the brink of extinction in Hawaii.

Hawaii's other native tree species for the most part do not possess good woodworking qualities, and although several timber mills have successfully operated since the early 1800's a sustainable export market has not yet been developed because less expensive wood-based building materials have been available from overseas sources such as the Pacific Northwest and Southeast Asia.

Large scale timber trials of introduced commercial species have been undertaken by the Hawaii Board of Forestry and Agriculture, the Hawaii Sugar Cane Grower's Association and the U.S. Forest Service since the 1900's. Despite the fact that several Hawaiian grown non-native commercial species have some of the highest growth rates in the world, we have yet to develop a viable and sustainable commercial timber industry. This will hopefully change in the next few years with the establishment of a medium-sized veneer plant and cogeneration facility to be built on the Hamakua Coast of the island of Hawaii, scheduled for initial operations in 2011.

### Hawaii's Forest Products

Increasing timber production and developing markets to support those products is highly desirable in Hawaii, but timber is not the only product derived from these forests. For the purposes of this assessment, forest products are defined as a suite of products including but not limited to the following categories and their corresponding examples:

#### *Timber and Commercial Products (see Map 8.6 Managed Tree Plantations)*

- Timber, wood chips, craft wood and other solid wood products – non-native planted commercial forests, new native forest plantations (koa most likely) for sustainable timber production, salvage operations
- Biomass and/or biofuel production – plantations, invasive species control efforts, commercial forestry byproducts, biomass fuel management, salvage operations
- Salvage and non-timber forest products – forest product recovery following natural disasters, pest or disease outbreaks or natural mortality

In addition to products, forests provide services including but not limited to:

#### *Ecosystem Services*

- Watershed protection and production of water – water capture, percolation, recharge and supply. (See *Issue 1: Water Quality & Quantity* for additional information.)
- Carbon sequestration – native or non-native plantations, reforestation or restoration projects for both non-commercial and commercial utilization. (See *Present Conditions & Trends* section of this Issue for more detail.)
- Native ecosystem protection – preservation of Hawaii's unique flora and fauna. (See *Issue 6: Conservation of Native Biodiversity* for additional information.)

#### *Social, Cultural and Non-Traditional Forest Products*

- Benefits to human health – open space, air quality, exercise opportunities
- Cultural – sacred site protection, resource gathering & medicinal plants, access for cultural practices, spiritual inspiration
- Recreational opportunities – hunting, hiking, camping

### Present Conditions & Trends

The commercial timber industry in Hawaii is in a nascent stage of development. A thriving forest products industry has many components that need to be operational in order for it to function at its capacity. Once fully operational such an industry will likely include lumber, veneer, wood biomass and biofuels, export wood chips, and more. Hawaii has a number of wood product companies, operators, and primary log processors who use small portable mills. However, there is currently no primary log or biomass processing equipment or facility operating on a large scale in Hawaii.

Although Hawaii does not yet have a large-scale timber industry, the craftwood industry is thriving. Local artisans produce an astonishing number of objects crafted from native wood species, notably koa (*Acacia koa*), but also out of the wide variety of introduced wood species. The Hawaii Forest Industry Association (HFIA) has been instrumental in helping this industry to grow and gain exposure locally and abroad. The HFIA has been sponsoring The Hawaii Woodshow every year since 1993. Only Hawaiian-grown wood works of art are displayed in Hawaii's Woodshow. The show is designed to strengthen appreciation for the artists' work and encourage sustainable forestry through the planting of native and non-native trees (See Figure 8.1 Poster for the 2002 Hawaii Wood Show).

An increased focus on reducing the reliance on fossil fuels and improving energy self-sufficiency has bolstered interest in development of wood biomass for fuel or electrical generation facilities in Hawaii. Also of interest are products such as biodiesel, biofuels, and carbon credits. Through implementation of appropriate policies and actions, such as Hawaii's *Greenhouse Gas Emissions* and *Climate Change* task forces, it is hoped that the forest products industry can become operational at a meaningful scale. If accomplished, this could strengthen economic opportunities for other entities to become involved in sustainable forest products, ecosystem services, and increased self sustainability for Hawaii. Clearly there is the potential for a 'win, win' situation in using the native *Acacia koa* for restoration of wildlife habitat, conversion of marginal pasturelands and degraded croplands to native species, timber production, and carbon sequestration. Koa may not be as fast growing a tree as some other non-natives, but the overall positive impacts of using this species for the above goals, clearly outweigh that of a rather short sided view/quick gain approach that focuses on non-natives. Certainly, there are non-natives that could work to achieve a suite of ecosystem benefits as well.

#### *A veneer plant and cogeneration facility*

There are plans for a medium-sized veneer plant and cogeneration facility on the Hamakua Coast on Hawaii Island, scheduled for initial operations in 2011. This facility will be supported by locally-grown hardwoods (see maps below). Tradewinds Forest Products ([www.tradewindsforestproducts.com](http://www.tradewindsforestproducts.com)) has proposed a two part plan: Phase One - construction of a \$62 million veneer manufacturing plant at Ookala on the Hamakua Coast. Phase Two entails building a small cogeneration biomass power plant that will burn mill residuals and provide steam for running the dryers to finish the veneer products. Tradewinds Forest Products has a





power purchase agreement with Hawaii Electric Company, as well as a Clear Air Permit issued by the State of Hawaii Department of Health - both of which are important steps in achieving these plans. Should Tradewinds complete these plans, the operation could have a significant impact on Hawaii's ability to produce, market, and export high value timber, which could also positively impact related operations throughout the state.

### *Carbon Sequestration*

The active management and sustainable use of carbon can help reduce the harmful effects of carbon dioxide in our atmosphere, but there is much to learn about how to go about accomplishing this. A number of studies suggest that carbon storage and sequestration play very important roles in climate change by removing harmful carbon dioxide (CO<sup>2</sup>) from the atmosphere via photosynthesis in plant matter.<sup>11, 12, 13, 14, 20</sup> The development of carbon markets is also occurring globally to incentivize 'smart' growth and 'green' living. Mathew Smith of the Society of American Foresters says "Carbon markets are more of a riddle to be solved than an easily defined path to a new payday for forestry."<sup>18</sup> Such a philosophy may be applicable to a small state with a young forest products industry such as Hawaii; however there is interest among private landowners, federally owned lands, and state agencies that hold & manage land to investigate the Voluntary Carbon Market. It is hoped that the use of this market could be an ideal option because it would highlight what is being phrased "charismatic carbon" that is to say carbon that has more values than fast sequestration of CO<sup>2</sup> from the atmosphere.

We seek to better understand what role countries, states and private landowners can play in positively affecting climate change. We also need to be more diligent at managing our carbon resources and the many services they provide. An important factor to consider is the kind of carbon we plant on State lands and/or promote on private lands. We need to be very careful when planting invasive species for short term products and CO<sup>2</sup> sequestration, and consider the potential total ecosystem impacts from such activities.

An alternative for Hawaii could be 'niche' or voluntary carbon markets or those that incorporate value added qualities to carbon. Such a proposal would be akin to paying more to purchase lumber that was sustainably harvested i.e., certified by the Forest Stewardship Council ([fsc.org](http://fsc.org)) or other such entities. A 'niche' carbon market could contribute to sequestration but also provide equally important services like conserving native habitat for endangered species, contributing to cleaner water and increased water supplies, and much more. This type of multi-faceted carbon market emphasizes the importance of including the entire ecosystem or *ahupuaa* concept as a center piece of our management goals. The forests are part of a larger system of which carbon is one element, therefore we should be looking at the whole system when considering how to manage the products from it.

### *The Natural Capitol Project*

This project works with State and private landowners to develop ecological and economic approaches for protecting and restoring biodiversity and ecosystem services, and in ways that are economically attractive. Their major focus is on opportunities to restore native koa tree cover for



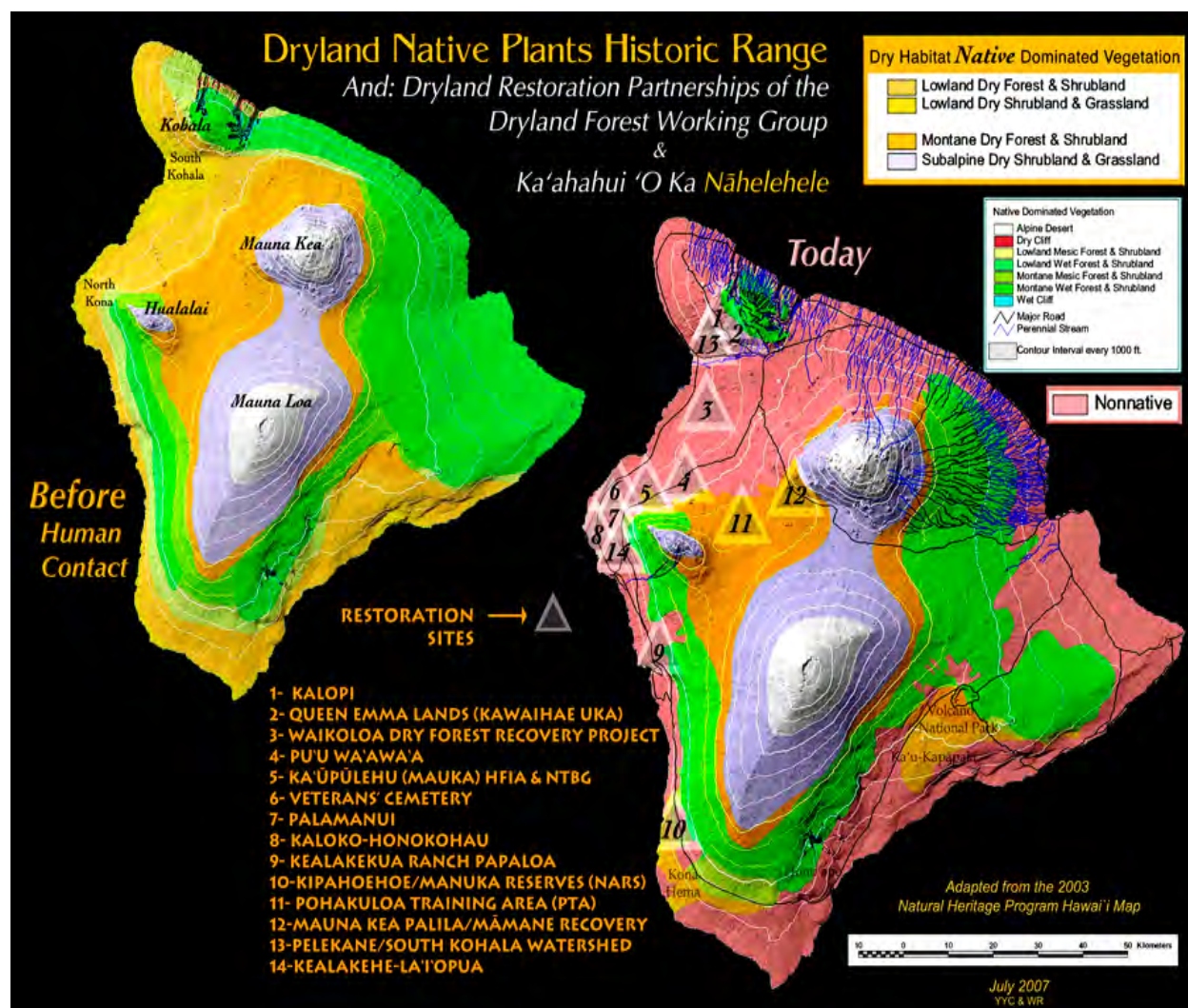


Figure 8.2 Dryland Restoration Partnerships on the island of Hawaii. Map courtesy of the Dryland Forest Restoration Group.

its diverse economic, ecological, and cultural benefits.<sup>15</sup> Collaborative efforts like this, offer hope that Hawaii can engage in new methods of maintaining natural resources and their products, while ensuring a sustainable economic return. The use of conservation easements, tax reductions for conservation practices, endowments for natural capital and other new programs are possible alternatives for maintaining Hawaii's forest products and services.

There are a number of community based forests with important social, cultural, and physically protected forests throughout Hawaii. Dry forest types are the most threatened in Hawaii, as they are in most of the tropics. Several public-private partnerships have formed to protect these unique forests. (See figure 8.2). These working groups increase the chances of survival of two endemic dry forest dominant tree species (*wili wili- Erythrina sandwichensis* and *Uhi Uhi- Caesalpinia kawaiiensis*). These species are very culturally important, but also at a high risk from

wildfire (*see Issue 3: Wildfire*) and the erythrina gall wasp (*See Issue 2: Forest Health: Invasive Species, Insects and Disease*).

Another important dry forest on the leeward side of the Island of Hawaii *kiawe* (*Prosopis pallida*) forest near the community of Puako. This forest protects the village of Puako from frequent flooding and wildfires, and also produces a very unique brand of honey gathered from *kiawe* nectar.

### *Programs*

There are a number of programs that support the development of forest products and services on State and private lands in Hawaii. The Forest Reserve System was established by the Territorial Government of Hawaii through Act 44 in 1903. Its primary purpose is to protect mauka forests, enabling them to provide forest products/services for makai communities and agricultural demands – sustainable water supply was the principal underlying consideration. Today the Forest Reserve System includes approximately 640,000 acres across the state and is managed to provide a suite of services for the public:

- 1) Protect and manage forested watersheds for production of fresh water supply for public uses now and into the future
- 2) Maintain biological integrity of native ecosystems
- 3) Provide public recreational opportunities
- 4) 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 within 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.

Other State and Federal programs that support forest product capacity, forest restoration and/or conservation needs on public and private lands are: the Forest Stewardship Program, the 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*

The development of a sustainable forest products industry, resource restoration and conservation through landowner assistance programs, policy change, outreach and education are all important goals in Hawaii. Achieving these goals can only be accomplished through a wide variety of partnerships and 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 such an industry in Hawaii.

Hawaii Forest Industry Association (HFIA) is dedicated to responsible forest management. HFIA produces the annual Hawaii Woodshow, sponsors the Hawaii's Wood trademark, and serves as an advocate for Hawaii's diverse forest industry from tree planting and harvesting to creating and selling wood products (see [hawaiiiforest.org/](http://hawaiiiforest.org/)).

Private timber plantations owners, land lessees & green energy companies such as Kamehameha Schools, Parker Ranch and others have large amounts of standing timber that will play an important role in a forest products industry in Hawaii. Hawaii Mahogany Inc. ([hawaiianmahogany.com](http://hawaiianmahogany.com)) operates a mature tree farm on Kauai that produces a variety of forest products including: animal feed, lumber, biochar & soil blends, carbon credits from tree farms and a small hydroelectric plant<sup>19</sup>. A green energy company, SunFuels Hawaii LLC, on the Big Island develops biomass-to-energy, uses gasification technology from renewable biomass feedstocks, and is examining other thermal conversion technologies suitable for the production of a renewable bio-oil to power electrical generation plants<sup>21</sup>.

Federal and nonprofit landowners such as The Nature Conservancy, U.S. National Park Service the U.S. Fish & Wildlife Service Refuge System and the Office of Hawaiian Affairs have large expanses of primarily native forests that are actively managed for a variety of forest products & ecosystems services.

Hawaii Agriculture Research Center ([harc-hspa.com](http://harc-hspa.com)) is actively pursuing *Acacia koa* and other hardwood tree species research to identify Fusarium resistant koa, as well as koa that exhibits a straight tree growth form.

### Benefits

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

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 social considerations is not an exact science; inherently, subjectivity plays an important role depending on your particular point of view. In Hawaii and much of the Pacific, these types of forest products are very important and are often managed specifically to perpetuate their long-term sustainability.

Due to the Forest Reserve tax deferment policy in 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 in 1958, to 4,121,000 board feet in 1967<sup>2</sup>. After the Endangered Species Act in 1973, commercial tree planting dropped from an average of 580 acres per year during the period 1956 to 1965, to only 82 acres in 1985<sup>2</sup>. However, the long process of slowing the rate of



extinction rate of plant and animals began. The 2004 survey "Economic Value of Hawaii's Forest Industry in 2001" revealed that over 900 workers were employed in the Hawaii forest industry, with a corresponding payroll of \$30.7 million<sup>3</sup>. This "placed the average wage rate for forest industry employees at over 50% higher than the average for farm labor"<sup>4</sup>.

We know that a multitude of benefits are derived from or positively influenced in some way by forests. Because islands function as an integrated system rather than a grouping of independent systems, it is important to understand that forest products need to be valued by more than the individual product but rather by its role in a larger system.

### Threats

A principal threat to the forest products industry in Hawaii is the conversion of forest to non-forest uses. Labor and land costs are high in Hawaii and with the global economic downturn, many landowners who have suitable land to support the production of forest products, are choosing or being forced to sell instead. Keeping forests from being converted to non-forest uses is an ever-present challenge in Hawaii. 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 between expanding agriculture areas for food and/or forest products.

People living in Hawaii are dependent on imported resources for a large percentage of life sustaining needs such as food, fuel, equipment and many wood products and supplies. On the Island of Oahu, an estimated two weeks of food, water and supplies are available to support a population of more than 800,000 people if the air and sea ports are rendered non-operational. It is very important that Hawaii 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.

Another obstacle to the development and maintenance of an operational timber industry in Hawaii is port capacity. Currently, existing ports and facilities may not have the proper size, configuration or accessibility to handle large volumes of primary or processed timber products. If an increase in exportation of Hawaiian grown timber or wood products occurs, some expansion or further development of port facilities may be necessary.

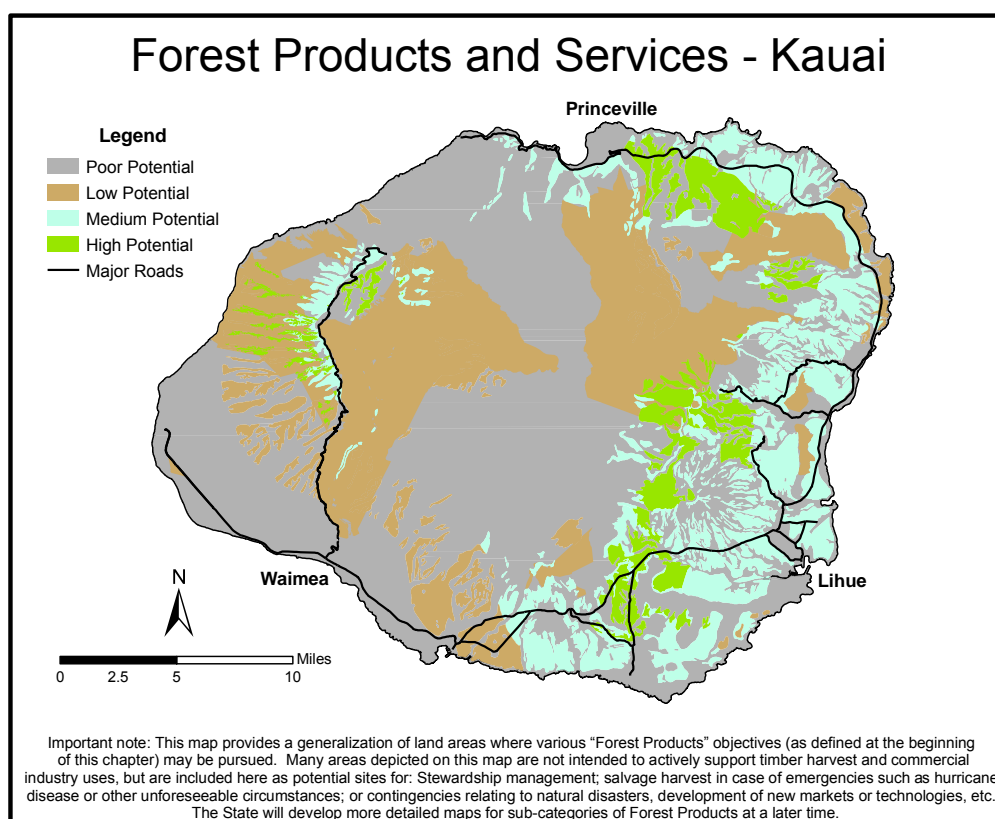
Lack of access to Federal and/or State programs for private landowner loans, land management planning assistance, and marketing assistance has also impacted the development of a timber industry. Due to considerations such as scale, geographic location and local economic conditions, entities seeking to develop forest industry infrastructure in Hawaii commonly encounter challenges in obtaining capital and loans, yet their success in this regard is critical for Hawaii's forest industry to grow.

### Priority Areas for Forest Products & Carbon Sequestration

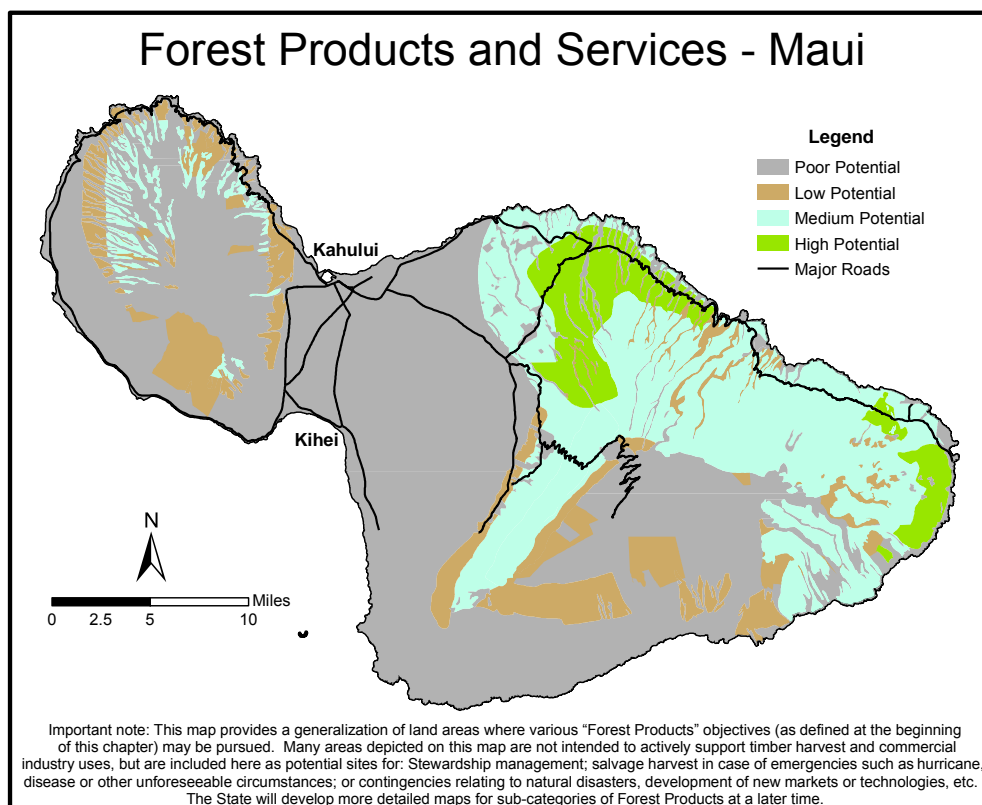
The Forest Products maps (Maps 8.1, 8.2, 8.3, 8.4 and 8.5) are based on the State's Prime Forest Land map units. This layer was derived by analyzing environmental factors such as rainfall, elevation and soils.

Forest Products Ranking	Prime Forest Land Map Units
High Potential	Prime 1 & Unique
Medium Potential	Prime 2
Low Potential	National Standard
Poor Potential	Other areas

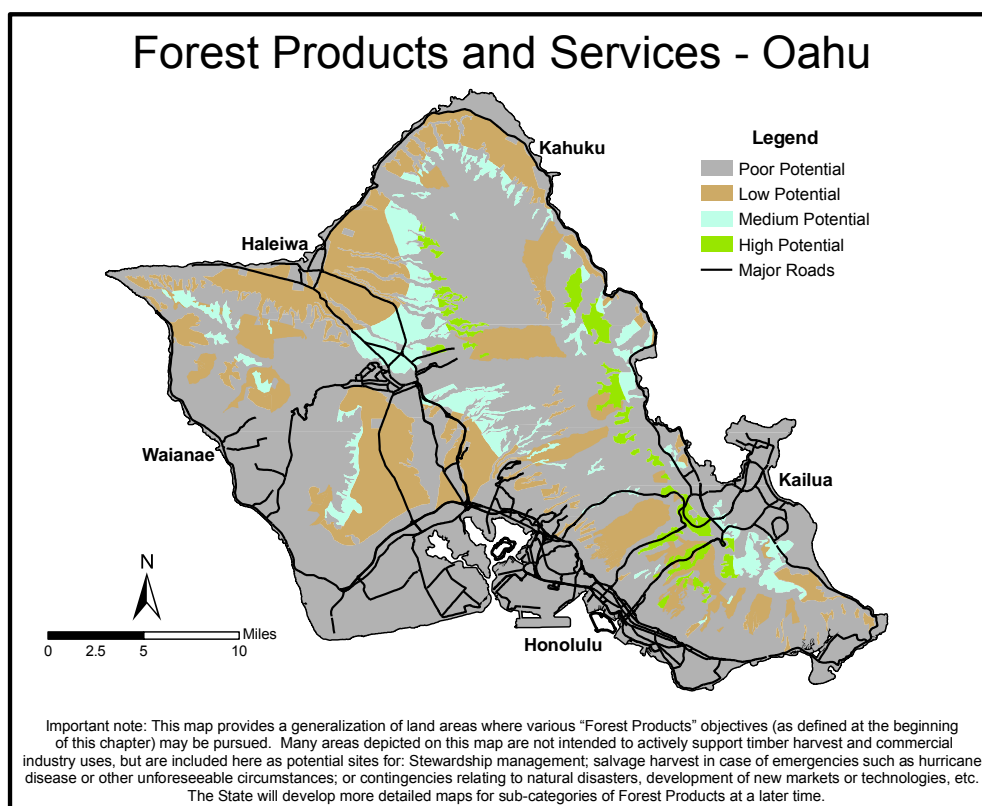
State Forest Reserve acreage not included within the original Prime Forest Land map units were subsequently added and categorized as low potential in part to recognize that opportunities exist for managing "low potential" areas for considerations such as ecosystem services, salvage of resources after natural disasters, invasive species control, native species reforestation, etc. Finally, non-native commercial timber plantation areas managed by DOFAW were automatically ranked as High Potential.



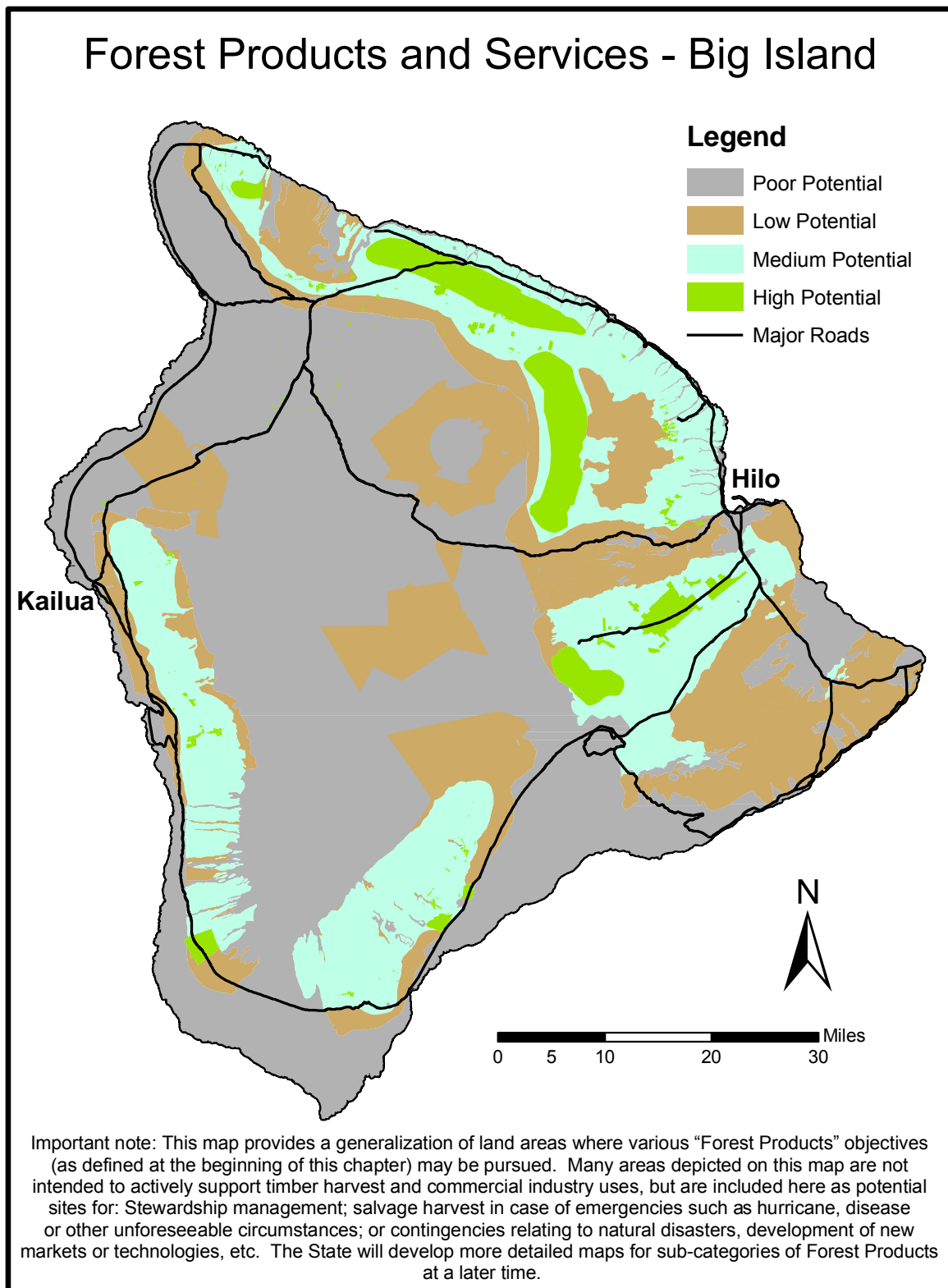
Map 8.1 Priority Area for Forest Products Island of Kauai



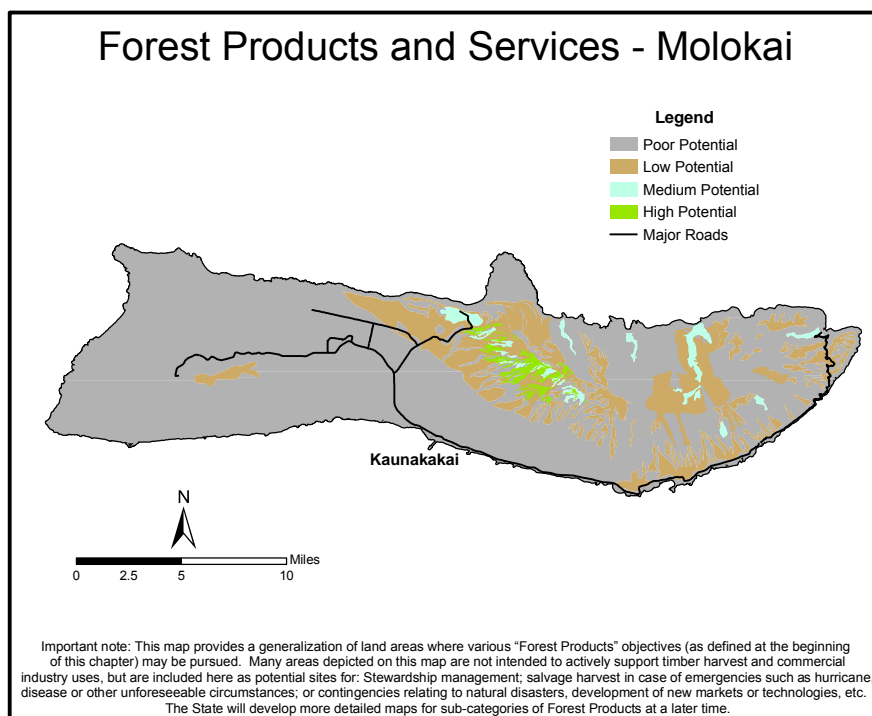
Map 8.2 Priority Area for Forest Products Island of Maui.



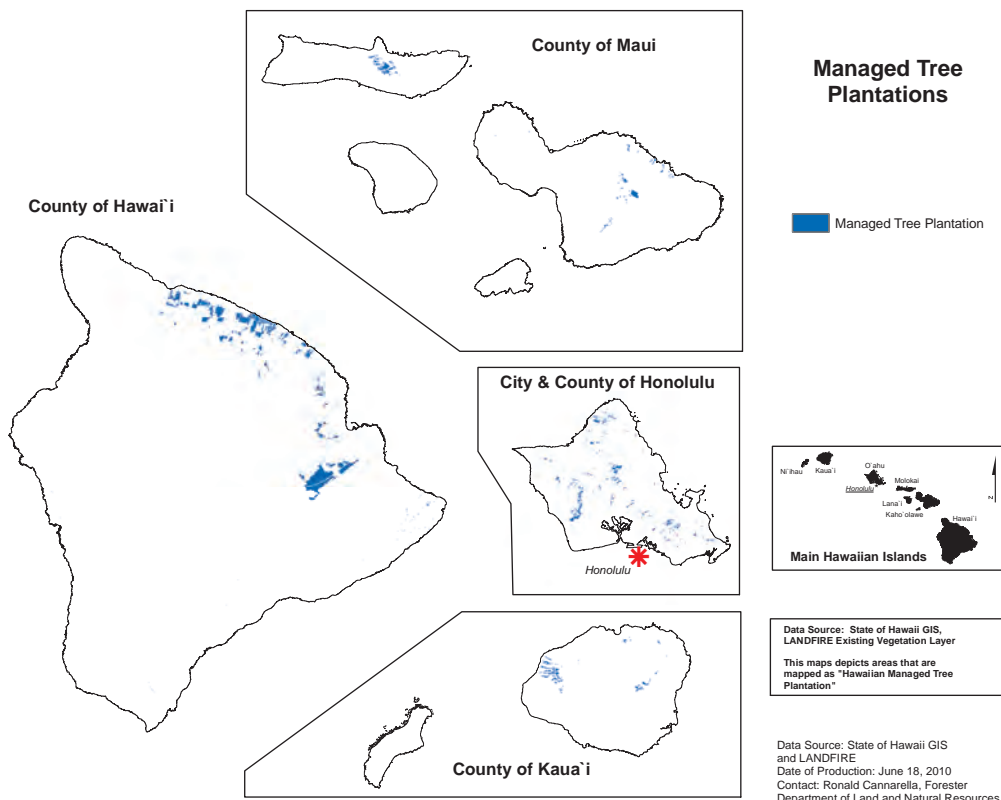
Map 8.3 Priority Area for Forest Products Island of Oahu.



Map 8.4 Priority Area for Forest Products Island of Hawaii



Map 8.5 Priority Area for Forest Products Island of Molokai.



Map 8.6 Managed Tree Plantations



### Data Gaps & Opportunities

1. Management of native forests for social and cultural objectives. For example, the State seeks to develop an *Acacia koa* canoe log production forest at Kapapala on the island of Hawaii.
2. Niche Carbon Markets as part of the voluntary and/or cap & trade system.
3. Studies or research to determine:
  - 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 biomass conversion to diesel or other fuels.
  - How do existing stands of mature commercial forest on state lands fit into the long term goal of a viable forest products industry. Sub-topics could include what are the best uses/ options for commercial stands on State lands, is there a combination of biomass and solid wood plantings that would meet the needs of both developing industries.
  - Where timber resources are relative to potential markets.
  - What range of products can be produced from available species.
  - What are the characteristics of the existing industry, including logging infrastructure.
  - What are the markets (expected price and depth) for various products including high, medium and low grade hardwood lumber and other products.
  - What opportunities exist to use or sell manufacturing and forest residue. How sustainable are the various components of the timber resource.
  - New products or services suitable for Hawaii.
  - Refining or providing silvicultural practices, volume tables, wood properties, certification, establishment and management of new koa forests on fallow lands for conservation or commercial purposes, etc.
4. Hawaii needs assistance with its nascent sawmill, veneer mill & bioenergy establishment. This includes loan programs to assist private businesses in capitalizing their field equipment and processing facility needs, marketing, infrastructure development, etc. What research and development is needed to facilitate access to such loan programs.
5. Development of genetically improved or disease resistant seedling stock for non-native and native species.
6. Use of commercial forestry as a way to convert weedy, invasive species, to productive forests and native forests.
7. Complete comprehensive management plans for all State Forest Reserves - [hawaii.gov/dlnr/dofaw/forestry/FRS/frplans](http://hawaii.gov/dlnr/dofaw/forestry/FRS/frplans).

### Summary

Hawaii's forests will continue to be critically important to the state's water supply, unique plants and animals, the economy, people and their culture. Benefits of Hawaii's forests go well beyond

wood and fiber products and include aesthetic value, recreational enjoyment, specialty non-timber forest products, water conservation, improved air quality, coral reef protection and many other important resources<sup>5</sup>. Increased economic and development pressures that alter land use and management will continue to be challenges for the state's forest product industry<sup>5</sup>. It is important that forest industry potential in Hawaii be considered from a holistic perspective in order to sustain the growth and health of the forests over the long term, as well as provision of the services and benefits associated with healthy forests. Hawaii's forest industry must also look towards the future for new technologies, programs, and cooperative opportunities that provide alternatives fitting for Hawaii's unique resources.

## Strategy Matrix for Issue 8: Forest Products and Carbon Sequestration

## Strategies for Issue 8: Forest Products and Carbon Sequestration

While the forest products industry is in its nascent stages in Hawaii, there is tremendous potential for a sustainable and economically viable industry if a series of actions take place such as: research on key species, developing carbon credit programs in Hawaii, garnering political will to support forest management and industry development from policy, statutory and financial perspectives, and provision of incentive programs that provide alternatives to converting forests to non-forest uses for private landowners.

Forest Products & Carbon Sequestration: Support Development of a Forest Products Industry							
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/required	Measure of Success	Supports National Objective
1) Foster the Development of an Integrated Forest Products Industry in Hawaii.	See maps	Solid wood products, carbon sequestration, biomass for energy and fuels reduction, economic growth. Salvage and invasive species control operations.	Rural Development, FSP, EQIP, Farm Bill Programs: Biomass & Biofuel, FSCG, Cooperative Fire Assistance	Public and private forest landowners, TNC, OHA, lessees	HFIA, WFLC, HCA, TNC, IPIF, Hawaii State Legislature, USFS	Increase public and private lands under commercial forestry management; Execute more leases for commercial timberlands. Proportion of energy or raw materials produced locally vs. imported.	1.1, 1.2, 3.1, 3.4, 3.5, 3.6
2) Develop and implement strategic research plan based on existing symposia and research findings regarding Forest Product Industry.	Statewide	Investment strategy, improved Best Management Practices, informed public.	Farm Bill: Biomass & Biofuel Programs; S&PF Rural Development Program, Ecosystem Services Program, FSP	Private landowners, PICCC, FWS, TNC, UH	Same as above	Hawaii forest product literature available at appropriate clearinghouses, websites, and research stations. New research projects initiated & 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 Hawaii.	Statewide	Creating economic opportunities; biomass & fuel production.	FRS, HCA, Special Technology Dev. Program, FSP, FLP, CREP, LLCF, FSCG, OHA, HCA	HCA, NPS, DOT, Office of Planning, HDOA, TNC	Same as above	Low interest loans available to private entities, cultural products available throughout the year, export potential enhanced.	1.1, 1.2, 3.1, 3.4, 3.6, 3.7

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 Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/required	Measure of Success
1) Research and development of a carbon market for Hawaii.	Statewide	Carbon sequestration; cap and trade; watershed protection & enhancement.	FRS, HCA, Special Technology Development Program, FSP, FLP, CREP, LLCF, FSCG, OHA, HCA	Resource managers increased budgets, private landowners, OHA, TNC	HCA, OHA, DOD, DOT, Office of Planning, TNC, WFCL, IPIF, HETF, HISC, universities, carbon brokers	Discussions with State Attorney General's office and various carbon credit companies; establish one or more carbon credit market demonstration projects.
						1.1, 1.2, 3.1, 3.4, 3.5, 3.6, 3.7
Forest Products and Carbon Sequestration: Hardwood Tree and Native Tree Research						
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/required	Measure of Success
1) Conduct research studies focused on improving growth from and <i>fusarium</i> resistance for <i>koa</i> , and rust resistance for <i>ohia</i> .	Statewide	More deliberate planting of <i>koa</i> and <i>ohia</i> at all elevations.	FRS, HCA, Special Technology Development Program, FSP, FLP, CREP, LLCF, FSCG, OHA, HCA	Resource managers increased budgets, private landowners, OHA, TNC	HCA, OHA, DOD, DOT, Office of Planning, TNC, WFCL, IPIF, HISC, CGAPS, HAWP	Improved genetic native tree stock distributed throughout the State; Reduced dieback of <i>koa</i> and <i>ohia</i> ; enhanced economic potential for <i>koa</i> due to more straight boles.
2) Identify invasive species vectors to reduce potential introductions such as <i>Erythrina</i> Gall Wasp.	Statewide	Informed literature shared with Pacific neighbors.	Dept. of Transportation, Dept. of Ag., PIER, HEAR, FSCG, DOA, FSP	Multi-State, International neighbors, HAWP, private landowners	HCA, OHA, DOD, DOT, Office of Planning, TNC, WFCL, IPIF, HISC, CGAPS	Improved biosecurity at sea and airports; reduced biosecurity threat to native flora and fauna.
						1.1, 1.2, 2.2, 3.1, 3.4, 3.5, 3.6, 3.7
						1.1, 1.2, 2.2, 3.1, 3.2, 3.4, 3.5, 3.6, 3.7

Strategies for Issue 8: Forest Products and Carbon Sequestration

Forest Products and Carbon Sequestration: Hardwood Tree and Native Tree Research							
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/required	Measure of Success	Supports National Objective
1) Social, Cultural and Non-Traditional Forest Products.	State-wide	Cultural uses, benefits to human health, recreational opportunities.	Conservation Education, UCF, FSCG, TPL, TNC, Land Trusts	Community groups, individuals, public and private landowners, recreation organizations	OHA, DBEDT, DLNR, TNC, HCA, National Park Service, FWS Refuge System	Reduce negative impacts on public lands due to increased education; more implementation of ancient Hawaiian land management practices.	3.1, 3.2, 3.4, 3.5, 3.6

**Acronyms Used:**

1. WFLC - Western Forestry Leadership Coalition
2. OHA - Office of Hawaiian Affairs
3. HAWP - Hawaii Association of Watershed Partnerships
4. EQIP - Environmental Quality Incentive Program (NRCS)
5. NARF - Natural Area Reserve Fund
6. FRS - Forest Reserve System
7. Forest Service Competitive Grants
8. HISC - Hawaii Invasive Species Council
9. Forest Stewardship Program
10. CGAPS - Committee Group on Alien Pest Species
11. Natural Area Partnership Program
12. HCA - Hawaii Conservation Alliance
13. IPIF - Institute of Pacific Island Forestry
14. UCF - Urban & Community Forestry (Kaulunani)
15. UH - University of Hawaii
16. DOD - Department of Defense
17. DOH - State Department of Health
18. CREP - Conservation Reserve Enhancement Program
19. PIER - Pacific Island Ecosystems at Risk
20. HEAR - Hawaii Ecosystem At Risk
21. DOA - Department of Agriculture
22. USFS - United States Forest Service
23. HETF - Hawaii Experimental Tropical Forest



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## **Issue 9: Multi-State Issues**

### Overview

Tropical forests serve many unique and essential life-supporting roles for the world at large; as such tropical islands have the potential to be leaders in the global dialogue pertaining to climate change and conservation of rare plants, animals and cultures. Pacific islands represent the “canaries in the coal mine” – by feeling the impact of climate change in coastal areas.<sup>1</sup> The forested ecosystems on Pacific islands are also heavily impacted by deforestation, urban growth and expansion, increased carbon emissions, and threats to tropical biodiversity.

The Hawaiian islands have developed a myriad of ecosystems with high rates of endemism among the plant, animal and invertebrate inhabitants.<sup>2</sup> These islands also afford opportunities for many different human cultures to coexist. Various areas in Hawaii are highly developed; offering a wealth of products and technologies. There are also world class marine and terrestrial experiences that stimulate tourism, sporting events and unique research opportunities. The U.S. Military in the Pacific is also quite substantial, with Oahu and Guam having the largest total presence.

This Issue will offer a broad look at some of the important historic, present, and future issues related to Hawaii’s interaction with other people and cultures from the Pacific and around the world. It will also explore ideas about how to improve technologies, expand opportunities, and offer ideas on how we can better manage and protect these natural resources of many islands in the Pacific.

### *Neighbors & Visitors*

Hawaii is located between several continents: Asia, Australia, and North & South America. Nearby countries are: Mexico, 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.

Hawaii’s vast beauty and convenient location in the Pacific make it a natural place for travelers to visit by air and sea using transportation such as: personally owned yachts, cargo vessels and small aircraft; national and international airlines, cruise ships; and a variety of military air and sea transportation.

This trend began when the whaling industry found Hawaii 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 an ideal place for millions of visitors, Hawaii, and other Pacific islands inevitably struggle with cultural and ecological resiliency. Despite having one of the most expensive costs of living

in of any state in the Nation, and with limited opportunity for ‘mega’ business opportunities, Hawaii’s resident population continues to grow. This growth 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 one of many U.S. Tropical Islands (USTI’s), which together, contain virtually all of the tropical forests associated with the United States. Most of these islands have significant indigenous populations, many of which continue to live traditional subsistence lifestyles. These highly diverse native ecosystems on small land masses are subject to increasing development pressures, are frequently susceptible to significant storm events, and operate under strained economies. Due to their strategic locations, many of these islands play important roles in trade, cultural exchange and in maintaining national security of the United States. All of the USTI’s share similar natural resource concerns, lifestyles and cultural practices. (See Table 9.1).

<b>Islands</b>	<b>Total Area (acres)</b>	<b>Existing Forest (acres)</b>	<b>Number of Islands</b>	<b>Population</b>
Hawaii*	4,110,720	1,490,000	8 main islands, with numerous atolls	1,275,000
American Samoa**	49,280	28,686	5	60,000
Commonwealth of the Northern Mariana Islands**	113,280	40,000	14	80,000
Guam**	135,680	65,005	1	170,000
Puerto Rico**	2,199,901	710,156	3	3,900,000
Virgin Islands**	85,760	not mapped	4	110,000
Republic of the Marshall Islands***	44,800	not mapped	5 and 29 atolls	60,000
Federated States of Micronesia *** (Kosrae, Pohnpei, Chuuk, Yap)	149,804	76,527	607	100,000
Republic of Palau ***	114,560	77,241	4 main islands, 200 rock islands, 6 remote islands	20,000

\*State, \*\* U.S. Territory or Commonwealth, \*\*\* Freely Associated State (US Compact Agreement)

Table 9.1. Shared Characteristics of U.S. Affiliated Tropical Islands in 2006<sup>3</sup>



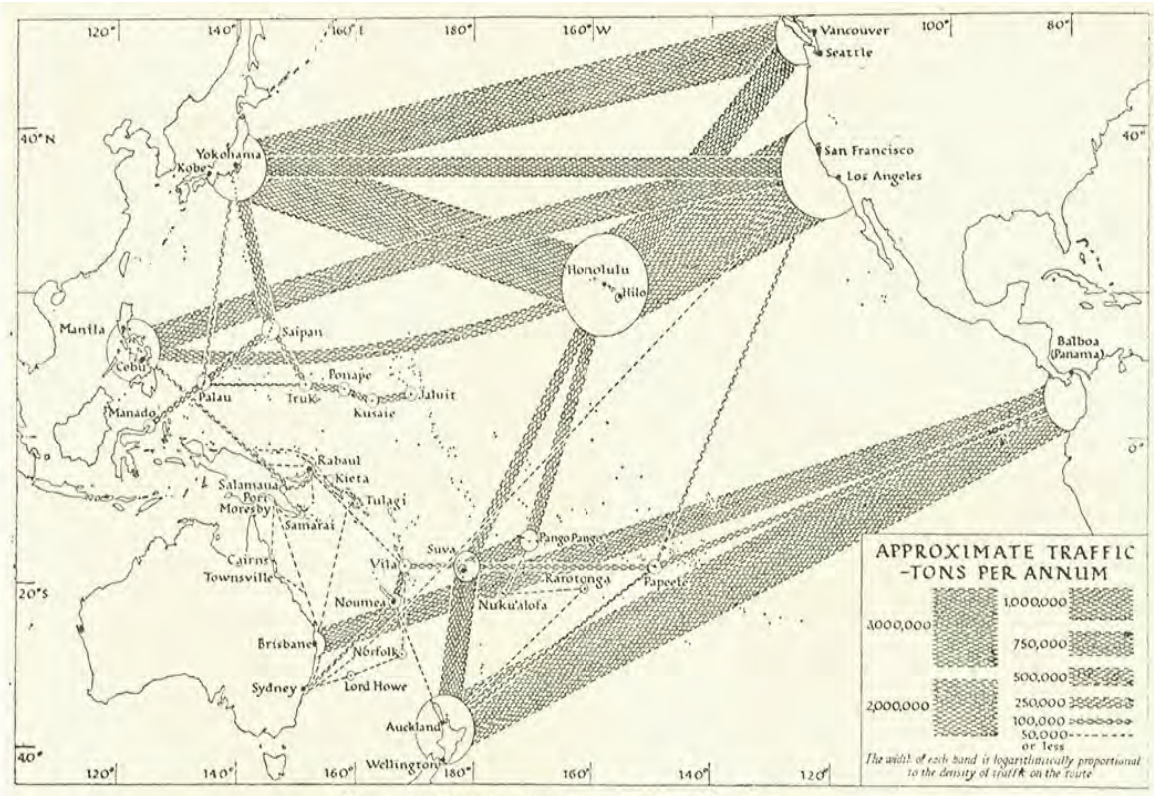


Figure 9.1. Density of Pacific shipping routes in 1938.<sup>3</sup>

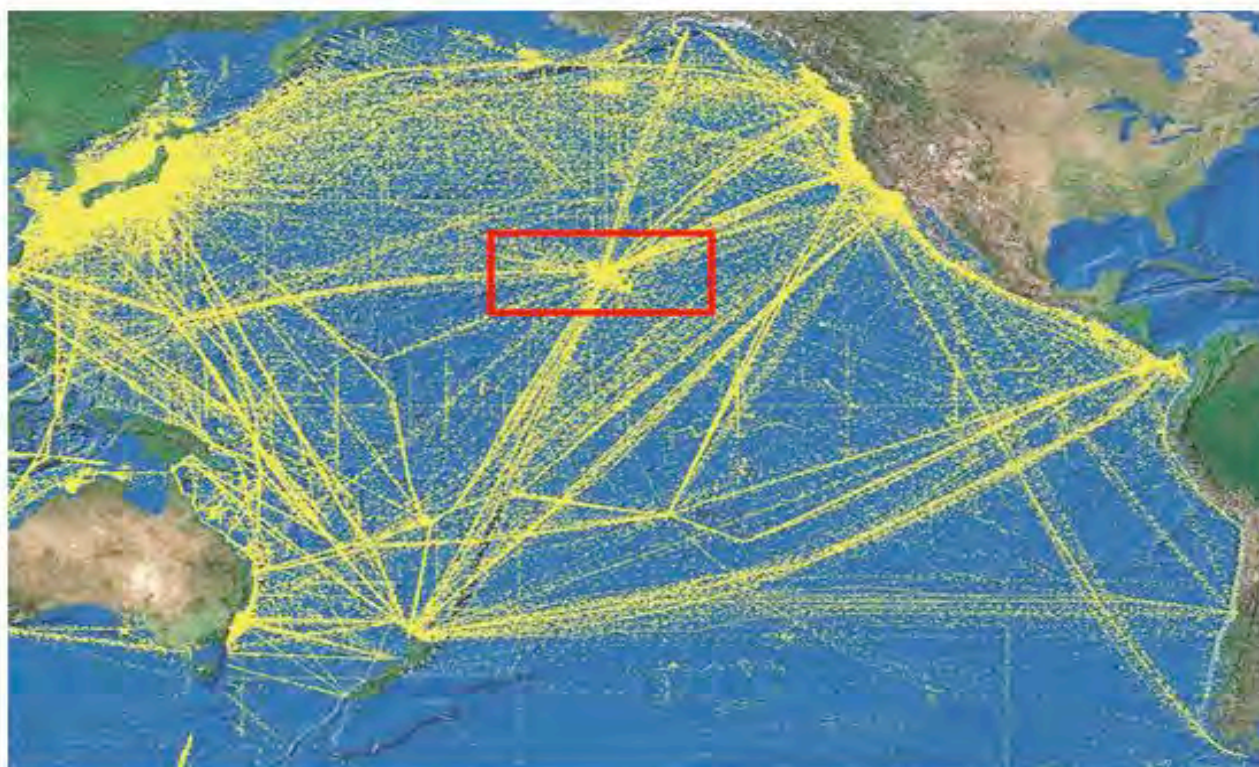


Figure 9.2. Pacific shipping traffic routes approx 2003.



Pacific islands are particularly vulnerable to a number of natural perturbations such as tsunamis, earthquakes, hurricanes and sea level rise. 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.”<sup>3</sup> Low islands and atolls must face climate change and sea level rise issues with cooperation from all levels U.S. and International governments, and begin implementing management actions, as this is an urgent problem.

Human caused problems that exacerbate natural resource management and sustainability are: deforestation due to increased population; hydrology changes; over harvesting; and invasive species. Outcomes from these pressures on the land often result in reduced water percolation into aquifers, increased soil erosion, coral reef siltation/reduction of marine resources, increased fire frequency and severity, reduced plant and animal habitat, and reduced forest products. These pressures can lead to the loss of indigenous cultures, traditional knowledge and continued island exodus to places that hold the chance of a better life.<sup>4</sup>

#### Benefits & National Interests in the U.S. Tropical Islands

- USTI's preserve a rich array of flora and fauna – a national and international biological heritage found no where else in the nation or the world.
- Sustainability of the tropical forests is integral in efforts to provide resilient communities, to diversify the local economies, and to mediate the impacts of burgeoning tourist industries.
- Forests replenish important fresh water aquifers and river systems, protect reefs, shelter and protect shorelines and coastal communities from hurricanes, storm surges, tsunamis and floods.
- The USTI's in general 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 vulnerable human populations due to ecosystem sensitivity and connectivity.
- The USTI's provide unique opportunities for scientific research in tropical ecology. Due to the vigorous growth potential, adaptations to natural disturbances and invasions of alien plants and animals, USTI's offer many opportunities to test approaches to management, and to understand the national and international landscape level effects.
- The USTI's provide 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 USTI's 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 an international arena.

- The USTI's, especially Guam, Kwajalein, American Samoa, Oahu and Puerto Rico provide 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 which could threaten national security. Sufficient attention is not currently provided to prevent the potential negative affects of these trends. 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.

#### Present Conditions, Trends & Opportunities

Traditionally, the Forest Service has not been deeply involved in coastal and nearshore marine resource protection, nor the management of terrestrial threatened and endangered species. This is in part due to the assumption that the U.S. Fish & Wildlife Service, NOAA and other federal agencies or initiatives focus on and provide adequate funding for these resource needs. This is changing in the Pacific due to the overwhelming need, and 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, either on isolated issues, islands or states, that understand the relationship between terrestrial and marine ecosystems. Tables 9.2 and 9.3 list a few examples of interactions Hawaii is currently involved in with a number of countries and international organizations that support education and technical capacity exchanges, research and natural resource management cooperative efforts.

**Table 9.2. Examples of Hawaii's Collaborations with Other Countries in the Pacific Region.**

Country	Area of Focus
Tahiti (A Department of France)	Miconia Suppression
New Zealand	Weed Risk Assessment
Australia, Caribbean	White Water to Blue Water
Thailand	Tsunami Technologies
Chile	Disaster Preparedness Collaborations

The connection between the uplands, lowlands and marine areas has long been part of the 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. Population increases, development, and reduced resources demand drastic changes in land use practices. Current practices result in extreme sedimentation from coastal and upland development, dredging, shoreline modifications, upstream agriculture and development. Coral reef impacts include smothering of live corals, and the prevention of successful establishment of new coral colonies

**Table 9.3. A Selection of International Organizations working on Pacific Island Issues.**

<b><u>Partnerships and Organizations</u></b>	<b><u>U.S. Natural Resource Agencies/Organizations</u></b>
<ul style="list-style-type: none"> <li>• Pacific Island Ecosystems at Risk (PIER)</li> <li>• South Pacific Regional Environment Programme (SPREP)</li> <li>• Secretariate of the Pacific Community (SPC)</li> <li>• International Union for the Conservation of Nature (IUCN)</li> <li>• German Technical Operation/ Deutsche Gesellschaft für Technische</li> <li>• Zusammenarbeit (GTZ)</li> <li>• United Nations Food &amp; Agriculture Organization (UN FAO)</li> </ul>	<ul style="list-style-type: none"> <li>• National Oceanographic Atmospheric Administration</li> <li>• USGS Pacific Biodiversity Information Node (PBIN)</li> <li>• Fish &amp; Wildlife Service (F&amp;WS)</li> <li>• Natural Resource Conservation Service (NRCS)</li> <li>• Farm Services Agency (FSA)</li> <li>• Pacific Coast Joint Venture (PCFV)</li> <li>• National Fish &amp; Wildlife Foundation</li> <li>• Trust for Public Lands (TPL)</li> <li>• The Nature Conservancy (TNC)</li> <li>• National Association of State Foresters (NASF)</li> <li>• National Association of University Forest Resources Programs (NAUFRP)</li> <li>• Society of American Foresters (SAF)</li> <li>• Association of Fish &amp; Wildlife Agencies (AFWA)</li> <li>• National Urban &amp; Community Forestry Advisory Council (NUCFAC)</li> </ul>

during periods of peak freshwater storm events on land. Simple changes to a limited number of practices could bring about dramatic changes that could not only reduce the negative impact on the coral reefs, but also improve the human practices that regulate these important ecosystems.

It is important to "strengthen policy frameworks and institutional capacities to reduce impacts to coral reef ecosystems from pollution due to land-based activities"<sup>5</sup>. Traditional land tenure systems include ridge to reef management of the land and are viewed as models of whole watershed or ecosystem-function management systems that are valuable to contemporary conservation.

### Threats & Concerns

A summary of the threats and concerns pertaining to regional Pacific island issues is provided in Table 9.4. While many are stand alone issues, they often relate 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 limit an already strained human collaboration capacity. Clearly more education and capacity building is needed in the Pacific if these threats and concerns are to be adequately addressed.

**Table 9.4. Key Regional Threats and Concerns**

Threats and Concerns	Forest Service National Themes
Aquatic health concerns i.e., litter, 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, fire frequency and other potential impacts. ( <i>Refer to Issue 5: Climate Change/Sea Level Rise</i> )	1.1, 3.5, 2.2, 3.1, 3.3, 3.7
Food security (land, sea and near shore reefs) - loss of traditional crops, native plants & genetic diversity, dependence on imports.	1.1, 1.2, 3.4, 3.6
Loss of threatened & endangered 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 - parasitic insects (dengue fever, filiriasis, malaria, schistosomiasis), drainage & industrial waste contaminants, etc.	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 and associated development pressures.	1.1, 1.2, 2.2, 3.5, 3.6
Impacts on Biodiversity – plant & animal extinctions due to loss of wildlife & their habitat and insects & disease.	1.1, 1.2, 2.2, 3.4, 3.5, 3.6, 3.7
Impacts of and increases in the number and intensity of tropical storms and typhoons.	1.1, 1.2, 2.2, 3.1, 3.5, 3.7
Invasive species transport and biosecurity i.e., brown tree snake, rhinoceros beetle, erythrina gall wasp, coqui frog, little fire ant. (The little fire ant is particularly widespread in the Pacific Islands region.	1.1, 1.2, 2.2, 3.4, 3.5, 3.6
Smart urban growth. Green growth is needed. Need to engage in more projects like the Hawaii Urban Tree Canopy Project that strives to help the City of Kapolei grow environmentally smart.	1.1, 1.2, 3.1, 3.5, 3.6
Sea level rise and associated migration. When native peoples loose the ties to their culture & community/land; it often leads to a loss of land ethic and increases in drug & alcohol use. More attention needs to be paid to preserving indigenous knowledge and historic management systems.	1.2, 2.2, 3.4, 3.6
Tourists and visitors as a method of plant, insect and disease dispersal.	2.2, 3.6
Tourists and visitors influence on cultural land ethics.	2.2, 3.6

## Priority Issues & Strategies for Inter-island Coordination

**1.) Invasive species** - There are the most important threat 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 they are found. Rats, especially the Pacific rat, and introduced insect such as ants such as the little fire ant are particularly widespread.<sup>6</sup>

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. 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.<sup>6</sup>

Figure 9.3 shows a real-time snapshot of flights in and out of Hawaii at 7:00 PM. As you can see, flights originating in many parts of the world use Honolulu as a hub, but because it is a U.S. state, Hawaii 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 subject to an even greater variety in 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 Island USTI's in an effort to prevent the introduction of new invasive species.

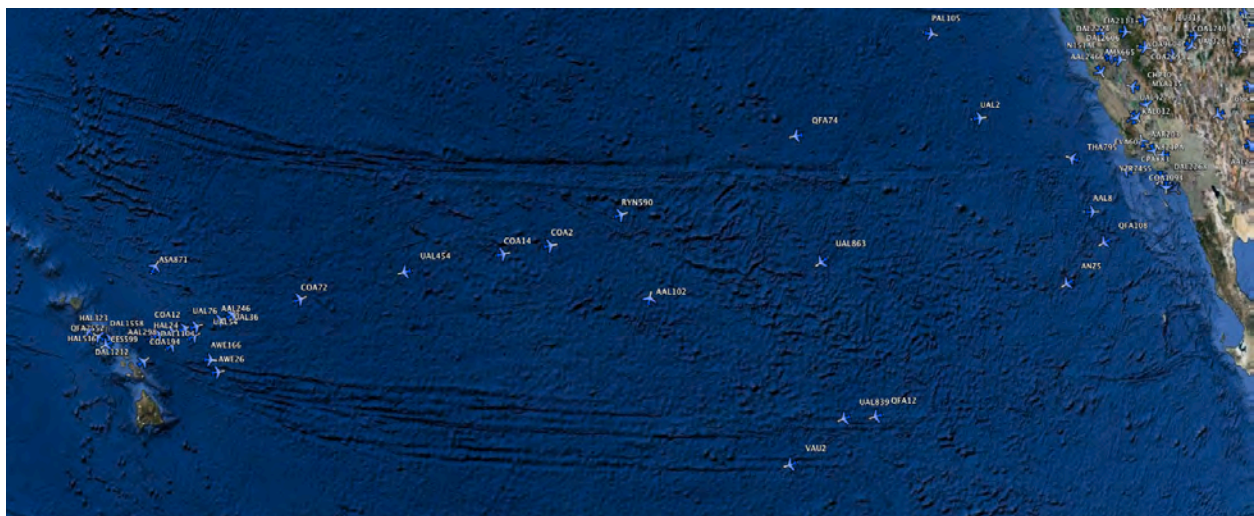


Figure 9.3 Real-time flights to and from Hawaii, 7 PM, June 3, 2010.



**2.) Public Land Management Funding** - Hawaii and all U.S. Pacific Islands do not have National Forests (with the exception of El Yunque in Puerto Rico), which receive substantial funding from the U.S. Forest Service to manage and maintain. As such, many public lands (State or Territory owned) represent the majority of productive/service producing lands in USTI's yet they are rarely eligible for many Landowner Assistance funding programs (*See Appendix C Forestry Related Assistance Programs*).

**3.) Unique Inventory/Monitoring Needs** - In order to understand the trends, threats and patterns in the loss of forests and inherent biodiversity in them, tropical forests must use more intensive survey, inventory and monitoring methods that are specifically devised for tropical forests, rather than methods applicable to less diverse continental forests. If surveys are to be used to assess forested conditions and trends locally, and then aggregated to reflect a national level for the determination of funding levels, the changes in tropical forest structures need to be accurately assessed and considered. The high degree of spatial variability in tropical forests must to be captured in vegetation surveys in order to adequately define and describe them.<sup>7</sup>

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. When storms damage urban trees, it typically affects large populations and multiple jurisdictions. The ability 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 and states. The time for the recovery and restoration of infrastructure through human response systems can be hastened after a storm. Information products necessary to speed response include high-resolution aerial or satellite imagery obtained before and after a storm, a coordinated effort before a storm to estimate biomass/volume removal for after the storm, and an economic and environmental assessment of damage to urban forests the storm event.<sup>8</sup>

**4) Land Development Pressures** - In Hawaii, agriculture zoned lands that were formally used for mono-crop production like sugar or pineapple, are being converted to support human development pressures, as opposed to being restored to their former food crop productivity. Formerly forested and/or marginal pasture lands are also being pressured to support human development needs and biomass production for fast growing single species, which are often very invasive.

**5) Food Security** - Pacific island societies have traditionally depended on the environment and natural resources for food, shelter, water, and medicine through agriculture and fisheries. Today, these traditional resources are vulnerable to increasing pollution, invasive species, over harvesting, climate change and sea level rise. In 2010, at the Pacific Island Committee meeting held in Chuuk, Federated States of Micronesia (FSM), representatives from seven island affiliated states and territories gathered to talk about important forestry issues and their importance to local communities. Food security was a top priority for nearly every representative

present at the meeting. In March 2010, the FSM launched an intensive research expedition gathering baseline data to answer questions such as: how much food does each island generate from their own lands; how vulnerable are individual islands to sea level rise; what are current development and land use threats, etc. The study will also integrate marine and terrestrial biodiversity information with socio-economic data. In Hawaii, an estimated 80 to 90% of food is imported. Because of recent economic pressures there is a growing interest in local food production and sustainable practices. More thought should be put to strategically planning for all of these needs and reducing Hawaii's dependency on imported food, fuel and other supplies.

**6) Technology Sharing** - There are a number of positive examples demonstrating the effectiveness of sharing technologies or methodologies for resource management in the Pacific. A good example is Hawaii's use of the New Zealand "Weed Risk Assessment". (See Issue 2: *Forest Health: Invasive Species, Insects and Disease* for additional information.) 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 swaths of areas around the specific island it is being used for, however, none of the images are shared with neighboring countries and some are desperately in need of this type of resource management tool.

**7) Technical Capacity** - Perhaps the most limiting factor to implementing successful natural resource programs throughout the USTI forests 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 for raising local community awareness about inter-island environmental threats, such as invasive species transport.<sup>9</sup>

**8) Fisheries** – Pacific island cultures historically and presently are dependent on marine resources. Any island management plan must have elements pertaining to the ocean and the interaction between the two ecosystems. Pacific Islands Fish & Wildlife Office, in their 2008 report, emphasize the global relationships between coral reef ecosystems, showing the importance of working collaboratively across borders.

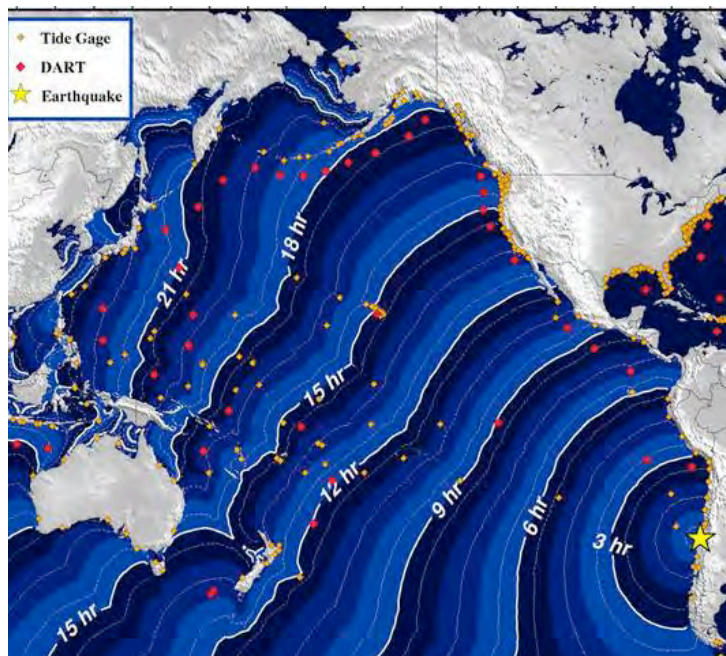


Figure 9.4. A tsunami travel time map for the Chilean earthquake generated tsunami in March 2010 that occurred across the Pacific.

"International efforts to promote healthy, resilient coral reef ecosystems also benefit coral reefs in U.S. waters. Most coral reef ecosystems in U.S. waters are interconnected with, depend on and affect coral reefs in other countries. Ocean currents carry not only essential larvae and juvenile corals, fish, and other invertebrates that replenish reefs but also potentially harmful pollutants and diseases. Thus, strategies for supporting healthy coral reef ecosystems in the United States must also consider protecting coral reefs beyond U.S. waters".<sup>10</sup>

Projects that support both terrestrial and marine ecosystem health are necessary, not only for cultural preservation, but also for food security and protection of fragile marine habitat and those important species that occupy them.

**9) Environmental Education** - Education, outreach and training needs to be elevated in the priorities for the Pacific islands. Education is an important focal point of President Obama's administrative agenda, is new among the Forest Service National Themes, and is part of the newly redesigned Forest Service's Pacific Southwest Research Station Programs. This newly designed program is a critical program, yet it has been given no specific programmatic designation within the Western Region 5 Forest Service. For this reason, Conservation Education

**Table 9.5. Climate Change and its Effects on Food & Agriculture in Hawaii<sup>9</sup>**

Primary Vulnerabilities	Primary Adaptations
1. Changes in temperature and sea level	1. New crops and controversial genetically modified organisms (GMO's)
2. Changes in rainfall amount and patterns	2. Manage water
3. Rising atmospheric concentrations of CO <sup>2</sup>	3. Alter management practices
4. Changes in water availability	4. Shift crop production/species
5. Increase in extreme weather events (droughts, floods, hurricanes)	5. Change human development areas & increase coastal vegetation resiliency

is not given the funding and support it desperately needs among the various programs offered to States and Territories. Conservation Education is a component of many existing S&PF programs and is an integral aspect of all environmental work done on islands. It is important that education funding be either included in the programs themselves or as a stand alone program so that islands have dedicated and continuous funding for enhancing public support for natural resources management.<sup>11</sup> More effort should be made to be creative with information sharing, capacity development and ensuring that important land management actions are based in sound best management practice technologies.

**10) Coastal Area Protection** - In tropical islands, the majority of human populations are found in coastal areas, where people live, work and play. These areas serve as very important protection of the inland areas from ocean sea storms/events, as well as protecting the near shore marine resources from inland/upland erosion and siltation depositing. Vegetation is important for shoreline protection and wetland preservation.<sup>11</sup> Direct the Forest Service to support comprehensive land use plans for all islands and coastal communities, including: coastal zone protection plans and regulations; watershed and land use management; draft and adopt local and regional ordinances to implement comprehensive land use plans; vegetation selection for coastal protection for example; mangroves".<sup>12</sup> Because islands utilize all parts of the island equally, we can not separate marine and coastal areas from our 'island resource' management planning efforts.



Figure 9.5. Kōlea or Pacific Golden Plover (*Pluvialis fulva*)

**11) Shorebirds and migratory waterfowl** can travel tremendous distances in the Pacific. For instance Kōlea or Pacific Golden Plover (*Pluvialis fulva*, See Figure 9.5) breed in Alaska and winter anywhere from American Samoa, Hawaii to Saipan. "Kōlea can spend eight months away from Hawaii each year and then return to the same grassland or wetland".<sup>13</sup> Habitat protection for these migratory birds must be collaboratively undertaken because they utilize and need more than one type of environment in order to flourish.

**12) Rare forest types and the species that occupy them** are a priority for Hawaii. For instance "90% of Hawaii's native dryland forest has been destroyed, largely by human activity and encroachment".<sup>14</sup> Hawaii's Plant Extinction Protection Program (PEP) states on its website "Hawaii has the dubious distinction of being the endangered species capitol of the world," with 37% of all endangered plant species in the United States and the highest number of endangered plant species on earth.<sup>15</sup> Yet Hawaii comprises only a small fraction of the earth's land area (0.02%), resulting in extreme diversity over very small areas. To date, Hawaii is home to an overwhelming 173 species that have fewer than 50 plants remaining in the wild, coined "PEP species."<sup>16</sup> It is important that more collaborative efforts take place in the Pacific and Caribbean to ensure that rare species protection and proliferation occur within and among island groups that can sustain them.

#### Priority Geographic Areas for Multi-State Issues

The areas described at the beginning of this Issue are frequently involved in Hawaii's economy, and therefore are high priorities for future collaborations. However, the greatest priority will be given to those areas that Hawaii interacts with the most: Australia, mainland United States, New



Zealand, Tahiti, Fiji, Tonga, Samoa, Philippines, Indonesia; and all of the U.S. territories and affiliated island groups.

As technologies, climates and interests change so too will priority areas upon which to focus natural resource management efforts. For the immediate future, collaborations with the Pacific Island states and Pacific Rim countries will be a priority for Hawaii.

### Summary

The United States Tropical Islands offer unique opportunities for Forest Service State and Private Forestry Programs and other local, regional and National programs (*See Appendix C Forestry Related Assistance Programs*) to work collaboratively at international, national and local levels. These types of collaborations support projects directly tied to the protection of forests, culture and marine resources; thus shaping land use on a scale and in a manner that optimizes benefits in critical watersheds to protect important ecosystem services.

Working collaboratively on biosecurity, transport of invasive species, health of coral reefs, preserving traditional knowledge, protection of rare species, sustainable fishing practices and other shared issues, benefits not only the natural resources and communities among tropical islands, but also the nation as a whole. The islands are harbingers of the future given their high population densities and dependency on external subsidies for energy, food and materials. U.S. Tropical Islands 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 the



Figure 9.6. Erythrina on a small atoll in Majuro Lagoon in the Marshall Islands.

connections between the social and ecological conditions are sometimes not as obvious as they are on islands. Vibrant programs and efforts, while crafted uniquely to suit islands and their associated cultures, will create valuable benefits that can be leveraged by states and nations located well beyond 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.



## Strategy Matrix for Issue 9: Multi-State Issues

*Strategies for Issue 9: Multi-State Issues*

Tropical forests serve many unique and essential life-supporting roles for the world at large. These important ecosystems are heavily impacted by deforestation, urban growth and expansion, increased global warming, and threats to tropical biodiversity. It is important to engage in the sharing of ideas, funding and opportunities with our Pacific Island neighbors because there is a vast amount of knowledge among peoples of these islands and their intimate knowledge of how to sustainably manage these unique and fragile ecosystems. Climate change and sea level rise are perhaps the number one threat the Pacific Island cultures and ecosystems and we must work together as a global community to ensure that the unique plants animals and peoples of these regions endure for generations to come.

**Multi-State and Regional Issue: Invasive Species Transport**

Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/required	Measure of Success	Supports National Objective
1) Develop and Implement a Collaborative Improvement Strategy (CIS) to raise awareness and implement programs to stop transport of insects & diseases, and export/import of species rated highly invasive across the Pacific.	Pacific-Wide, US & International	Airlines contribute to screening protocols; more inspectors at high vector areas; coordinated message across the Pacific.	Forest Health Protection & Monitoring, UCF, CE/EE, EQIP, CIG, FSCG, UN FAO, SOPAC, NARF, CGAPS, SPREP, SPC	US Dept. of Ag. in all, HCA, PIC, SPREP, SPC, New Zealand DOC, Australia, NPS, NOAA, NRCS, Forest Service, DOT, TNC, US Airline Companies, APHIS, Homeland Security, RISC, DOD	USFWS, PICCC, UH, University of Guam, Australian Universities, New Zealand Universities, Community Colleges, Heads of Forestry across Pacific, NOAA Service, NRCS, TNC	Better boarder entry protocols; More awareness of invasive spp. issues by travelers that visit Pacific Islands and countries; More stringent screening for incoming visitors to Pacific Islands; Reduce transportation and relocation of highly invasive species.	1.1 2.2 3.1 3.4 3.5 3.6
<b>Multi-State and Regional Issue: Protection of Genetic Diversity and Important Food Plants</b>							
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/required	Measure of Success	Supports National Objective
1) Workshops among Hawaii and various Pacific Islands to share technical and cultural knowledge related to sustainable agroforestry and marine resource practices.	Chuuk, American Samoa, Yap, Hawaii, other international Pacific Islands.	Coral reef protection; critical habitat protection; cultural knowledge sharing.	Seacology, FSCG, CE/EE, FSP, Forest Health, UN FAO, SOPAC, FWS, Seagrant	Private and public land owners in the Pacific, HCA, PICCC, TNC, NOAA, DOD, UH Ocean & Earth Sciences, USGS, NWHI, Seagrant,	USFWS, PICCC, UH, University of Guam, New Zealand, Heads of Forestry across Pacific, NOAA, TNC	A series of workshops aimed at bringing highly successful agroforesters and near shore fishery management experts that allow cross-sharing of this rare knowledge. Brochures and videos describing the techniques and rotational practices.	1.1 2.2 3.1 3.4 3.5 3.6
2) Work collaboratively to mitigate impacts of loss of genetic diversity of food plants, native species and	Pacific Wide	T&E species protection; improved remote nursery	FWS Section 7 grants, UCF, Conservation Education, FSP,	HCA, PICCC, USFWS, NPS, USDA, HDOA, DOT, TNC, NOAA, DOD,	US FWS, Dept. of Ag across Pacific, Local and Fed. EPA, Dept. of Transportation, NOAA,	Increased food security; More studies that define monitoring of Hawaiian biodiversity, test new crop species under new climate	1.1 2.2 3.1 3.4

### Strategies for Issue 9: Multi-State Issues

2) Work collaboratively to mitigate impacts of loss of genetic diversity of food plants, native species and culturally important species.	Pacific Wide	T&E species protection; improved remote nursery installation techniques; invasive spp. controlled.	FWS Section 7 grants, UCF, Conservation Education, FSP, FLP, schools, volunteer groups, NARF, PEP	HCA, PICCC, USFWS, NPS, USDA, HDOA, DOT, TNC, NOAA, DOD, CWRM, UH Ocean & Earth Sciences, USGS, NWHI	US FWS, Dept. of Ag across Pacific, Local and Fed. EPA, Dept. of Transportation, NOAA, Coastal Zone Mgmt Program, Forest Service Competitive grants, PBIN	Increased food security; More studies that define monitoring of Hawaiian biodiversity, test new crop species under new climate conditions; Shift agriculture to suitable new lands; Initiate more trainings and expanded nurseries production areas for rare plant seed protection and propagation with forest plants and food crops; Use methodologies that can be duplicated.	1.1 2.2 3.1 3.4 3.5 3.6
<b>Multi-State and Regional Issue: Migratory Shorebird Protection</b>							
<b>Long Term Strategy</b>	<b>Priority Landscape Area(s)</b>	<b>Secondary Issues Addressed</b>	<b>Program Areas that Contribute</b>	<b>Key Stakeholders</b>	<b>Resources Available/required</b>	<b>Measure of Success</b>	<b>Supports National Objective</b>
1) Collaborate on the protection and enhancement of known migratory habitat. Increase capacity to monitor and protect these birds.	Pacific Wide	Wetland and upland bird habitat protection; Improved Best Management Practices for bird habitat.	FWS Section 7, FLP, Forest Health Protection, Watershed Partnerships, Fire & Aviation, EQIP, WHIP, FLP, FSP, FSCG, NARF, SPREP, SPC	HCA, NOAA, DOD, HTA, USFWS, NPS, DOT, Office of Planning, HDOA, TNC, DOH, Marine & Coastal Zone Advocacy Council, US Coast Guard, Sea Grant, SPREP, SPC	PICCI, CZM Pacific-wide, US FWS Section 7 grants, Audobon Society, Ducks Unlimited, Audubon Society	Increase in habitat; Increase in knowledge about these birds; More collaboration with international countries in the Pacific for collaborative opportunities.	1.1 2.2 3.1 3.5 3.6 3.7
<b>Multi-State and Regional Issue: Collaborative Multi-Regional Plan</b>							
<b>Long Term Strategy</b>	<b>Priority Landscape Area(s)</b>	<b>Secondary Issues Addressed</b>	<b>Program Areas that Contribute</b>	<b>Key Stakeholders</b>	<b>Resources Available/required</b>	<b>Measure of Success</b>	<b>Supports National Objective</b>
1) Work collaboratively across the Pacific to identify the highest	Pacific-Wide	Incorporate multiple resource needs	UCF, Forest Health Protection, Watershed	HCA, NOAA, DOD, HCA, USFWS, NPS, Office of Planning,	Center for Island Climate Adaptation and Policy (ICAP) at UH,	Develop a clearly defined plan detailing priorities; Reiterations in the process to review management	1.1 2.2 3.5

*Strategies for Issue 9: Multi-State Issues*

**Acronyms Used:**

1. CZM – Coastal Zone Management
2. OHA – Office of Hawaiian Affairs
3. C&C – City & County of Government of Hawaii
4. NARF – Natural Area Reserve Fund
5. PEP – Plant Extinction Prevention
6. FRS – Forest Reserve System
7. DOFAW – EE – Environmental Educational
8. HARC – Hawaii Agriculture Research Center
9. LLCF – Legacy Land Conservation Program
10. FLP – Forest Legacy Program – Forest Service
11. FSCG – Forest Service Competitive Grants
12. DAR – Division of Aquatic Resources
13. HTA – Hawaii Tourism Authority
14. HISC – Hawaii Invasive Species Council
15. FSP – Forest Stewardship Program

16. CGAPS – Committee Group on Alien Pest Species
17. HCA – Hawaii Conservation Alliance
18. IPIF – Institute of Pacific Island Forestry
19. UCF – Urban & Community Forestry (Kaulunani)
20. NOAA – National Oceanographic and Atmospheric Administration
21. USGS – US Geological Service
22. YCC – Youth Conservation Corps
23. STDP – Special Technology Development Program
24. PSWRS – Pacific Southwest Research Station
25. SPC – The Secretariat of the Pacific Community
26. SPREP – South Pacific Regional Environmental Program
27. FAO UN – Food and Agriculture Organization of the United Nations
28. SOPAC – Secretariat of the Pacific Applied Geoscience Commission
29. PBIN – Pacific Biodiversity Information Node

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## Epilogue

June 14, 2010; 8:24 PM

Honolulu, Hawaii

It's going to be another late night working at home in my kitchen again. I can tell. My computer is tired, it's hot, the screen is flickering. I find a new typo every time I look at this document. And where did Issue 6 go? It was here this afternoon . . . But this document has to go out tomorrow, so I'm off to the printers in a few minutes. I hope . . .

I think of all of the data that I would have liked to include; no time. I think back on all of the great ideas that people have contributed; nobody to do them. How many more people we could have involved in the process; no money for travel.

But mostly I think about what went right; the new friends I have made; the exciting new collaborations between agencies that had never worked together in such a focused way; the enthusiasm of our students and interns; the ah-ha moments in peoples' faces when they see a map for the first time. All that I have learned in the process; about Hawaii; about the power of GIS; about exciting new datasets; about my capabilities and my limits.

I am grateful for the encouragement of family, friends and colleagues who helped me materially and spiritually throughout this project. I am grateful for the times that they came over with food, only to remind me why I went into this profession in the first place. "Ron," they would remind me, "look at the big picture. Tomorrow you won't have writer's cramp, but we have produced something important and enduring."

And then, a few minutes ago just as I finished my last edits, this happened outside my lanai:



This rainbow appeared, like it does almost every day in my neighborhood. From my lanai I see the entire watershed, the ahupuaa of Makiki. This rainbow spans the entire watershed. The distance from Diamond Head and Waikiki on the right, to Manoa valley at the left is less than two miles as the elepaio flies. You can walk from the beach to Oahu's own "Continental Divide" in 2 hours.

The ridge you see on the left is the lower portion of Waahila ridge. It forms the eastern flank of Manoa valley. Several years ago the electric company wanted to run a high-voltage line up that ridge. Many residents were opposed to the project, and so, as a fundraiser, they put together a CD of twelve Hawaiian songs **only about Manoa and Waahila** ("Wa'ahila", various artists, 2001).

What a place! Every hill has dozens of songs praising its beauty. And the rain that creates this rainbow every day has its own name; "Tuahine o Manoa". In Hawaii we honor our rains by name, we praise every hill and valley, we see the whole watershed, we live our aloha. And I am reminded once again why I went into this profession and how fortunate I am to play a small part in working to preserve this precious `aina into perpetuity. - Ron Cannarella, forester