Issue 4: Urban and Community Forestry

Overview

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

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

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

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

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

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

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

Kaulunani's Mission Statement

Balance the urban and natural environment by encouraging, empowering and equipping the people of Hawai‘i to Mālama the trees in our ‘āina.

Population and Land Use

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

Hawai‘i's Urban Realm

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

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

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

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

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

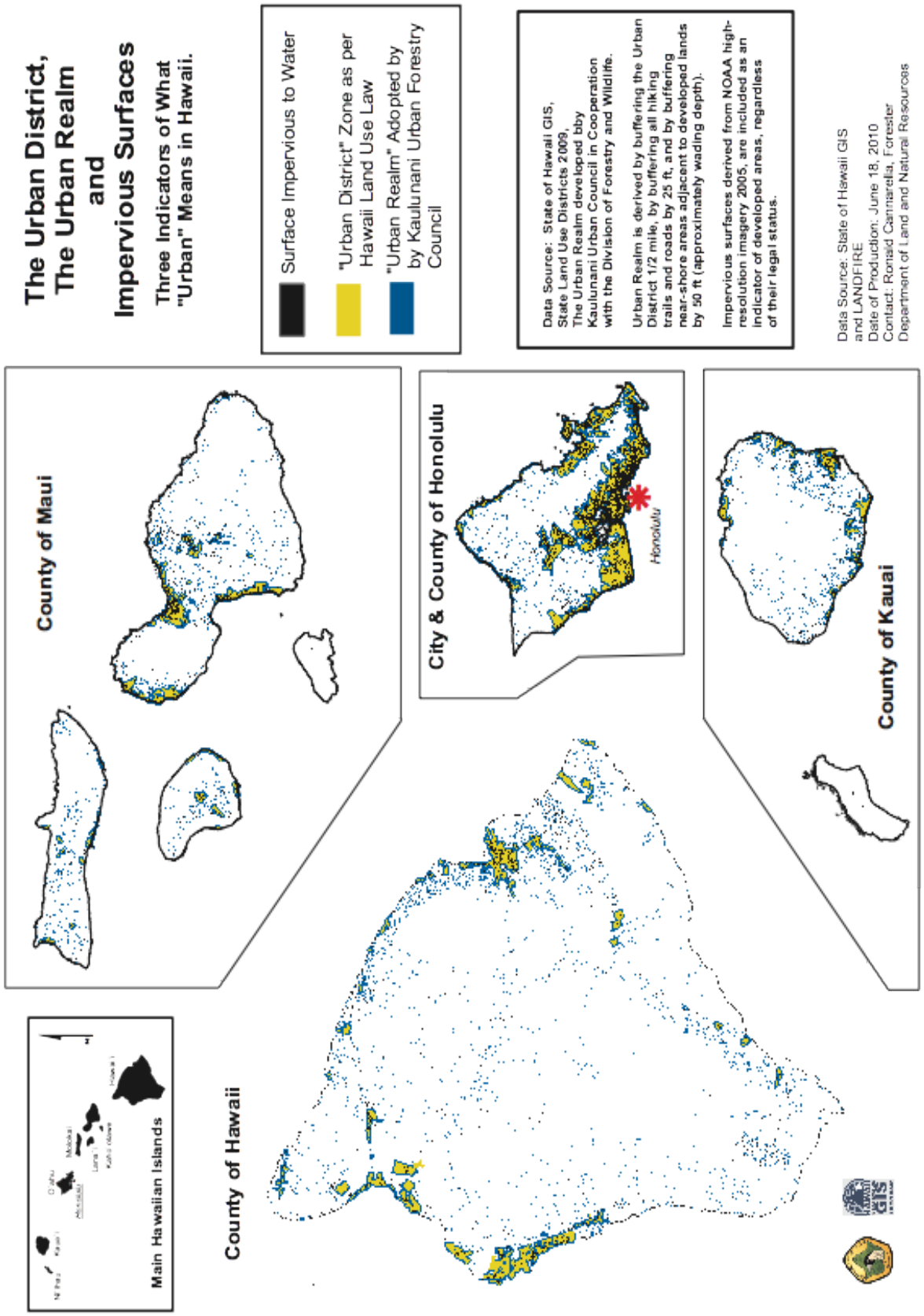
Map 4.1 shows the impervious surfaces, including roads and buildings, and the urban realm where people live, work, and play and where urban forestry is mainly focused. The proximity of urban areas to agricultural areas and to *makai* resources (Map 4.2) is the main reason why urban forestry must be considered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

Benefits

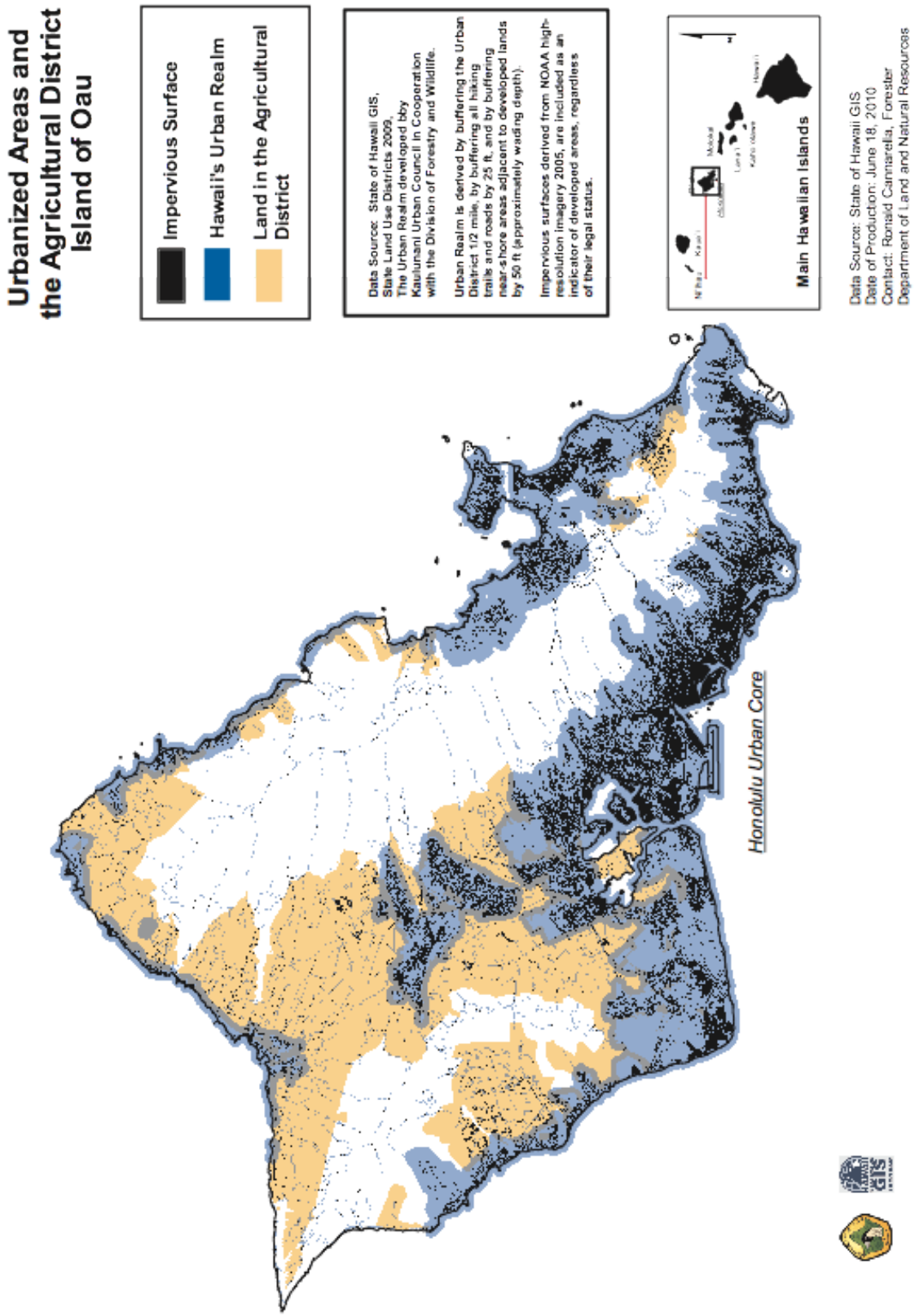
Urban forests, whether public or private, offer a multitude of benefits. Research indicates that healthy trees can decrease negative impacts of urbanization while improving human health. Trees and plants buffer wind and noise and generally are recognized as positive influences on health and well-being.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

Honolulu’s Street Trees

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



Map 4.1. The urban realm in Hawai'i.



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

Value of a Tree in the Tropical Urban Forest

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

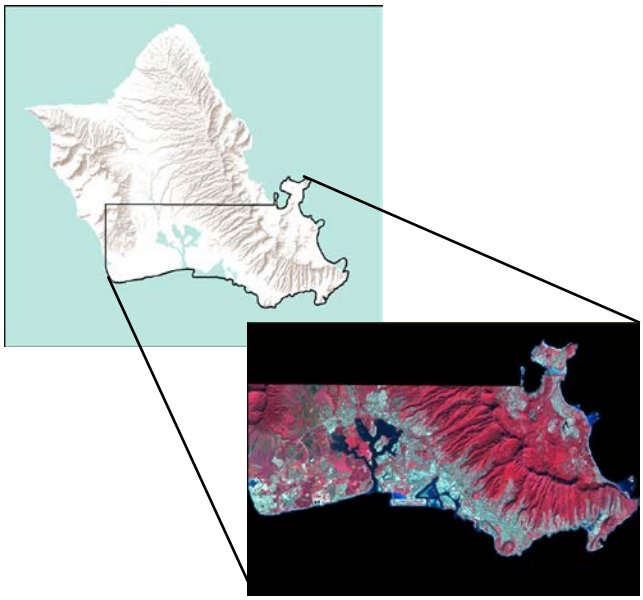


Figure 4.2. Urban tree canopy assessment in O'ahu from *Kāne'ohe* to *Kalaeloa*. Red areas indicate tree canopy cover.

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

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

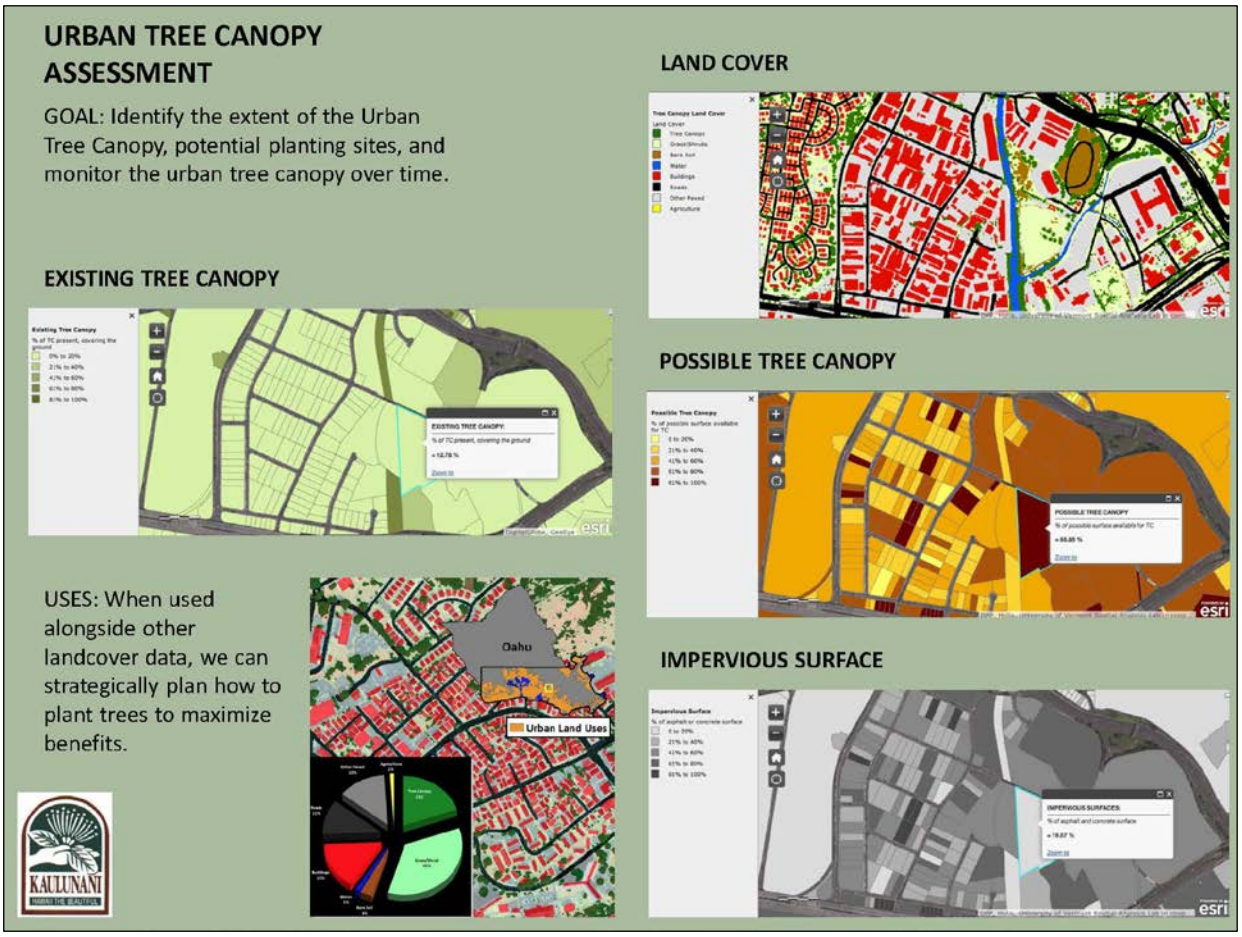


Figure 4.3. Results of urban tree canopy assessment on O‘ahu: existing canopy cover (top right), vegetated and potential for canopy cover (left center), and impervious surfaces (bottom right).

Tree City USA and Tree Campus USA

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

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

Table 4.1. Tree City USA communities of Hawai'i.

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

Priority Issues and Areas in the Urban Forest

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

Federal Priorities for Urban and Community Forestry

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

Climate Change

Present Conditions and Trends

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

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

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

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

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

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

Gaps, Issues, and Concerns

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

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

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

Strategies to Address Gaps

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

Education and Outreach

Present Conditions and Trends

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

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

Figure 4.4. Arbor Day in Hawai‘i.

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

Gaps, Issues, and Concerns

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

Strategies to Address Gaps

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

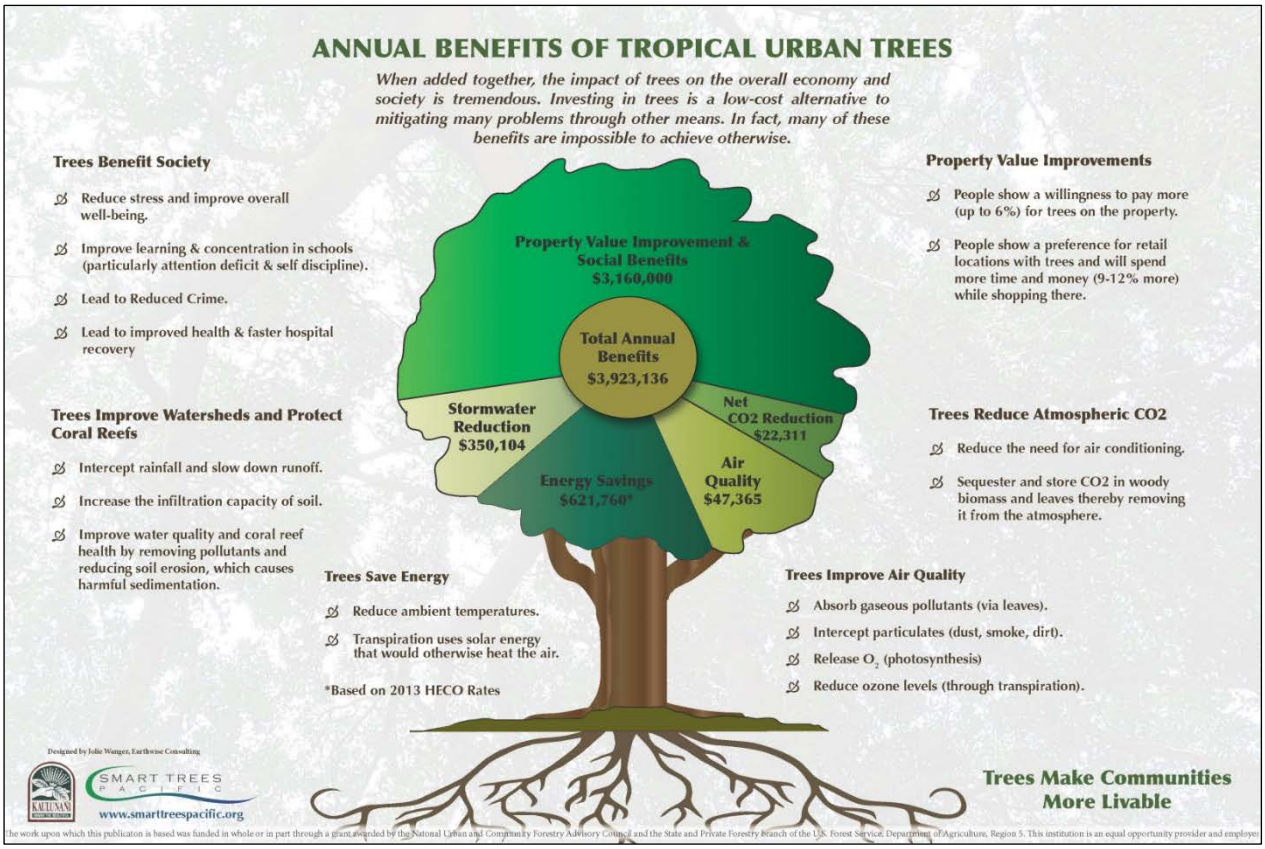


Figure 4.5. The poster, prepared by Kaulunani, illustrates the annual benefits of tropical urban trees.

Emergency Management

Present Conditions and Trends

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

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

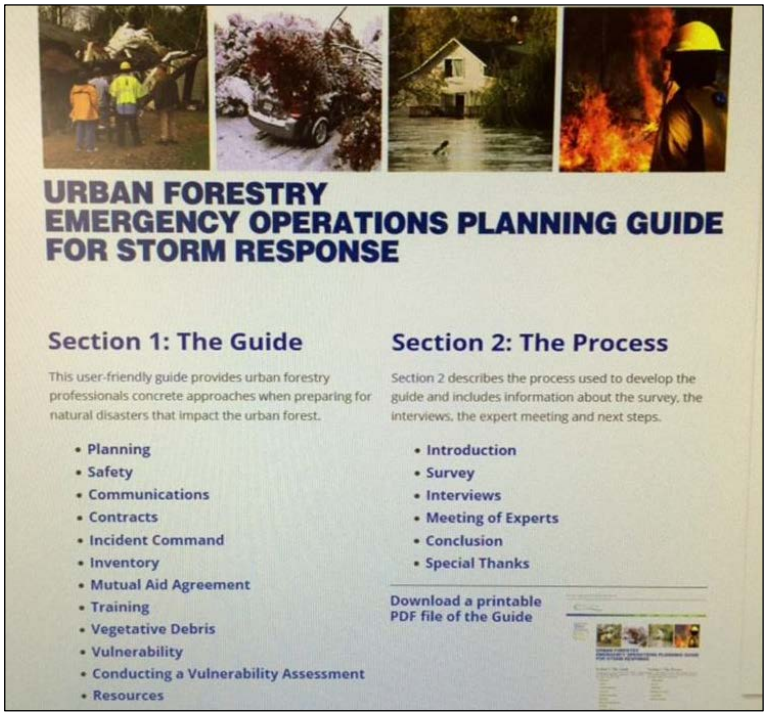


Figure 4.6. Information poster prepared by Smart Trees Pacific for its project—*Urban Forestry Emergency Operations Planning Guide.*

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

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

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

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

Gaps, Issues, and Concerns

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

Strategies to Address Gaps

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

Health and Well-Being

Present Conditions and Trends

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

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

Gaps, Issues, and Concerns

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

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

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

Strategy to Address Gaps

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

Invasive Species

Present Conditions and Trends

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

Weed Risk Assessment Working Group

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

Plant Pono

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

Erythrina Gall Wasp and Other Pests

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

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

Gaps, Issues, and Concerns

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

Strategies to Address Gaps

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

Ordinances and Legislation

Present Conditions and Trends

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

Gaps, Issues, and Concerns

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

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

Strategies to Address Gaps

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

Urban Tree Care

Present Conditions and Trends

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

An urban tree's life span is very short, and often trees are planted in small spaces and are poorly irrigated. Monocultures have become the norm, trees are often topped, and there is a lack of

knowledge about basic tree pruning or a comprehensive county tree planting program. A diverse pallet of trees that is properly pruned can provide a community with benefits for many years.

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

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

Gaps, Issues, and Concerns

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

Strategies to Address Gaps

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

Water Quality and Green Infrastructure

Present Conditions and Trends

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

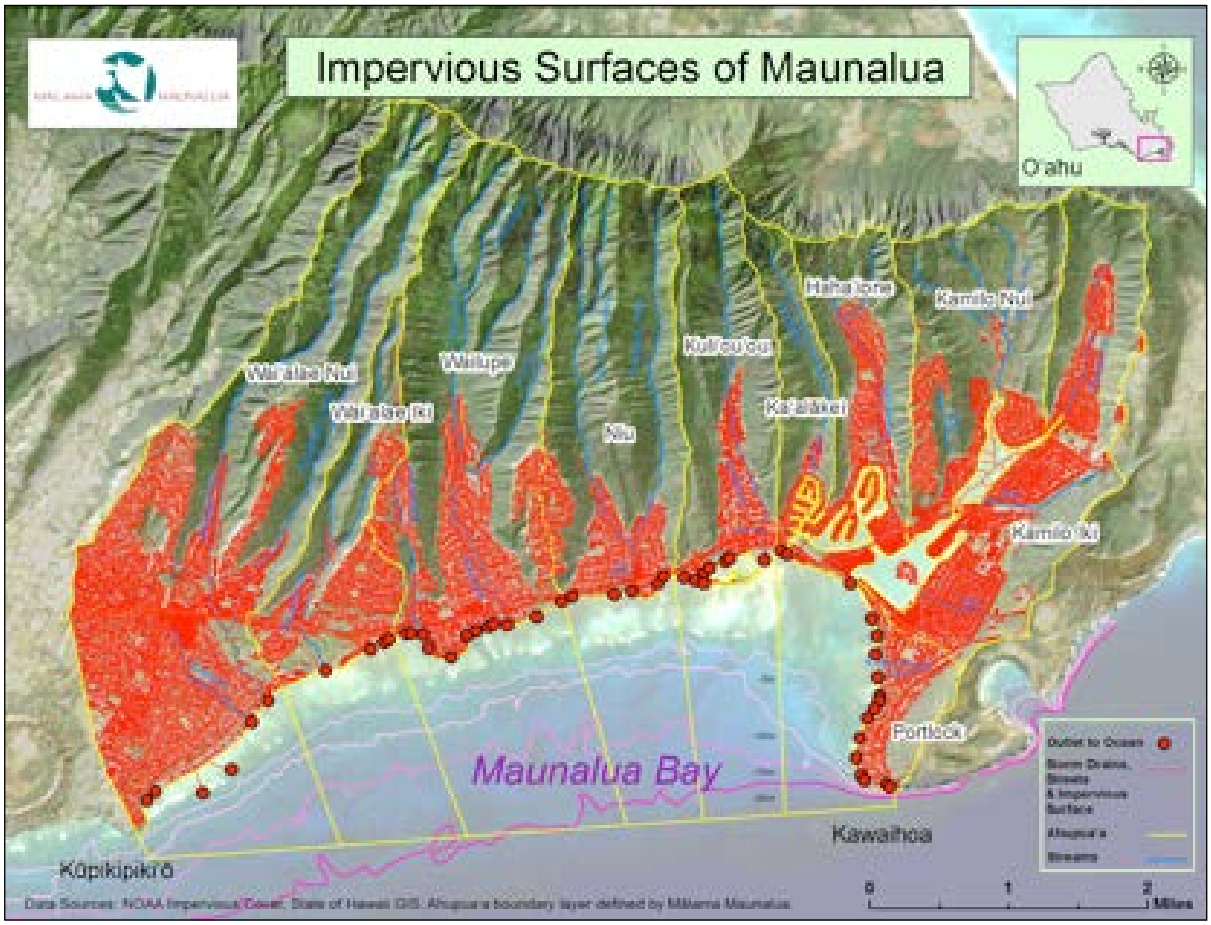


Figure 4.8. Impervious cover in the urbanized region of Maunalua, located in East O‘ahu. These surfaces, including streets, drainage canals, parking lots, driveways, and rooftops, cause excessive overland water flow into nearshore aquatic ecosystems. The increase in impervious cover decreases the extent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

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

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

Gaps, Issues, and Concerns

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

Strategies to Address Gaps

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

Wildland-Urban Interface

Present Conditions and Trends

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

Gaps, Issues, and Concerns

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

Strategies to Address Gaps

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

Summary

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

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

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

Strategies for Issue 4: Urban and Community Forestry

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

Strategies for Issue 4: Urban and Community Forestry

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

Strategies for Issue 4: Urban and Community Forestry

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

Strategies for Issue 4: Urban and Community Forestry

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

Key:

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

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Issue 5: Climate Change and Sea Level Rise

Overview

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

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

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

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

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

Future climate projections for Hawai‘i, based on current data and trends, indicate that climate change will result in an increase in the mean annual air temperature of approximately 1.5°F to 5°F by the latter half of the 21st century.[3] Precipitation will vary across the state, with O‘ahu and Maui experiencing decreasing precipitation trends, while the Big Island will have potentially increasing trends. Some studies conclude that the region should expect more frequent tropical cyclones and an increase in the frequency of heavy rainfall events, while other studies project a decrease in heavy rain events. Downscaling climate change models predict, on average, a

decrease in rainfall and reduced availability of freshwater resources.[6] Regarding distribution of rainfall, the downscaling model for Hawai‘i predicts that most areas will have a decrease in wet-season rainfall, with the exception of the trade wind–dominated wet regions along and above the eastern slopes of the mountains, which are expected to see slight increases or remain stable in rainfall amounts. The leeward, climatically dry areas of the islands are predicted to have drier than normal conditions during both the wet and dry season.[6]

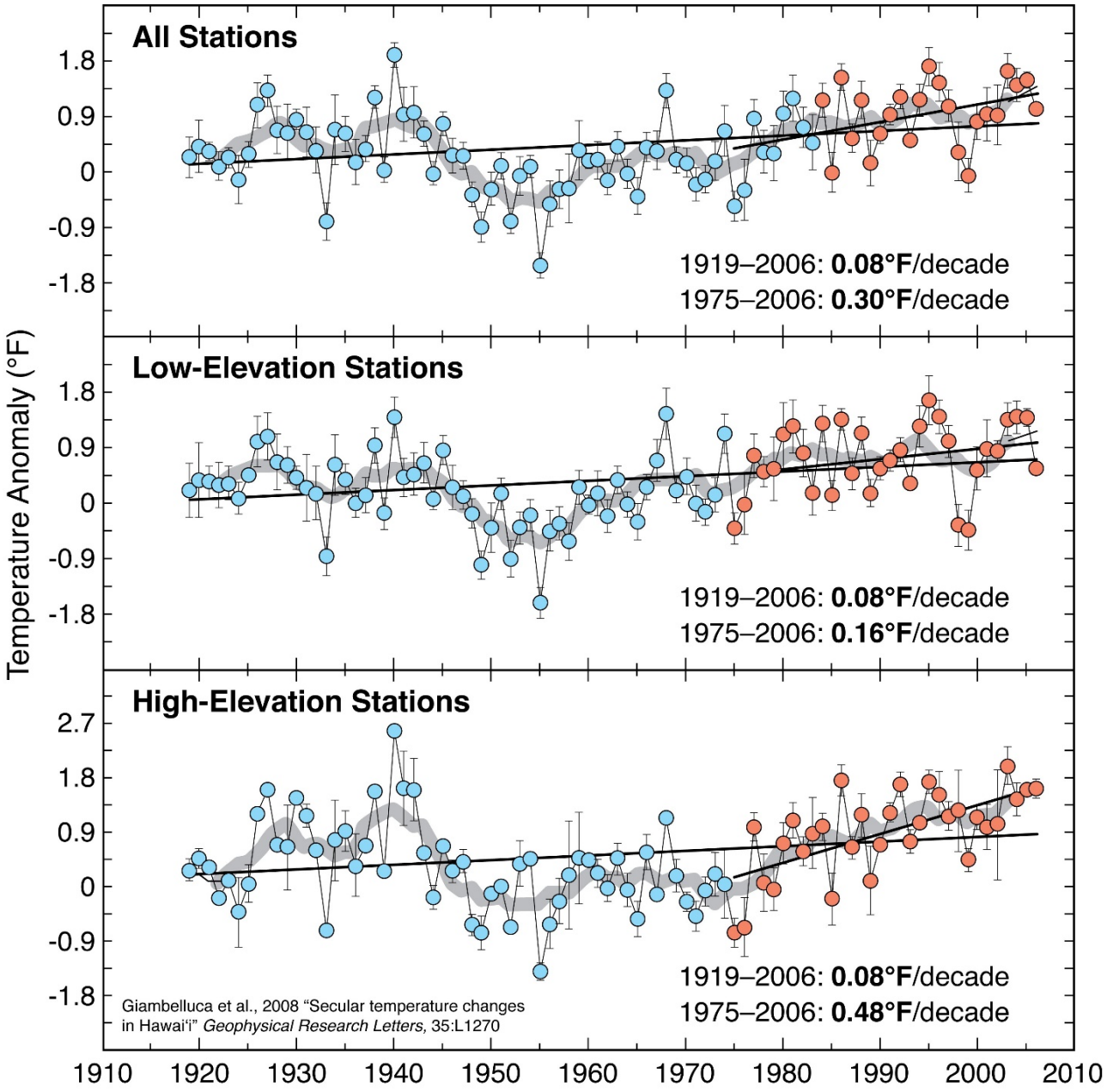


Figure 5.1. Data show a rapid rise in air temperature in the past 30 years (averaging 0.3°F per decade), with a stronger warming at higher elevations.[2]

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

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

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

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

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

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

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

Threats

Reduction in Rainfall and Fresh Water

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

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

Rain recharges groundwater aquifers, which are the principal sources of municipal water supplies in Hawai'i. Groundwater also feeds Hawai'i's streams and provides water for agriculture and aquaculture systems. However, base stream flow supplied by groundwater

discharge has declined around the state since the early 1940s, likely because of decreased rainfall.[3, 9]

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

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

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

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

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

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

Greater Risk of Larger and More Frequent Wildfires

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

More Severe Tropical Storms and Increasing Rain Intensity

Although global climate change will result in a reduction in fresh water, the intensity of storms will likely increase. Typhoons and hurricanes will become more forceful, with larger peak wind speeds and greater precipitation.[1, 3] Warming will cause the global average intensity of tropical cyclones to increase by 2–11% by 2100. Modeling consistently projects decreases in the global average frequency of tropical cyclones, by 6–34%, but the frequency of the most intense cyclones is predicted to increase.[14] Although global models generally predict a decrease in the number of cyclones worldwide, more specific and recent modeling for Hawai‘i indicates that, by the last quarter of this century, Hawai‘i could see a two-to-three-fold increase in tropical cyclones.[15, 16] Such storms can devastate forests as well as threaten Hawai‘i’s communities and

infrastructure. Damage from high winds associated with hurricanes will exacerbate changes to forest structure and species composition, spread exotic species, affect critically endangered plants and animals, reduce carbon storage, and elevate vulnerability to fire.[17] In 1992, Hurricane *Iniki* forcefully demonstrated the destructive force of cyclones on Hawai‘i when it struck Kaua‘i with sustained winds of 130 miles per hour and caused more than $2.3 billion in property damage.[18] Healthy coastal forests can play a significant role in reducing the impact of storm events, including damage associated with storm surges and tsunamis. *(See “Issue 4: Urban and Community Forestry,” for additional information.)*

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

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

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

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

Long-term sea level rise will exacerbate coastal erosion, coastal flooding, and drainage problems, all of which are occurring in Hawai‘i (Figure 5.4). Sea level in Hawai‘i has risen at approximately 0.6 inch per decade over the past century[22] and probably longer.[23] This long-term trend has increased the effects of short-term fluctuations in coastal sea level and tides, leading to episodic flooding and erosion along the

coast.[24] Shoreline retreat, larger storm surges, and water-table salinization will likely diminish the health and integrity of forests and wetlands close to sea level.[25] For coastal native plant communities, modeling suggests numerous species will be vulnerable by 2100, particularly those that have no compatible climate areas remaining. Coastal species, and particularly those species already of conservation concern and with decreasing or limited range size, are more vulnerable to climate change impacts according to the climate change modeling.[12]

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

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

Pressure on Resources Important to Recreation and Tourism

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

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

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

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

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

Trends

Management of Forests in Response to Climate Change

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

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

Climate Change Mitigation

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

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

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

Climate Change Adaptation

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

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

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

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

Priority Issues and Areas for Climate Change and Sea Level Rise

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

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

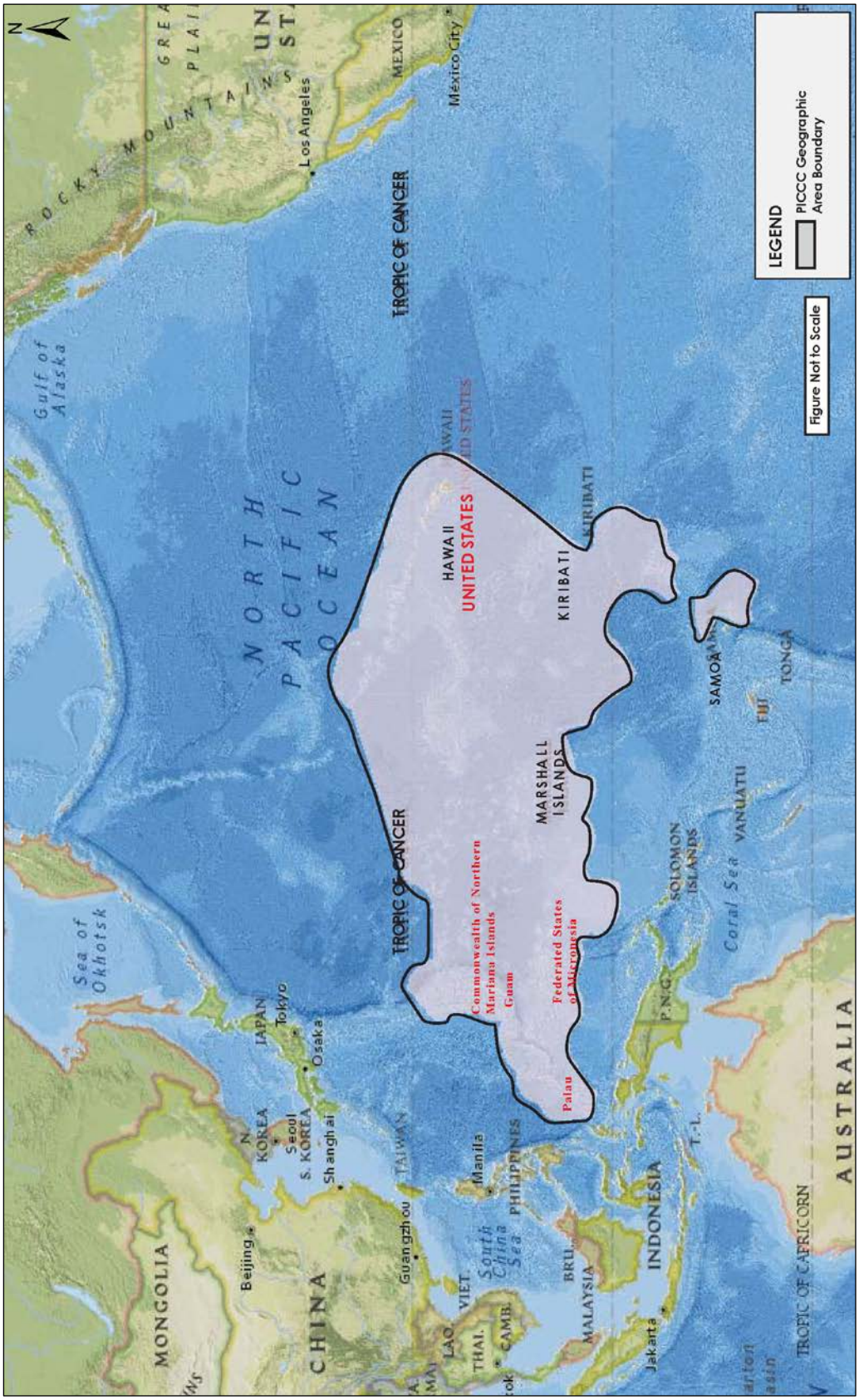
- ICAC, established by the Hawai‘i Climate Adaptation Initiative Act (Act 83, Session Laws of Hawai‘i, 2014) to address the effects of climate change in order to protect the state’s economy, health, environment, and way of life
- Office of Planning, Coastal Zone Management Program, Ocean Resources Management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

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

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

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

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



Map 5.1. PICCC Geographic Area.

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

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

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

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

Data Gaps and Opportunities

Monitoring of Resource Vulnerability to Climate Change

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

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

Improved and Down-Scaled Modeling

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

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

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

Using climate scenario modeling and ecological knowledge, we can identify potential climate change impacts on natural systems, community and environmental infrastructure, operations across planning sectors, and key resources on which Hawai‘i’s residents and communities depend. It is necessary to: (1) determine the degree to which natural and built systems will be

directly or indirectly affected by changes in climate conditions; and (2) assess their ability to accommodate changes in climate with minimal disruption or minimal additional cost. A vulnerability assessment, conducted collaboratively, would accomplish these two goals and indicate the susceptibility of systems to harm from climate change impacts. This type of assessment would help in the process of prioritizing areas on which to focus climate adaptation efforts and funding.

Information Management

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

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

Long-Term Monitoring

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

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

Summary

Hawai‘i’s climate is changing in ways that are consistent with the influence of global climate change. Climate projections for Hawai‘i anticipate an increase in mean annual air temperature of

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

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

Strategies for Issue 5: Climate Change and Sea Level Rise

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

Strategies for Issue 5: Climate Change and Sea Level Rise

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

Strategies for Issue 5: Climate Change and Sea Level Rise

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

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Issue 6: Conservation of Native Biodiversity

Overview

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

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

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

In 2005, Congress required all states to develop a Comprehensive Wildlife Conservation Strategy (CWCS).[3] In Hawai‘i, this provided the opportunity for resource managers to develop and modify a comprehensive planning process to help manage all of Hawai‘i's unique native wildlife. In 2015, the state updated the CWCS, which is now referred to as the State Wildlife Action Plan (SWAP).[4] Hawai‘i's SWAP lays the foundation for conservation of native wildlife

and their habitats for the next 10 years. The SWAP assesses threats to species and their habitats and their conservation needs at three levels: statewide, island-wide, and taxa-specific. The SWAP recognizes the importance of protecting all native terrestrial animals, all endemic aquatic wildlife, other aquatic species threatened with decline, and a broad range of native flora. The plan identifies important species and habitats, objectives and strategies for their conservation, and a framework to measure the effectiveness of these strategies. On the ecological level, the SWAP takes a habitat management approach, adopting a landscape view that takes into account the complex inter-relationships between species and their habitats and the need for change and adaptability. By taking a proactive approach, Hawai‘i’s SWAP also takes a fiscally responsible approach. By emphasizing measures that benefit multiple species groups and habitats in which they reside, the SWAP represents an improvement over single-species management, aiding many species for the same cost. This plan builds on and synthesizes information gathered from existing conservation partnerships and cooperative efforts. Additionally, it highlights partnerships and their efforts in Hawai‘i, with a goal of enhancing and expanding existing partnerships and creating new partnerships, ultimately increasing support for implementing Hawai‘i’s wildlife strategy.

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

Benefits and Services

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

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

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

Threats

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

Table 6.1. Principal threats to native terrestrial habitats.

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

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

Table 6.2. Principal threats to native terrestrial habitats.

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

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

Table 6.3. Principal threats to native taxa.

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

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

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

Invasive Alien Species

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

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

terrestrial reptiles, six amphibians, and over 8,000 plant species have been introduced to date. The existing complement of established invasive aliens has the capacity to overwhelm most remaining native habitat if left unchecked.

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

Invasive Plants

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

Invasive Animals—Ungulate Grazers/Browsers and Predators

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

Hawai‘i’s terrestrial plants and animals are also extremely vulnerable to predation by rats (*Rattus* spp.), feral cats (*Felis silvestris*), and the Indian mongoose (*Herpestes auropunctatus*). The long-term ecological effects of herbivorous, omnivorous, and predatory small mammals has drastically reduced populations of native flora and fauna species, sometimes to extinction. Small mammals such as rats, mongooses, and feral cats prey on native birds. Rodents, particularly rats, damage lowland forests; they are implicated as wholesale vegetation modifiers via selective seed predation. Rodents seem particularly damaging in the Wai‘anae conservation area of O‘ahu,

where they affect endangered tree snails, rare native plants, and an endangered forest bird, the *‘elepaio* (*Chasiempis sandwichensis gayi*).[19] Predatory invertebrates such as ants and other social Hymenoptera have greatly disrupted invertebrate communities at all elevations.

Invertebrate Pests and Diseases

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

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

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

Climate Change

Global climate change, bringing changes in baseline moisture and temperature conditions and thereby rising sea levels, increased climate variability, and increased flooding, is expected to have multiple disastrous effects on Hawai‘i’s native biodiversity (see *“Issue 5: Climate Change and Sea Level Rise”*). Effects of sea level rise on the islands include increased water levels,

erosion, salinity, and flooding, all of which threaten our coastal wetlands, waterbirds, nesting seabirds, monk seals, and sea turtles.

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

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

Development

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

Grazing

Clearing of forest for production of cattle has a 200-year history in Hawai‘i. Cattle have the same effects on native vegetation as other ungulates, and the devastating effects of cattle in Hawai‘i

are well documented. Today, there are still a number of very large private ranches, several of which occur within native ecological systems or former native forest areas. Ranching-related loss of native ecosystems is active in the North and South Kona District conservation area in particular. There is a long history of the state providing extremely low-cost leases to ranchers on state lands, which perpetuates grazing impacts on already degraded lands and the loss of more cattle (which become feral) into forested areas.

Unsustainable Harvesting

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

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

Military Training Activities

Live-fire training, large-scale troop movements, and heavy equipment operations are serious threats to native species at U.S. Army training facilities in areas of O‘ahu and the Big Island. Training operations have resulted in vegetation clearing, increases in wildfire frequency, and the

introduction and spread of unwanted alien species. The U.S. Army has instituted an ecosystem management program to mitigate these impacts, and is now among the state's most active and well-funded stewards of native systems. The U.S. Army and other military branches in Hawai‘i also provide acquisition buffer programs that have played important roles in acquiring important threatened and endangered species habitat. *(Refer to "Appendix C: Forestry-Related Assistance Programs," for more information.)*

Recreational Overuse

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

Stream Diversion

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

Wildfire

In fire-adapted ecosystems, fire plays a vital role in forest successional patterns and other ecological functions; however, in Hawai‘i and many other Pacific islands, fire is not a large part of, and rarely positive for, the native ecosystems. Fire-adapted aliens (especially grasses and short-lived shrubs) are established in lower, leeward slopes and some subalpine areas of Hawai‘i. When ignited, these weeds fuel major wildfires that can carry into native forests. Native forests are destroyed and replaced with fire-adapted weeds in a trend that increases the range and

intensity of these fires. This grass/fire cycle perpetuates itself and, without intervention, can render native ecosystems permanently altered and unable to be restored to a natural state. According to DOFAW biologists, many native plant and animal species are just one fire away from extinction. For example, seven out of the remaining eight Hawaiian gardenia (*Gardenia brighamii*) plants known to occur on O‘ahu were wiped out in a fire in Nānākuli in May 2015. And, if a fire swept through the core *māmane* forest on Mauna Kea, it could wipe out the endangered *palila* birds that depend on this forest. *(See “Issue 3: Wildfire.”)*

Other Threats

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

Trends

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

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

Although the threats to Hawai‘i’s native species persist, recent years have seen greater awareness of the need to take action to conserve biodiversity with a more assertive political will to address these problems, as well as wider community involvement in project implementation. These changes have resulted in positive steps toward the recovery of many of Hawai‘i’s endangered species and in the protection of species that remain common, so that they do not become endangered. Success stories include 120,000 native trees planted over the last 5 years by Watershed Partnerships, 210 listed endangered plants and animals protected by watershed partnerships, release of the ‘alalā (Hawaiian crow, *Corvus hawaiiensis*) in the Pu‘u Maka‘ala Natural Area Reserve on Hawai‘i Island ending a decade long of extinction in the wild,

recovering the *nene* from the edge of extinction, increasing populations of *honu* (*Chelonia mydas agassizi* [green sea turtle]), protecting numerous important habitats, and implementing community-led restoration efforts such as in Waimanalo streams, which encouraged the return of the endangered *ae'o* (*Himantopus mexicanus knudseni* [Hawaiian stilt]). However, despite these success stories, Hawai'i continues to face major conservation challenges in protecting its more than 10,000 native wildlife species, some of which are critically endangered, such as the Hawaiian monk seal (*Monachus schauinslandi*).

Collaborative Working Groups and Partnerships

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

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

Birds[19] and five-year implementation plans for identified critical species, propagation of captive birds, annual surveys for forest bird, and implementation of other identified research and management projects.

- Dryland Forest Working Group (DFWG) is an ad hoc partnership formed in the early 1990s. In 1993, DFWG began to advise and participate in a cooperative restoration project and an agreement between the Hawai‘i Forest Industry Association (HFIA) and the U.S. Fish and Wildlife Service (USFWS). It is the driving force behind restoration science at Ka‘ūpūlehu dryland forest and, since its formation, has expanded to public and private dry forest restoration sites. DFWG hosts an annual symposium of dry forest restoration initiatives on the islands.

Innovative Management Techniques

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

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

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

Funding for Conservation

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

are more non-native predators), management actions are expensive, and in many cases actions must be conducted in perpetuity. Because of the status of many Hawaiian birds and the threats facing them, current recovery expenditures are inadequate to prevent additional extinctions.[22]

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

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

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

Funding levels from federal sources also are inadequate and inequitably apportioned. In 2014 Hawai‘i received 16% of the national appropriation under the Endangered Species Act (the traditional Section 6 Program) and only 1% of the national appropriation under the State Wildlife Grants Program. However, through related competitive grant programs within the Section 6 program, additional funding for conservation on private lands and for land acquisition *(see "Appendix C: Forestry-Related Assistance Programs"*) has become available. Though Hawai‘i has been successful in securing a portion of these grants because of extensive and progressive

partnerships with landowners, lack of sufficient overall funding to implement recovery programs, especially on state lands, leaves both critically endangered species and lesser-known native species (e.g., terrestrial invertebrates) with little support.

Loss and Degradation of Habitat

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

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

Present Conditions

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

land area. Similarly, much of the habitat for freshwater species has declined, with 58% of the perennial streams in the state having been altered in some way.

Terrestrial Habitats

The distribution of terrestrial habitats in Hawai‘i is influenced by elevation, climate, and substrate. Using elevation zones and moisture gradients, Hawai‘i 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 Hawai‘i*[23] recognizes 33 native forest communities, 36 native shrubland communities, eight native grassland communities, and four native herbland communities. Subterranean systems form a tenth habitat type defined by geology rather than elevation zones and moisture.

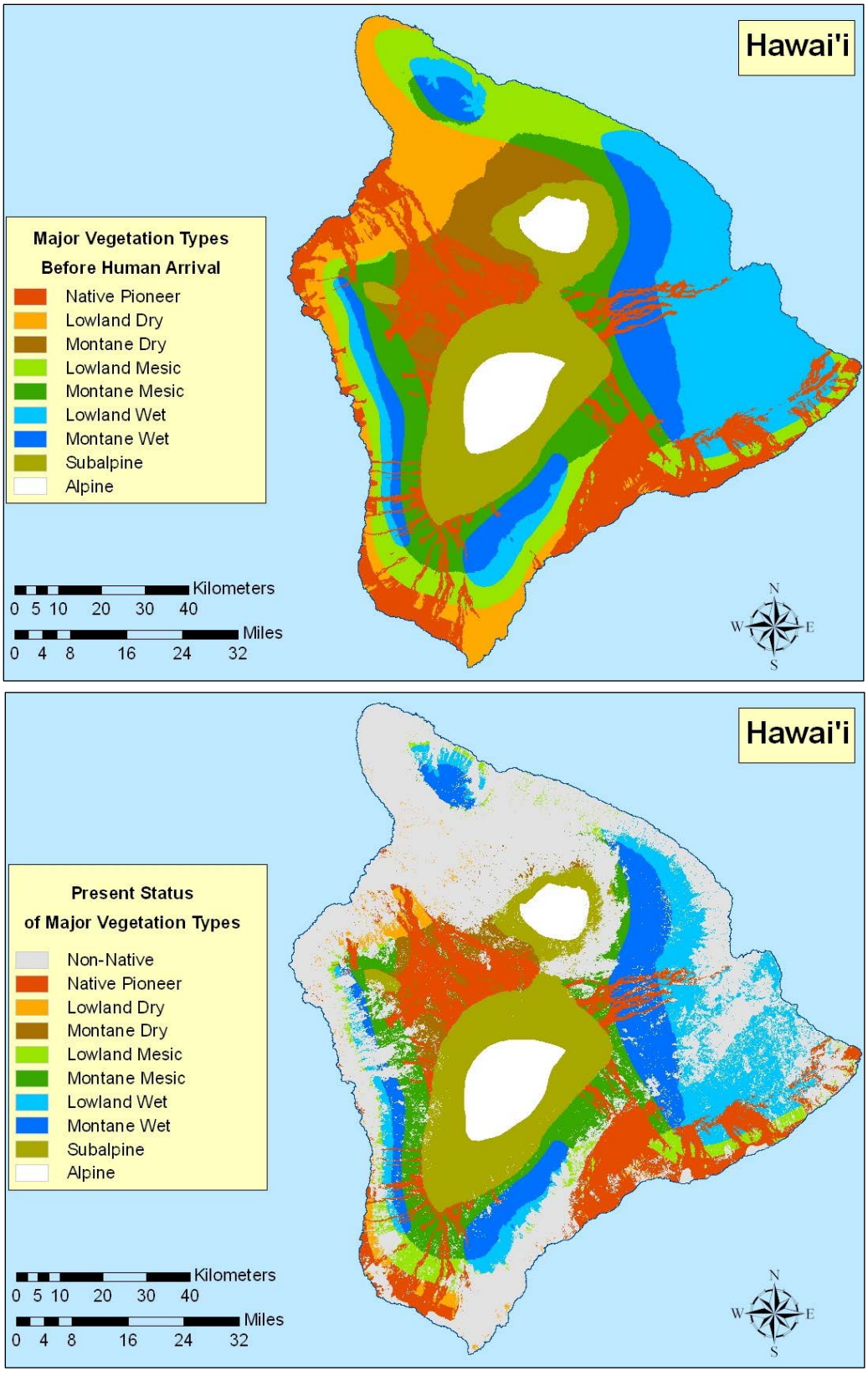
Aquatic Habitats

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

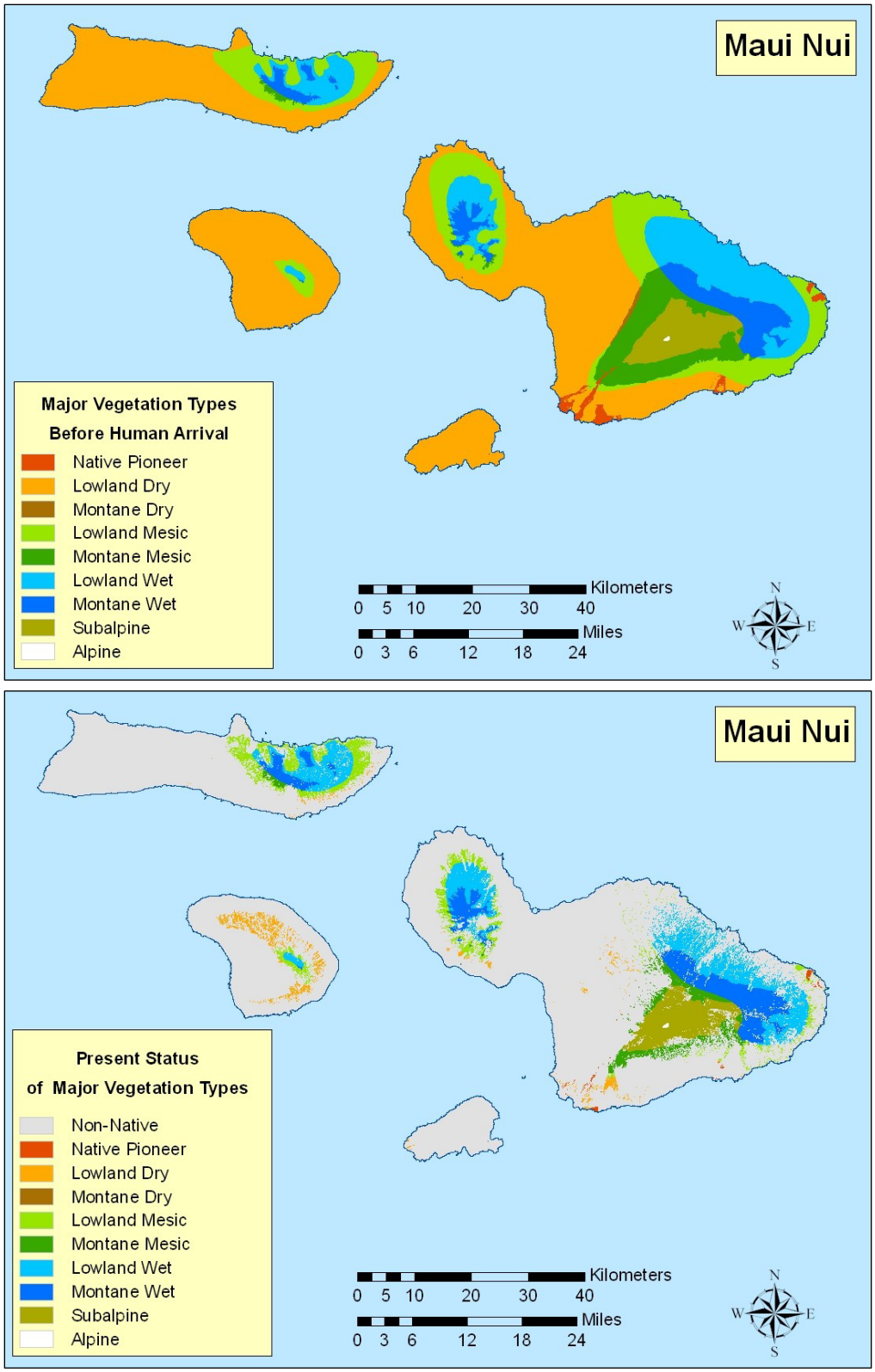
As discussed in “*Issue 1: Water Quality and Quantity*,” this interconnected network of aquatic habitats and adjacent land areas collectively is referred to as a watershed, which is similar to the traditional Hawaiian land division *ahupua‘a*. Activities or threats that affect one part of this interconnected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

Native Taxa

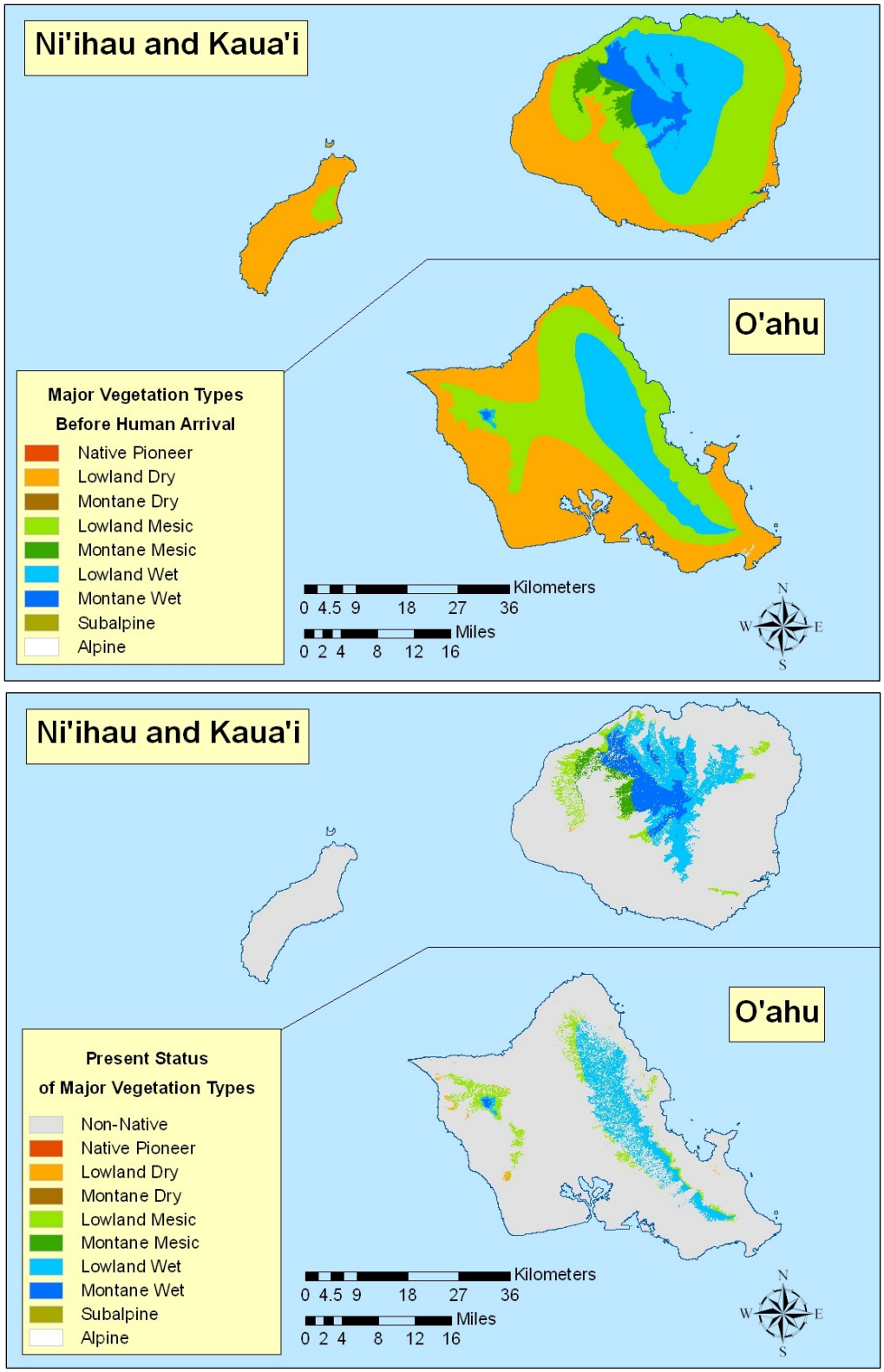
Because of the extreme isolation and distance, relatively few life forms successfully colonized the Hawaiian Archipelago over its 70-million-year history. Those species that did, however, found habitats that varied enormously over very short distances. As a result, the archipelago has some of the world’s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



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



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



Map 6.3. Major vegetation types for the Kauaʻi, Niʻihau, and Oʻahu before the arrival of humans and in 2005. Map by Page Else, Hawaiʻi Conservation Alliance.

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

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

Priority Issues and Areas for Conservation of Native Biodiversity

Public Outreach and Education

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

Improved Information Access and Management

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

Priority Areas for Conservation of Native Biodiversity

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

Category 1: Intact Native Ecosystems, Highest Biodiversity

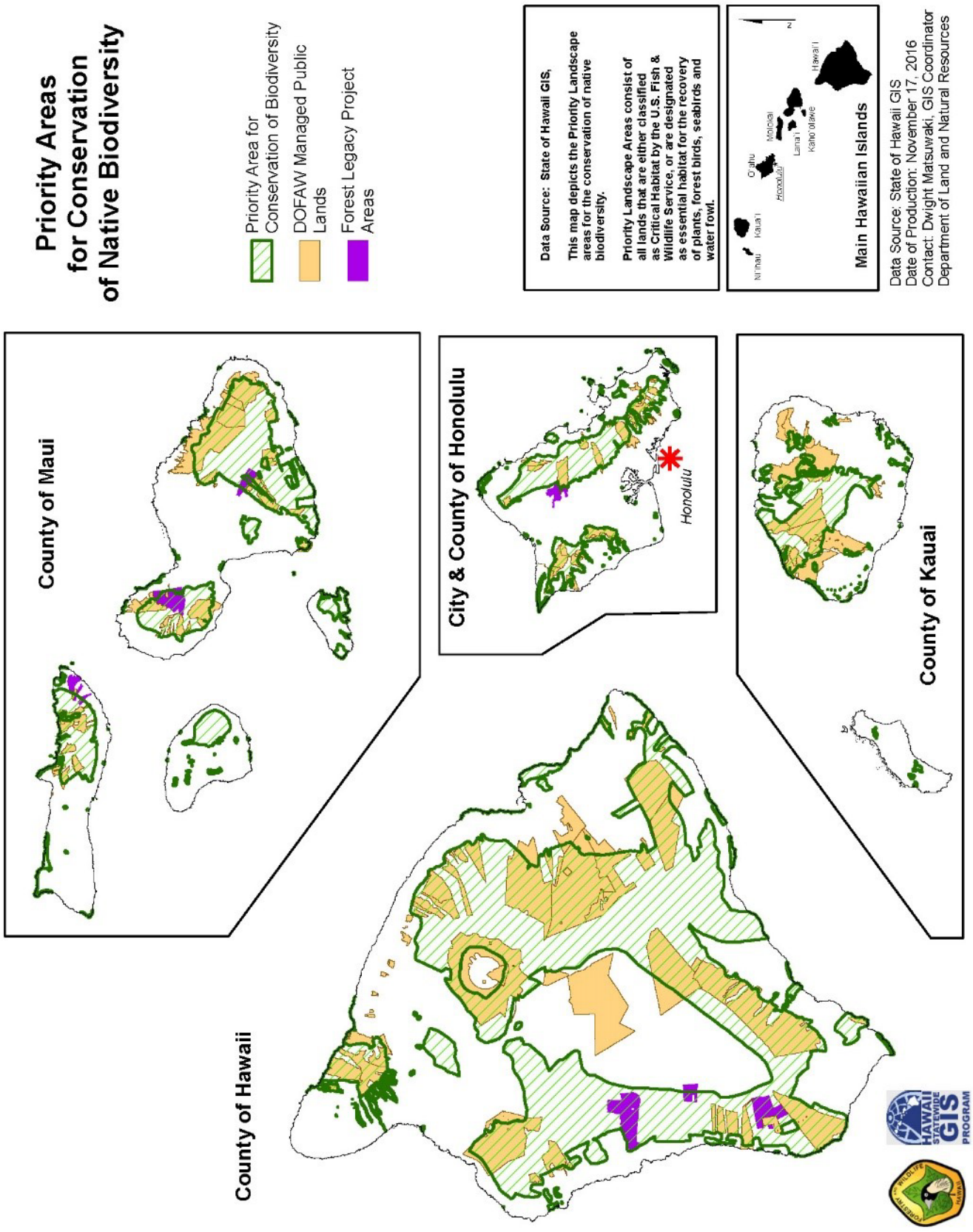
Areas that fall under this category are important for maintaining native ecosystems and forest birds. These high-quality native-dominated areas (as identified by a habitat quality analysis developed from a combination of Hawai‘i Gap Analysis and LANDFIRE datasets) have more intact structure and function,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

Category 2: Intact Native Ecosystems, High Natural Biodiversity

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

Category 3: Rapidly Degrading Native Ecosystems

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



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

Category 4: Non-Native Ecosystems with High Recovery Potential

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

Category 5: Degraded Ecosystems

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

Category 6: Native Ecosystems No Longer Exist

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

Data Gaps and Opportunities

Information Quantity and Management

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

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

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

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

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

Funding for Conservation

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

Summary

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

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

Strategies for Issue 6: Conservation of Native Biodiversity

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

Strategies for Issue 6: Conservation of Native Biodiversity

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

Strategies for Issue 6: Conservation of Native Biodiversity

Biodiversity Objective/Management Strategy for Lands with Degraded Native Ecosystems and Where Native Ecosystems No Longer Exist (Categories 5 and 6)								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Conduct localized restoration in non-native-dominated areas with localized potential for restoration. Incorporate native biodiversity consideration into commercial forest management and urban landscaping projects.	All lands designated by USFWS as critical habitat and/or recovery habitat and that are in Category 3, 4, 5, or 6.	Develop information, promote education.	Same as above.	Public and private landowners, OHA, and non-profit organizations.	CREP, non-profits, HFIA, SWCD Kaulunani.	Number of common native plant populations established; number of constituent native plants genetically and historically appropriate to location; soil improvement if necessary.	1.1 2.2 3.5	1.5
Conservation of Native Biodiversity: Education and Outreach								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Develop environmental education curriculum that supports the link between Hawai'i's unique cultural traditions, native biodiversity, and student learning objectives.	Statewide.	Develop information, promote education, increase preservation of cultural knowledge.	HELP, HEEA, HIDOE, Hawai'i Association of Independent Schools.	Communities and schools, Hawaiian cultural organizations.	HEEA, educational non-profits.	Env. ed. aligned with HIDOE standards; curriculum in use in all schools public and private; curriculum available for use by informal programs.	3.6	1.1 1.2 1.4 1.5 2.2 3.1 3.2 4.4 6.1 6.2 6.3

Strategies for Issue 6: Conservation of Native Biodiversity

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

Key:

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

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

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

Overview: Hunting

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

Hunting for Game Management and Recreation

HRS Chapter 183D is the basis of the DOFAW hunting program. The program is organized around participation in the federal Pittman-Robertson Wildlife Restoration Act, which defines

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

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

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

Hunting and Conservation

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

The Degradation of Kaho‘olawe

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

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

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

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

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

Benefits of Hunting

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

Threats

Loss of Areas for Game Management

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

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

Priority Issues and Areas: Hunting

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

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

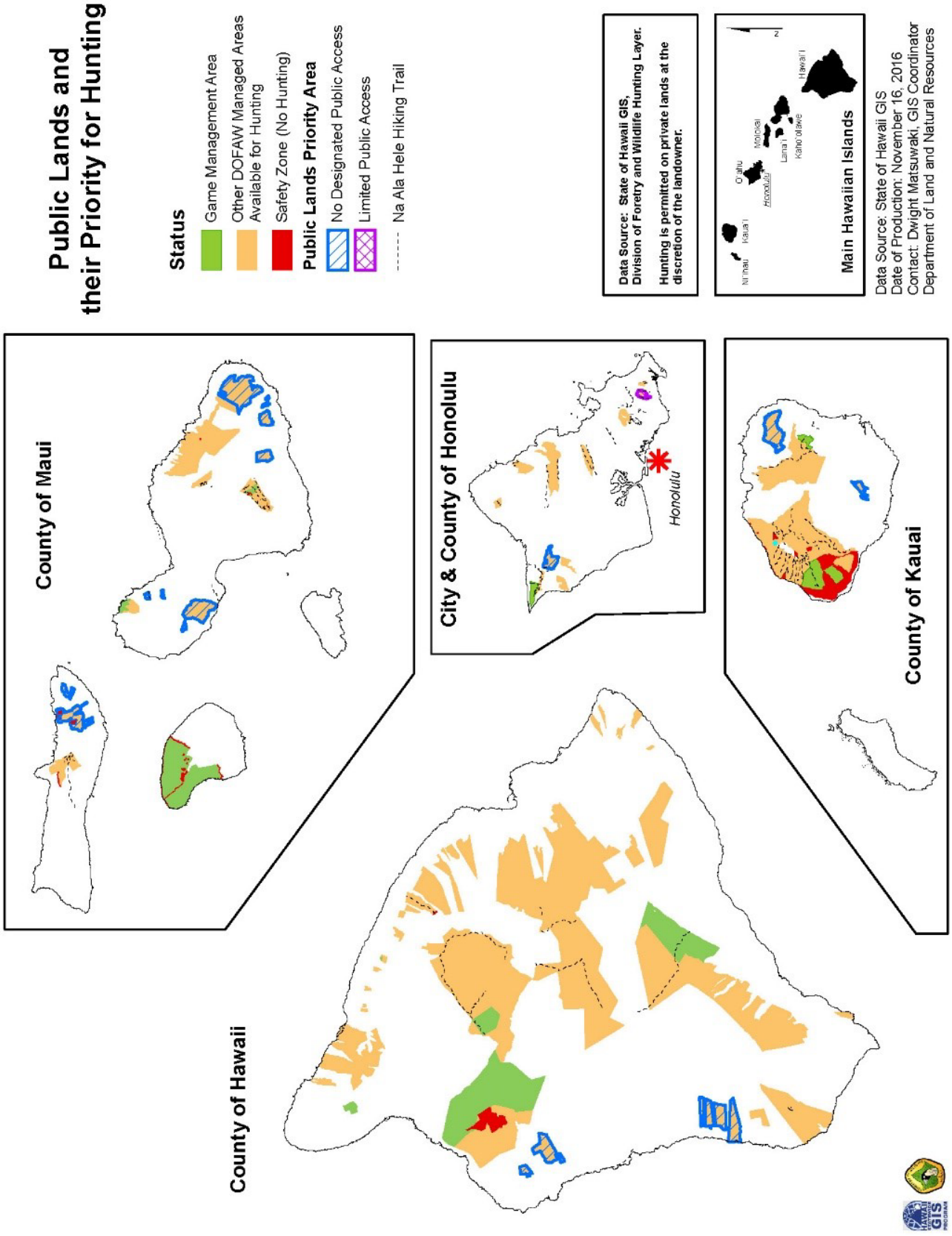
Other DOFAW Managed Areas Available for Hunting—In these areas, hunting is integrated with other uses, such as hiking, production of forest products, and protection of native resources. These areas include other lands managed by DOFAW such as the Forest Reserve lands.

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

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

Data Gaps and Opportunities: Hunting

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



Map 7.1. Public Lands and their Priority for Hunting.

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

Overview: Nature-Based Recreation and Tourism

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

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

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

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

Cultural Tourism

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

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

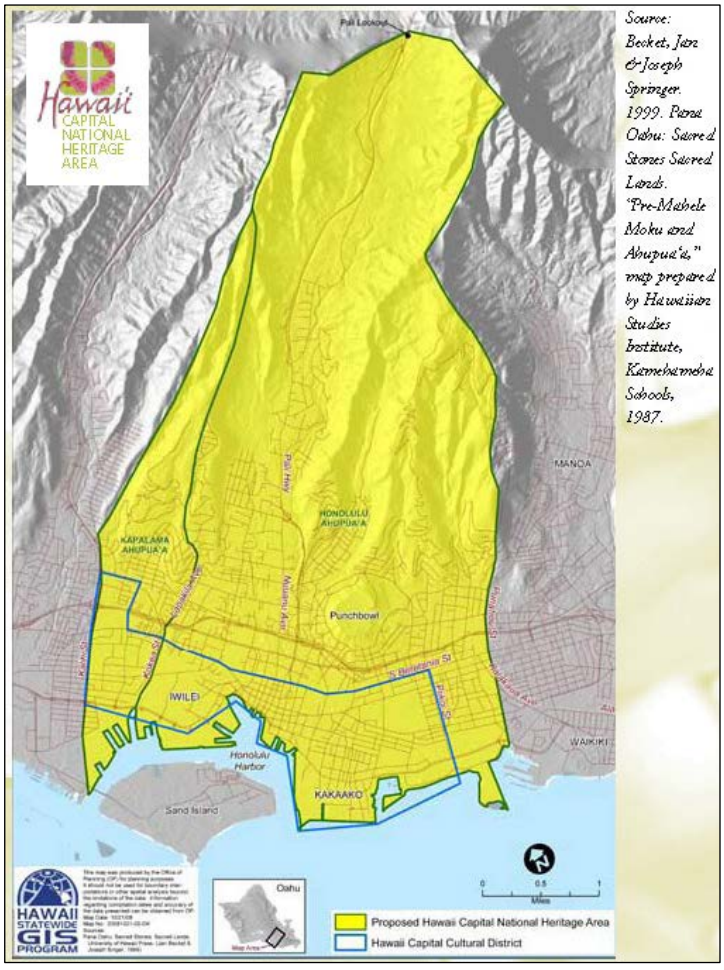


Figure 7.1. The entire *ahupua'a* of Honolulu is proposed for National Heritage Area designation.

The proposed boundaries are the ancient boundaries of the *ahupua'a* of Honolulu and Kapālama, covering the beautiful valley of Nu'uanu and adjacent coastal plains in the ancient and historical village of Kou, now the City of Honolulu, on the island of O'ahu (Figure 7.1).[10] According to the *mo'olelo*, the storytelling oral tradition of native Hawaiians, this area has been an important region for thousands of years. Its rich cultural and natural history is written in the lands that reach from the heights and mountain ridges of the majestic Ko'olau mountains to the

welcoming seas of the Pacific. The example of the Hawai‘i Capital National Heritage Area highlights the connection that can be made between tourism and Hawai‘i’s cultural and natural resources. Further development of eco-cultural tours that link traditional culture to forest resources strengthens social ties to Hawai‘i’s forests.

Nature-Based Recreation and Tourism

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

One hundred and ten sites were selected based on a comprehensive review of travel guides and other sources of information used for vacation planning, meetings with HTA’s Natural Resources Advisory Group, consultation with various agencies and organizations responsible for recreational and natural resource management, and public input. The final list of sites assessed comprised: 30 sites on O‘ahu, 19 sites on Maui, five sites on Moloka‘i, six sites on Lāna‘i, 27 sites on Kaua‘i, and 23 sites on the Island of Hawai‘i.

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

Hawai‘i’s Parks

Hawai‘i’s parks are situated in forested, coastal, mountainous, and urban landscapes. In 2007, it was estimated that 10.1 million people visited Hawai‘i state parks each year. Of this total, two-thirds were out-of-state visitors and one-third were residents. [11]A large percentage of visitors engage in photography and general enjoyment of scenic views while visiting state parks. Almost three-fifths of out-of-state visitors to parks are repeat visitors.[11] Maintaining the natural beauty of

the parks and the lands surrounding them increases the likelihood that visiting state and national parks will continue to be a high priority for many Hawai‘i vacationers. The benefits of Hawai‘i’s state parks are discussed below, under the general section on the benefits of nature-based recreation and tourism.

National Parks

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

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

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

State Parks

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

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

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

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

Limited state park funding is used primarily to:

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

Forest Reserves

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

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

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

Natural Area Reserves

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

City and County Parks

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

Na Ala Hele Trails and Access Program

Na Ala Hele (NAH) (Figure 7.4) is the State of Hawai‘i Trail and Access Program administered by DOFAW. This program was established in 1988 by HRS Chapter 198D in response to public concern about the loss of public access to trails and the threat to historical trails from development pressure. NAH plans, develops, acquires lands or rights for public use of lands, constructs, and engages in coordination activities to implement a trail and access system. It also

conducts environmental risk assessment and establishes methods to improve public safety by assessing trail and ancillary natural resource conditions for specific hazards, executing mitigation actions, and applying warning signs along transit corridors.[13] NAH has become increasingly engaged in trail management and regulatory issues because of public, private, and commercial recreational activities and emerging legal issues. DOFAW lands, including the Forest Reserve and Natural Area Reserve Systems, also contain and provide recreational opportunities for residents and visitors of the Hawaiian Islands.

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

Ecotourism

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

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

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

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

Benefits of Nature-Based Recreation and Tourism

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

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

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

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

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

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

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

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

Threats and Concerns

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

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

Table 7.2. Threats and concerns for recreation and tourism.

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

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

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

Trends

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

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

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

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

Present Conditions

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

budget, despite the fact that DLNR manages more than a quarter of the total land mass, as well as many coastal areas.

Priority Issues and Areas: Nature-Based Recreation

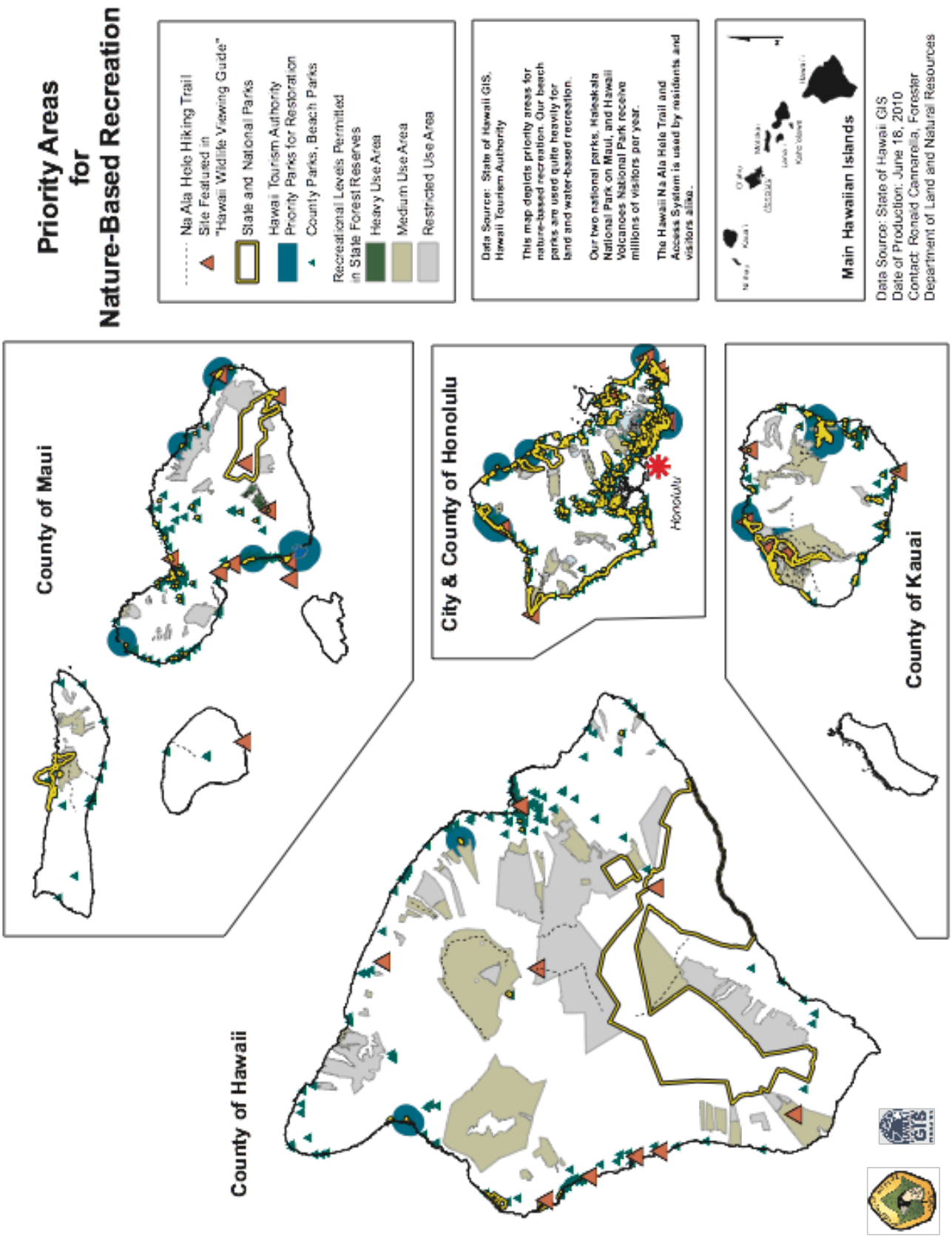
In addition to DOFAW, the Division of State Parks and the HTA have identified priority landscapes, issues, and goals relating to nature-based recreation and tourism in Hawai‘i. Documents referenced include the 2015 *Statewide Comprehensive Outdoor Recreation Plan,* DLNR’s *Recreational Renaissance Plan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

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

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

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

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



Map 7.2. Priority areas for nature-based recreation.

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

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

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

Figure 7.6. Kalalau lookout, Kaua‘i.

Kaua‘i County

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

O‘ahu

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

Maui County

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

Hawai‘i County

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

Data Gaps and Opportunities: Nature-Based Recreation

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

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

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

Summary

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

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

There is a demand for ecotourism; however, more research needs to be conducted to identify the impact of ecotourism in Hawai‘i and determine whether a certification program is needed. Many recreational sites and trails are experiencing heavy use, which is affecting not only natural and cultural resources but also visitor experience and safety. Additional recreational sites are needed on public and private lands to provide more opportunities. Also, more opportunities need to be

created for visitors to be able to pay to engage in conservation in exchange for enjoying protected areas that are otherwise closed to recreational use. Lastly, there needs to be an increase in awareness among visitors regarding safety and respect for access, resources, and culture.

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

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

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

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

Recreation and Tourism: Priority – Provide Recreational Opportunities and Manage Game Mammals								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Continue to comply with relevant state statutes (HRS 183D and 195D) and federal laws (PR and ESA Section 7).	Forest Reserves, private lands, land-locked state lands.	Identify and control incipient invasive species.	NAH, conservation education, forest stewardship, FSP, CREP, UCF, FLP.	Recreationists, hunters, rural communities, private landowners.	Hunting fees, PR, appropriate land parcels engaged, FSCG.	Hunting licenses sold; hunter days in the field; game mammals harvested; new acres added/removed for hunting.	3.4 3.6	
2. Increase capacity to effectively manage game mammals through better research and monitoring.	Public hunting areas, private hunting lands, state leased lands.	Same as above.	Wildlife program, USGS-BRD UH-Manoa Dept. of Nat. Res. and Env. Mgmt., FLP, FSP, UCF, FSCG.	Hunters, rural communities, UH, watershed partnerships, private landowners.	Hunting fees, PR, research capacity of state and federal institutions, HCA.	Number of areas and game spp. with population estimates; number of plans and estimates of desirable game population numbers.	2.2 3.4 3.6	
3. Increase effective communication between programs and the public, and among programs, regarding resource problems and management and protection issues.	Urban and rural communities and institutions statewide.	Enhance env. ed., identify and control incipient invasive species.	HISC, invasive species program (wildlife), forest health, watershed partnerships, FRS, NARS, FSP, CREP, UCF.	Public and private landowners, resource management agencies.	HCA, Forestry and Wildlife Education and Outreach, HISC and CGAPS outreach staff, NOAA.	Reduced conflict and increased cooperation in natural resource management; public support and participation in management and protection initiatives.	2.2 3.4 3.6	1.2 1.5 3.1 3.3 5.1
Recreation and Tourism: Outreach and Education								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Establish a Children's Forest Program to provide educational and recreational opportunities in forests for K–12 students across the state.	State forests, Hawai'i Tropical Experimental Forest.	Support multi-state and multi-island participation.	Conservation education, FSP, FRS, NAPP, UCF, FSCG.	All private residents, landowners, and visitors, schools, env. ed. orgs.	HCA, TPL, TNC, IPIF, Dryland Forest Alliance, Outdoor Circle, Parks.	Number of children engaged; broad Pacific Island involvement; Demonstration Sites.	3.6	1.2 1.4 1.5 2.2 3.1

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

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

Key:

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

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Issue 8: Forest Products and Carbon Sequestration

Overview

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

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

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

society made use of a variety of other forest products to supply building materials, tools, clothing, medicine, and food, among many other uses.

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

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

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

In recent years, the use of biomass for energy production has emerged as a viable way to use existing plantation forests and for the state of Hawai‘i to reach its renewable energy goals. There

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

Forest Products of Hawaiʻi

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

Timber and Other Commercial Products

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

Ecosystem Services

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

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

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

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

Benefits

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

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

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

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

Threats

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

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

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

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

Invasive species are a major threat to the forests of Hawai‘i (*see “Issue 2: Forest Health: Invasive Species, Insects, and Disease*). The introduction of invasive species, insects, or diseases that would affect the vitality of the major native forest product species, such as *koa* or *‘iliahi*, or non-native commercial production species such as *Eucalyptus*, would impede or slow the development of the forest products industry in the state. Already, the statewide occurrence of *koa* wilt in native forests, plantations, and nurseries limits the use of this ecologically and economically important species for ecosystem restoration and commercial reforestation efforts. Introduction of other new diseases and pests could have similar effects on native and introduced commercially important species. Consequently, the invasiveness of any proposed new

introduction or currently occurring commercial forest products species should be evaluated and considered when developing it for the industry. If non-native species are being introduced for commercial purposes, they should be screened using the Hawai‘i Pacific Weed Risk Assessment or similar tool, and only introduced if found to have a low probability of becoming invasive. The suitability of native species should be investigated, and native species should be invested in as alternatives to the introduction of new commercial species.

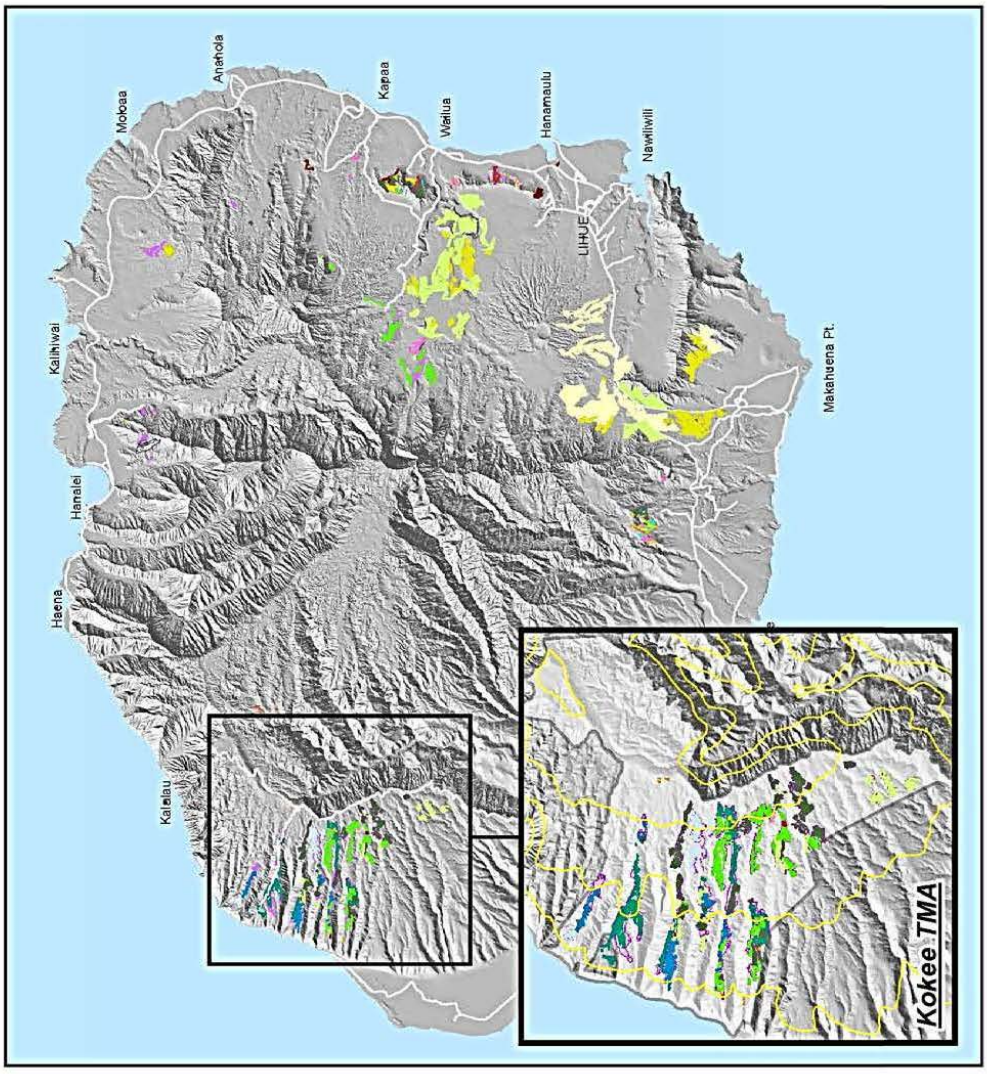
Developing any new industry is challenging, especially in Hawai‘i, which has limited land and resources. Hawai‘i also has some of the rarest species and natural habitats in the world, including 434 plants and animals that are federally and state-listed as threatened and endangered,[9] necessitating extra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

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

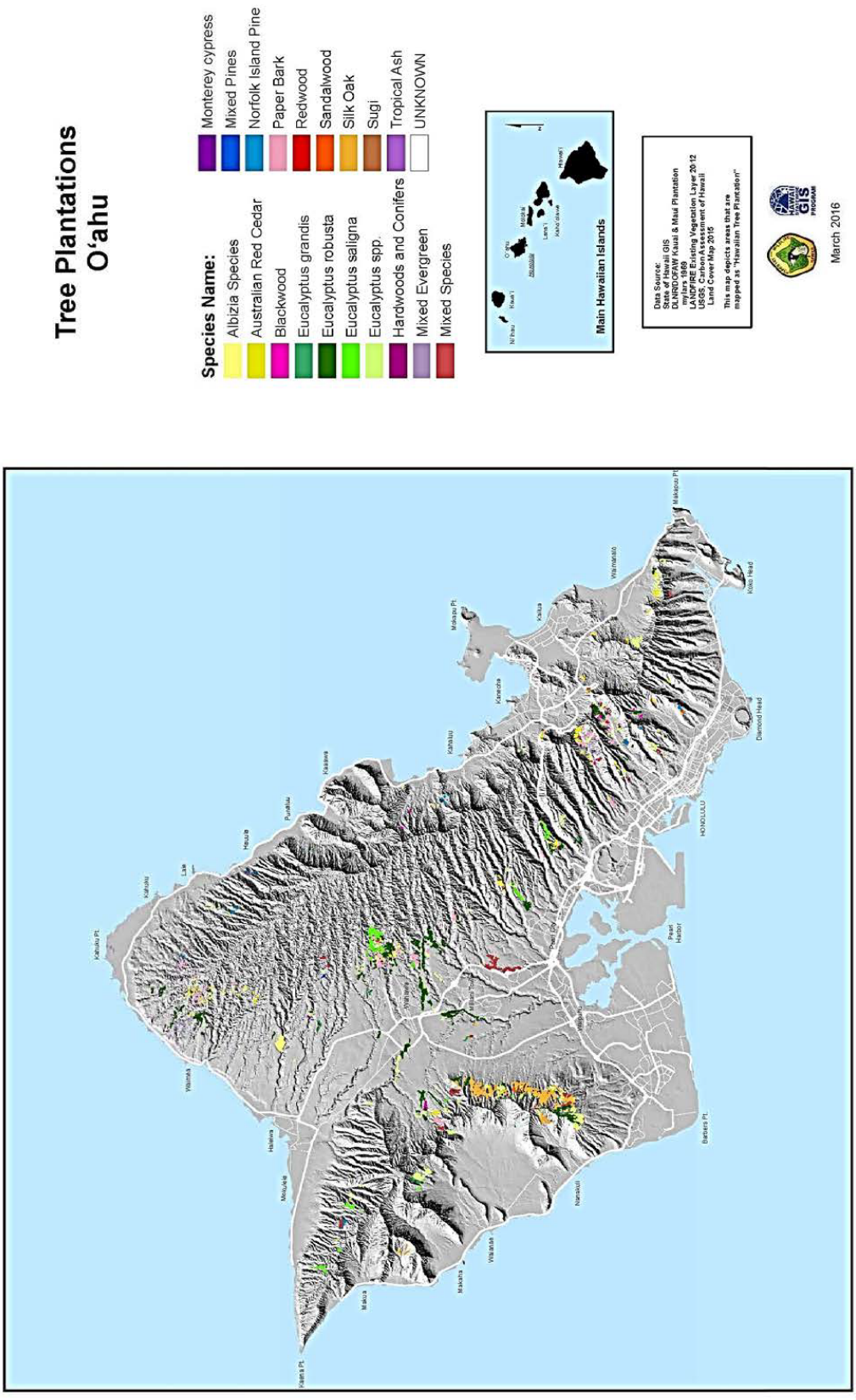
Present Conditions and Trends

Forest Products

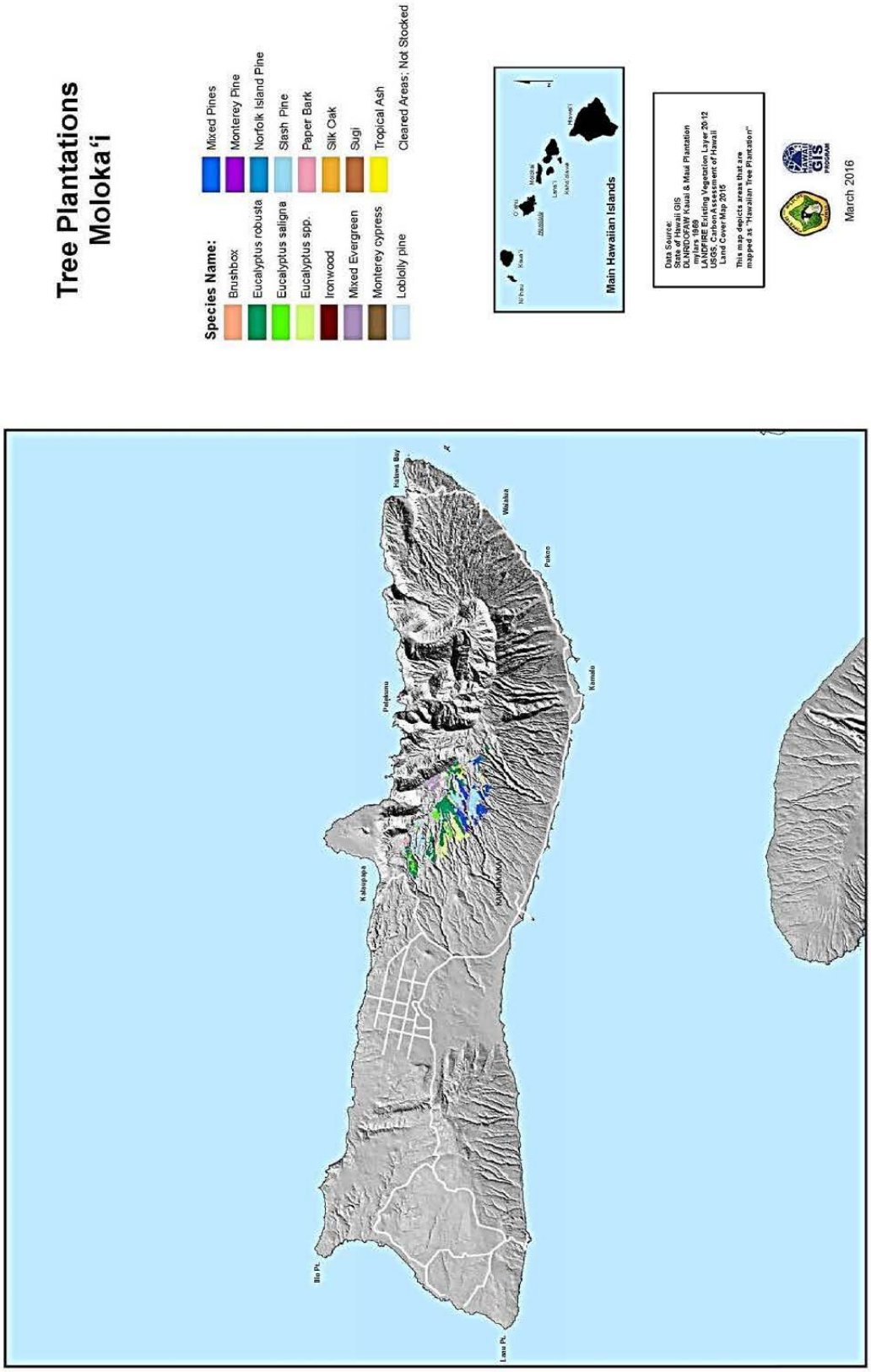
Any large-scale commercial timber industry in Hawai‘i is in a nascent stage of development despite decades of efforts to generate commercial ventures. A thriving forest products industry has many components that need to be operational in order for it to fully function at capacity, including both native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



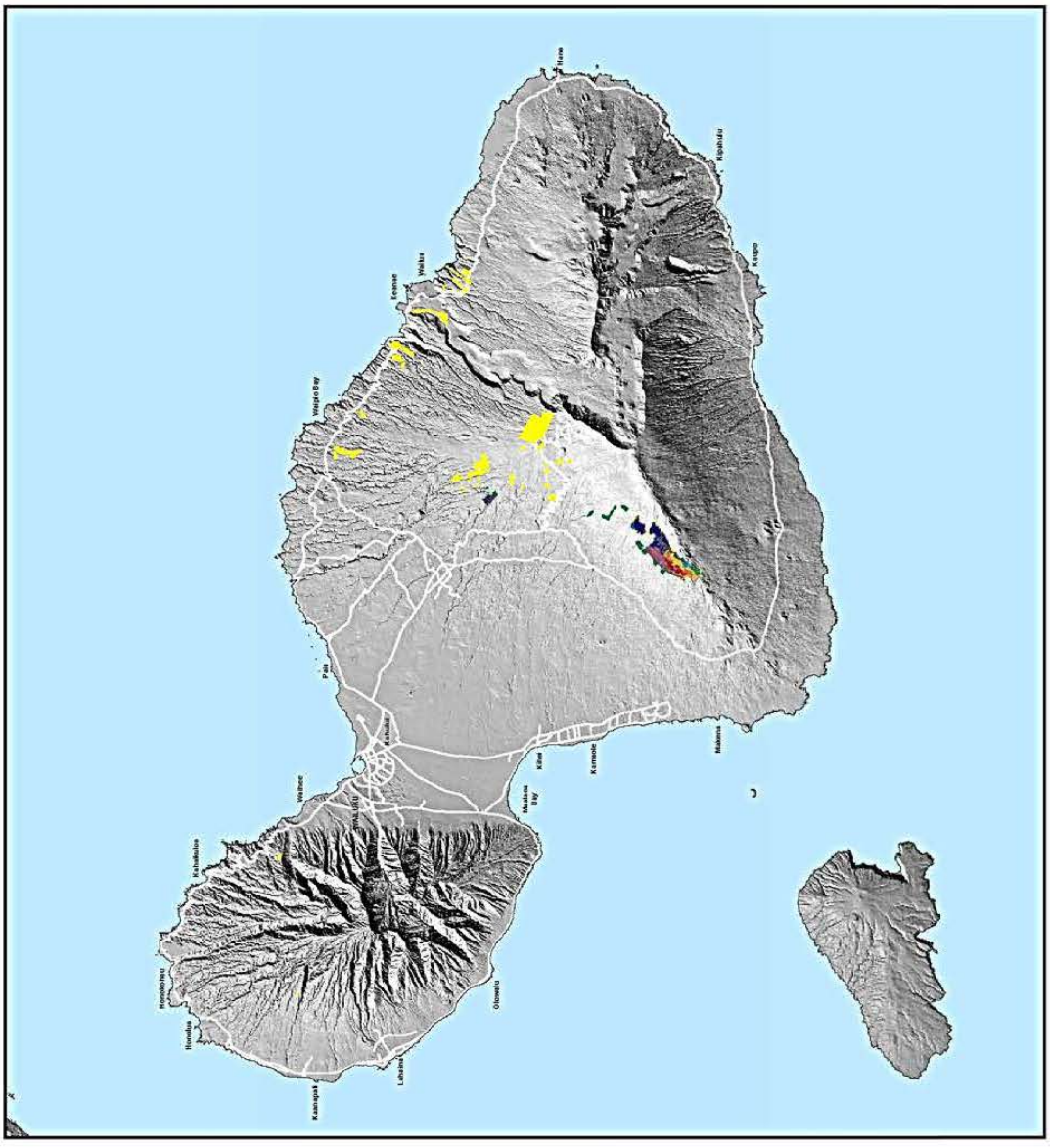
Map 8.1. Locations and species composition of tree plantations on Kaua'i.



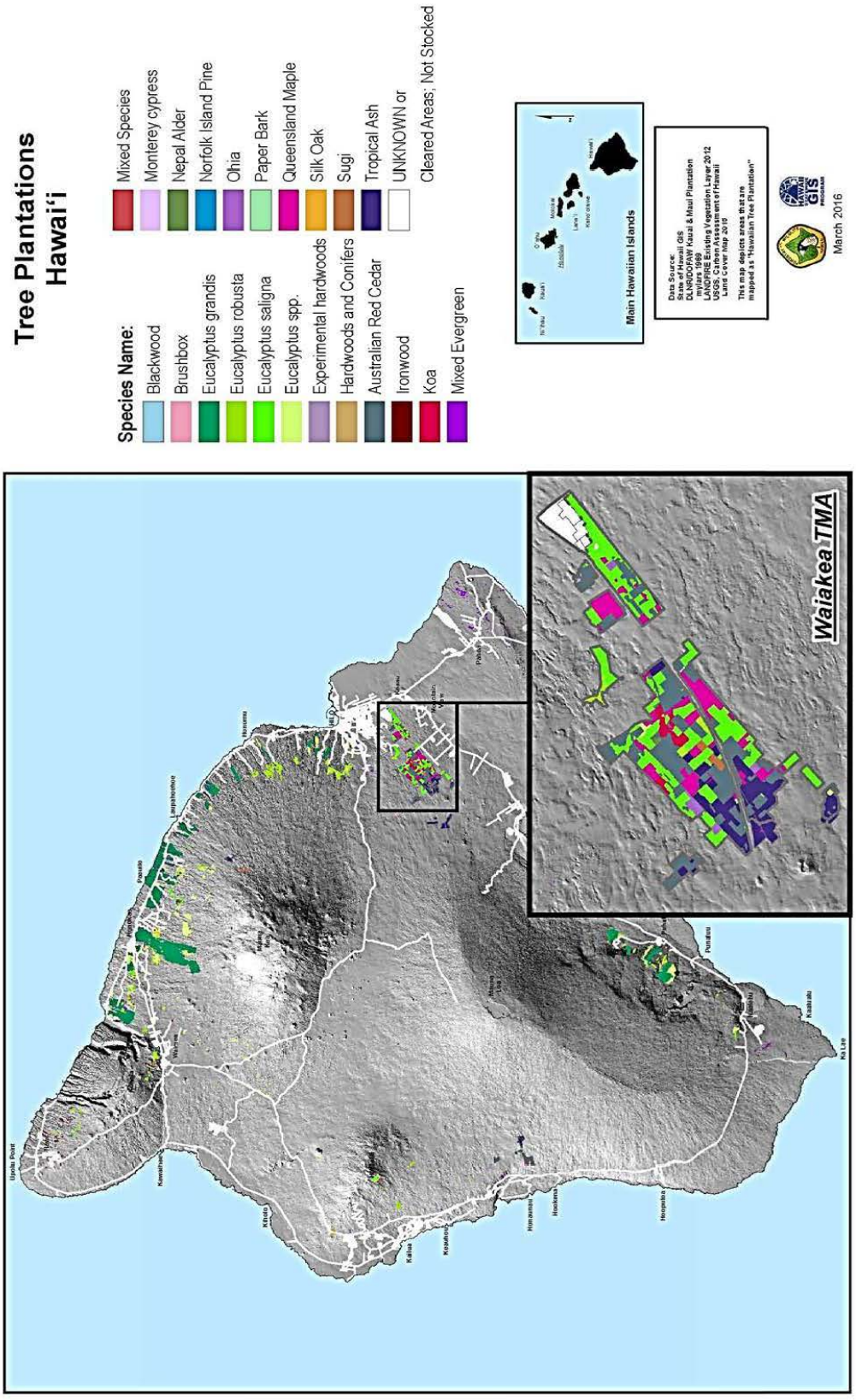
Map 8.2. Locations and species composition of tree plantations on O‘ahu.



Map 8.3. Locations and species composition of tree plantations on Moloka'i.



Map 8.4. Locations and species composition of tree plantations on Maui.



Map 8.5. Locations and species composition of tree plantations on Hawai'i.

Once components are fully developed and implemented, the industry in Hawai‘i likely will include timber for craft woods, lumber, veneer, wood biomass and biofuels, export wood chips, and more.[11, 12] Hawai‘i has several wood product companies, operators, and primary log processors who use small portable mills to process timber resources. Demand already exists for solid wood products in local, mainland, and foreign markets, especially in the case of *koa*.[7, 8, 13] Hawai‘i forest-grown non-native products such as *Eucalyptus robusta* (Robusta) and *Eucalyptus saligna* (Saligna) make beautiful hardwood flooring, furniture, cabinetry, and other fixtures, including doors, windows, and moldings. Plantations stands of these species are ready for harvest.

Development of a mid-size wood mill on the Island of Hawai‘i remains a worthy goal and could be attainable. Some of the critical pieces needed for a wood mill may be coalescing, with an increase in wood supply coming from release of new acreage to lease on state lands in the Waiākea Timber Management Area.[14] A mid-sized mill would have access to wood supply from both public and private lands. There is potential for the mill to run its own biomass operation, using waste material for heat or electricity to dry lumber; it also could team up with another biomass operation under construction to provide affordable services.

Finally, there is market demand for high-quality Hawaiian hardwoods in domestic and foreign markets. At present, 160,000 tons of *Eucalyptus* logs from the Hāmākua coast are being shipped to foreign markets, and market studies identify consistent domestic demand.[7, 8, 9] *Koa* has continued to increase in value as new mainland markets are developed, and other native and Polynesian hardwoods are being highlighted by local and international woodworkers. While there are several non-native tree species that are used in the forest industry for timber and other forest products, there continues to be a strong trend to develop a wood products industry based on endemic tree species such as *koa* and *‘iliahi* (Figure 8.1). Planting and management of such endemic tree species could potentially be a win-win situation for conservation and the forest products industry. The commercial production of an endemic species would provide a financial incentive to convert marginal pasturelands and degraded croplands to native forests and thereby support the development of a high-value forest industry. In particular, planting and management of *‘iliahi* would help restore this endemic species and associated native plants and wildlife. This in turn would support continued traditional and cultural uses of *‘iliahi* and encourage landowners to value, manage, and retain native forest.

Figure 8.1. *'Iliahi*, or Hawaiian sandalwood (*Santalum* spp.), seedlings, essential oil, and adult tree. *'Iliahi* is an endemic species that was the foundation of the forest products industry in Hawai'i during the 1800s, and today has the potential to once again become a major contributor to the industry.

Much of the historical harvest of the endemic forest, which still continues in some places today, has been a series of high-grading, unsustainable extractions, ultimately resulting in conversion of the forest to pasturelands. Improved silvicultural practices for native forest production are needed, in addition to implementation of sustainable forest management guidelines. Some plantations, primarily of *koa*, have begun to be established on private lands, but degraded site conditions, pests, and diseases remain concerns at most sites. Many native species are not as fast-growing as some non-native timber species, but the overall positive environmental impacts and high economic value of using endemic species for forest products, especially *koa*, *'iliahi*, *milo*, *kamani* (*Calophyllum inophyllum*), and *kou*, clearly provide far more benefits and services than using non-natives alone. DOFAW, through a variety of private landowner assistance programs, offers technical assistance and cost-share incentives for the development and improved management of sustainable forest production.

The state, along with a number of key partners, is developing a Koa Action Plan. This plan will include short- and long-term goals to prioritize and promote research on *koa* resilience to disease and insect damage, market development and commercial use, demonstration trials, and conservation planning. With such a plan in place, funds and resources can be leveraged from a number of *koa* interest groups to support a sustainable *koa* forest industry that may include large-scale timber production, genetic improvement of commercial and conservation stock, carbon sequestration, and a market for carbon credits (discussed further below). *Koa* forests will also provide vital ecosystem services, including provision for cultural and societial uses, conservation of wildlife habitat, and a plethora of other uses that *koa* supports in Hawai'i. Similar action plans may also be developed for other native tree species, such as *'iliahi*.

The FS Institute of Pacific Islands Forestry, University of Hawai‘i, Hawai‘i Agricultural Research Center, and state, federal, industry, and private organizations partnered with Purdue University to establish a Tropical Hardwood Tree Improvement and Regeneration Center (THTIRC) in 2010 for Hawai‘i and other Pacific islands. The focus of THTIRC is to provide additional resources to advance the science of Pacific island hardwood tree breeding, conservation, genetics, and silviculture for sustainable production of forest products, improved ecosystem services from native forests, economic development of local communities, and cultural enhancement for indigenous cultures, local communities, and visitors. A major focus of THTIRC is to expand upon existing efforts to improve *koa* for traits such as better growth, form, wood quality, pest/disease resistance, and abiotic stress resistance for restoration and forestry applications. The program adds needed research, but also transfers information and technical expertise on breeding, silviculture, and nursery management among stakeholders. The services of THTIRC are available for *koa* and other native tropical hardwood species. The successful program of tree improvement through breeding and genetic research can also be applied to other important production species, such as *‘iliahi* and *milo*, and *‘ōhi‘a* (*Metrosideros polymorpha*) for its ecosystem services.

Hawai‘i’s Clean Energy Initiative, Biomass, and Development of the Forest Products Industry

There is an increased focus in Hawai‘i on reducing reliance on fossil fuels and improving renewable energy self-sufficiency. In 2015, the governor signed legislation adopting the most aggressive clean energy goals in the nation, to achieve 100% clean energy production by 2045.[15] This ongoing long-term commitment to clean energy production has encouraged interest in development of wood biomass for electrical generation and/or biofuel production in Hawai‘i. A primary objective of the Hawai‘i Clean Energy Initiative (HCEI) is to wisely use the energy resources we currently have. One of the identified strategies under this objective is to harness energy from biomass resources.

The HCEI discusses a wide variety of products suitable for biomass energy production, including conventional sources such as trees, but also agricultural residues like sugarcane bagasse and macadamia nut shells, dedicated energy crops such as hemp (*Cannabis sativa*) and bana grass (*Pennisetum purpureum*), and even urban wastes. The nascent forest industry in Hawai‘i is recognized as a potential source of biomass feedstock,[16] including biomass produced through wood residues generated as a byproduct of timber harvesting and wood processing, or potentially through the development and production of dedicated forest biomass crops. The HCEI also envisions the development of biorefineries that will convert biomass into biodiesel to provide a renewable source of fuel for land, sea, and air transportation.

The State of Hawai‘i’s clean energy goal of using 100% renewable energy for electric power generation by 2045, presents some unique opportunities for win-win solutions in forest management. Use of biomass helps the state meet its renewable energy goal, and it may help yield a viable economic return from the use of lower-elevation croplands that otherwise would sit fallow, facilitating the spread of weeds. Additionally, biomass energy projects can support the development of a solid-wood forest products industry by providing an economic use for the waste stream from harvest and milling processes. Also, biomass operations can further contribute to forest management by making use of invasive trees such as albizia. Biomass use not only would help control this pest, but may even contribute economic incentives to support the control of invasive species and/or fund reforestation of cleared areas with economically valuable forest products such as *koa* or a non-invasive commercial species like *Eucalyptus*.

Another forest management benefit that would occur with the development of biomass facilities is the opportunity to use salvaged materials following natural disasters, pest or disease outbreaks, or natural mortality events. Damaged wood products could thus be incorporated into energy generation. For instance, a portion of the 3,000 acres of trees that were killed or damaged during the 2012 fire season in Kōke‘e, Kaua‘i, have been salvaged and hauled to the biomass plant on Kaua‘i.[4, 5] The fees paid for the salvaged trees are being used to help reforest the burned area using native and non-invasive commercial species. This biomass facility is also helping to clear thousands of acres of forest land infested with albizia to support its electricity production.

Many of the foundational policies and principles being followed in the development and implementation of the HCEI[15] mesh closely with, and support the development of, a sustainable forest products industry in Hawai‘i.[17] Both initiatives aim to maximize the diversity and use of natural resources in the state; strive to create substantial economic benefits in employment and diversified economic activity; aim to be technologically advanced; and are largely privately funded and market driven. [15, 17] The integration and codevelopment of renewable energy and a local forest products industry is achievable, as we have seen on Kaua‘i.[4] Through implementation of forward-looking renewable energy policies, such as those outlined in the HCEI, combined with a variety of forestry incentive programs, it is hoped that the forest products industry can participate in and make a positive contribution to the future of clean energy in Hawai‘i at a meaningful scale.

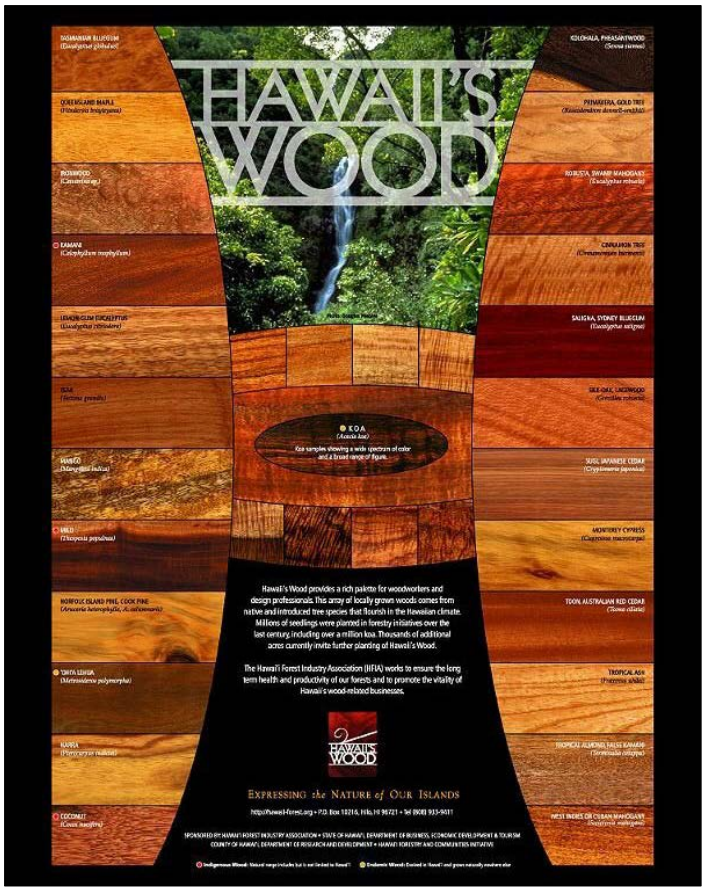


Figure 8.2. Poster advertising the 2002 Hawaii's Woodshow. Image courtesy of Hawai‘i Forest Industry Association. Photo courtesy of Hal Lum, photographer.

Although Hawai‘i does not yet have a large-scale timber industry, the craft wood industry is thriving. Local artisans produce an astonishing number of objects crafted from native woods, notably *koa*, but also from a variety of other native and introduced wood species such as mango (*Mangifera indica*), *milo*, and *kamani*. The Hawai‘i Forest Industry Association (HFIA) has been instrumental in helping this industry to grow and gain exposure locally and abroad.[18] The HFIA has been sponsoring Hawaii's Woodshow every year since 1993. Only Hawaiian-grown wood works are displayed in Hawaii's Woodshow. The show is designed to strengthen appreciation for locally grown woods and artists' work, as well as encourage sustainable forestry through the planting of native and introduced but non-invasive trees (see Figure 8.2).

Non-Timber Forest Products

Although not as well described or studied, the use of non-timber forest products (NTFPs) is likely the most significant use of Hawai‘i's forests. NTFPs are substances, materials, or commodities that are obtained from forests, but their collection does not require harvesting of trees.[19] They include animal products, edible and medicinal plants, berries, seeds, oils, sap and syrup, foliage, fuel wood, forage, and building materials, as well as one of the most important products in Hawai‘i as on all islands, water. The harvest of NTFPs remains widespread throughout the world, and is often important to rural communities, including those in Hawai‘i, for household subsistence, maintenance of cultural and familial traditions, and spiritual fulfillment, as well as house heating and cooking, animal feeding, medicine and healing, and a source of income. In Hawai‘i, common NTFPs include flowers and foliage collected from the forest for making *lei* and handicrafts, wild fruits and edible plants, bamboo (*Bambusa vulgaris*), game animals, and water that is collected or diverted. Common fruits trees that can be found growing wild in the forest include mango, mountain apple (*Syzygium malaccense*), banana (*Musa*

spp.), coconut (*Cocos nucifera*), noni (*Morinda citrifolia*), and many other domestic fruits planted intentionally or escaped from backyards. For hunting game, Hawai‘i provides opportunities to hunt for 15 species of game birds and six species of game mammals. In 2015, forests and game management areas provided over 33,000 game mammal and bird hunting trips, with the harvest of 13,300 game birds and 4,883 game mammals.[20] *(See "Issue 1: Water Quality and Quantity," for additional information on watersheds, and "Issue 7: Hunting, Nature-Based Recreation, and Tourism," for additional information on hunting and recreational uses of forest.)*

Carbon Sequestration

Carbon sequestration is the capture of carbon dioxide (CO_2) from the atmosphere. Forests play an important role in light of climate change by sequestering CO_2 via photosynthesis.[21, 22, 23, 24, 25, 26, 27] Sequestration can be improved by protecting forests from conversion, by improving management to retain carbon in the forest for longer periods, and by planting trees, reforesting, and afforesting (establishing new forests). International, national, and regional efforts to mitigate increasing atmospheric concentrations of greenhouse gases (GHGs) have led to the formation of carbon markets. Both mandatory-compliance markets and voluntary carbon markets are now recognized as cost-efficient ways to reduce net global CO_2 emissions. These programs allow entities to meet CO_2 emission reduction obligations by investing in projects globally that can capture and store carbon.

Globally, the forestry industry has been engaged in the carbon market through the sale of carbon credits to emitters. Eligible forestry carbon credits are derived from avoided conversion, reforestation or afforestation, and forest stand improvement projects. Although carbon markets have been around for a number of years, successful participation has a steep learning curve. Mathew Smith of the Society of American Foresters said, "Carbon markets are more of a riddle to be solved than an easily defined path to a new payday for forestry."[28] This outlook may well apply to a small state with a young forest products industry such as Hawai‘i; however, there is significant opportunity and interest among state, federal, and private landowners in Hawai‘i to investigate the voluntary and developing mandatory carbon markets.

There are no mandatory GHG emission trading schemes (ETS) regulated by the U.S. government, but some states and state cooperatives have implemented mandatory carbon markets in their regions, including the California compliance market (approved by the California State Legislature in 2006) and the Regional Greenhouse Gas Initiative begun in nine northeast and mid-Atlantic states in 2012.[21] Hawai‘i does not have a locally mandated GHG ETS, but with the aggressive renewable energy goals[15] carbon market opportunities may soon be developed. From a forestry perspective, DOFAW has been investigating participation in either out-of-state mandatory carbon markets such as the cap-and-trade market of California or a voluntary carbon market to generate revenue for maintenance of underfunded state forestry lands.

In a report produced jointly with the University of Hawai‘i, DOFAW explored three voluntary carbon market standards, the American Carbon Registry, the Climate Action Reserve, and the Verified Carbon Standard, as well as one mandatory standard, the California compliance market. The purpose of the report was to explore opportunities for state and private landowners in Hawai‘i to contribute positively to climate change action while using the carbon market as a revenue-generating tool. The report highlights the variety of considerations, components, and financial investments associated with these carbon markets, and identifies the most attractive options for participation by Hawai‘i landowners. One notable outcome of this report is the interest, demand, and in some cases requirement that carbon projects focus on carbon sequestered by native tree species.

Voluntary carbon markets in Hawai‘i have the potential to incorporate value-added qualities to our forest resources. Such projects are akin to sustainable-harvest forest certifications, such as those awarded by the Forest Stewardship Council, American Forest Foundation, and other such entities. Like certifications, carbon market projects could contribute to sequestration but also would provide the equally important services of conserving native habitat for endangered species, contributing to cleaner water, and increasing water supplies, among other benefits. Thus, multi-faceted carbon projects that provide multiple benefits in addition to sequestering tons of carbon can complement existing forest management goals in Hawai‘i.

DOFAW is continuing to explore carbon market opportunities for public lands, as well as encouraging private landowners and managers to consider carbon sequestration as part of their overall forest management. While the state is still working on policy and procedures regarding the use of state forests to generate revenue through the carbon market, forestry companies on Kaua‘i and the Big Island are moving ahead with selling carbon under the voluntary carbon market, which involves planting and managing non-native trees and native *koa* plantations. To date, there is one reforestation project (in the Hāmākua District of the Big Island) actively selling voluntary carbon credits in Hawai‘i, and two other landowners have expressed intent to do so. The various landowner assistance programs (see below and *Appendix C*) offered by DOFAW can be used to support private landowners to maintain forests or plant forests that can generate revenue, not only by providing various forest products but by facilitating the sale of carbon credits.

Community-Based Forest Management Projects

In Hawai‘i, there are a number of community-based forest management projects that focus on socially and culturally important forest resources. These projects are public-private partnerships that have formed to protect native dry forests, which are one of the most threatened ecosystems in Hawai‘i. These partnerships increase the chances of survival of two endemic dry forest dominant tree species: *wiliwili* (*Erythrina sandwichensis*) and *uhi uhi* (*Caesalpinia kavaiensis*). These species are very culturally important, but also at a high risk from wildfire (*see “Issue 3:*

Wildfire") and infestation by the *Erythrina* gall wasp (*see "Issue 2: Forest Health: Invasive Species, Insects, and Disease"*). The Hawai'i Forest Stewardship Program and Watershed Partnerships are particularly important to the development and support of community forest projects.

Programs

There are a number of programs that support the development of forest products and services on state and private lands in Hawai'i by providing educational and technical assistance, as well as financial support through cost-share grants, conservation easements, and land acquisition.

The Forest Reserve System was established by the Territorial Government of Hawai'i through Act 44 in 1903. Its primary purpose is to protect *mauka* forests, enabling them to provide forest products and services for *makai* communities and agricultural demands—sustainable water supply was the principal underlying consideration. Today, the Forest Reserve System includes approximately 678,000 acres across the state and is managed to provide a suite of services for the public[29]:

- Protect and manage forested watersheds for production of freshwater supply for public uses now and into the future
- Maintain biological integrity of native ecosystems
- Provide public recreational opportunities
- Strengthen the economy by assisting in the production of high-quality forest products in support of a sustainable forest industry

Timber management areas can be found in a number of the Forest Reserves and contain economic opportunities supporting local timber and wood product industries. These timber management areas contain a variety of primarily non-native species and non-timber forest products that can be harvested for commercial purposes or small-scale salvage uses.[14]

The Forest Legacy Program is a federal grant program administered through DOFAW. As stated in the Forest Legacy Program Assessment of Needs, this program identifies important private forest lands that are threatened by development or fragmentation and contributes to the following overall program goals:

- Protect unique and fragile environmental resources of Hawai'i
- Encourage the protection of rare and/or endangered species
- Promote the preservation of aesthetic beauty in Hawai'i
- Preserve watershed health and protect the sustainable yield of fresh water
- Protect working forests as economic assets for the state and counties of Hawai'i
- Protect traditional and cultural forest practices and resources

- Protect recreational forest practices

Through this program, private landowners have an option to preserve forests on their property by either entering into a conservation easement or by selling their land to a government agency for conservation purposes.

The Legacy Land Conservation Program is a state grant program administered through DOFAW that provides funds for the acquisition and protection of threatened resources. Many of the cultural, natural, agricultural, historical, and recreational resources of Hawai‘i are lost when private lands possessing these resources are sold and developed. The Legacy Land Conservation Program provides grants to local organizations and agencies seeking to purchase and protect lands with unique, rare, and valuable resources.

Other state and federal programs that support forest product capacity, forest restoration, or conservation needs on public and private lands are the Forest Stewardship Program, Kaulunani Urban and Community Forestry Program (*see "Issue 4: Urban and Community Forestry"*), Tree Farm Program, Native Forest Dedication, Watershed Partnership Program, Conservation Reserve Enhancement Program, Environmental Quality Incentives Program, and others. (See "Appendix C: Forestry-Related Assistance Programs.")

Participants

Development of a sustainable forest products industry, resource restoration and conservation, watershed protection, and outreach and education are all important goals in Hawai‘i. Achieving these goals can be accomplished only through a wide variety of partnerships and with expertise focusing on creative solutions to challenging endeavors. There are a number of organizations and private landowners that are engaged in forest product development and which contribute to such achievements in Hawai‘i.

Hawai‘i Forest Industry Association (HFIA) (http://www.hawaiiforest.org/) is dedicated to responsible forest management. HFIA produces the annual Hawaii's Woodshow, sponsors the Hawaii's Wood trademark, and advocates for the diverse forest industry in Hawai‘i, from the planting and harvesting of trees to the creation and sale of wood products.

Private timber plantation owners, land lessees, and green energy companies, such as Kamehameha Schools, Parker Ranch, and other large landholders, have large amounts of standing timber that will play an important role in a forest products industry in Hawai‘i. Several private companies operate mature tree farms that produce a variety of forest products, including animal feed, lumber, biochar and soil blends, and carbon credits.[30] A utility-scale biomass electrical energy production plant has been built and is operational on Kaua‘i,[4] and a second plant is under construction on Hawai‘i.[6] A few other green energy companies are developing

biomass-to-energy facilities for the production of biodiesel or biofuel to power electrical generation plants.[31]

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

The Hawaii Agriculture Research Center (http://www.harc-hspa.com/) is actively engaged in management of Acacia *koa* and supports other research on hardwood tree species. One project in particular works to identify fusarium-resistant *koa*, as well as *koa* stock that exhibits a straight tree growth form *(see "Issue 2: Forest Health: Invasive Species, Insects, and Disease").*

The FS Institute of Pacific Islands Forestry (IPIF) (http://www.fs.fed.us/psw/programs/ipif/) provides research, education, demonstration projects, and scientific and technical information for state, federal, industry, and private partners to restore, conserve, and sustain tropical forests and wetlands of the Pacific. IPIF provides research and information on climate change, carbon, water, silviculture, tree improvement, sustainable agro-forestry and bio-energy production, and best practices for forest management.

The Tropical Hardwood Tree Improvement and Regeneration Center (THTIRC) (http://www.trophtirc.org/) is a partnership between Purdue University's Hardwood Tree Improvement and Regeneration Center, FS, University of Hawai'i, and state, federal, industry, and private organizations to establish a tropical hardwood tree improvement research center in Hawai'i. THTIRC's mission is to advance the science of Pacific island hardwood tree breeding, conservation, genetics, and silviculture for sustainable production of forest products, improved ecosystem services from native forests, economic development of local communities, and cultural enhancement for indigenous cultures, local communities, and visitors. A major focus of THTIRC is improvement of *koa* for traits such as growth, form, wood quality, pest and disease resistance, and abiotic stress resistance for restoration and forestry applications. The major focus is on *koa*, but tree improvement also can be applied to other important production species such as *'iliahi.*

The Hawaii Experimental Tropical Forest (HETF) (http://www.fs.fed.us/psw/ef/hawaii/) is located in two units on the Island of Hawai'i, at Laupāhoehoe and Pu'u Wa'awa'a. HETF was established to address the critical natural resource and conservation questions that must be answered to properly manage tropical forests and watersheds for a variety of objectives, including restoration, preservation, and use. The experimental forest provides a land base for conducting relevant natural resource related research—both biological and physical in nature—and has a major emphasis on climate change monitoring, invasive species control, and documentation of forest carbon storage and watershed function.

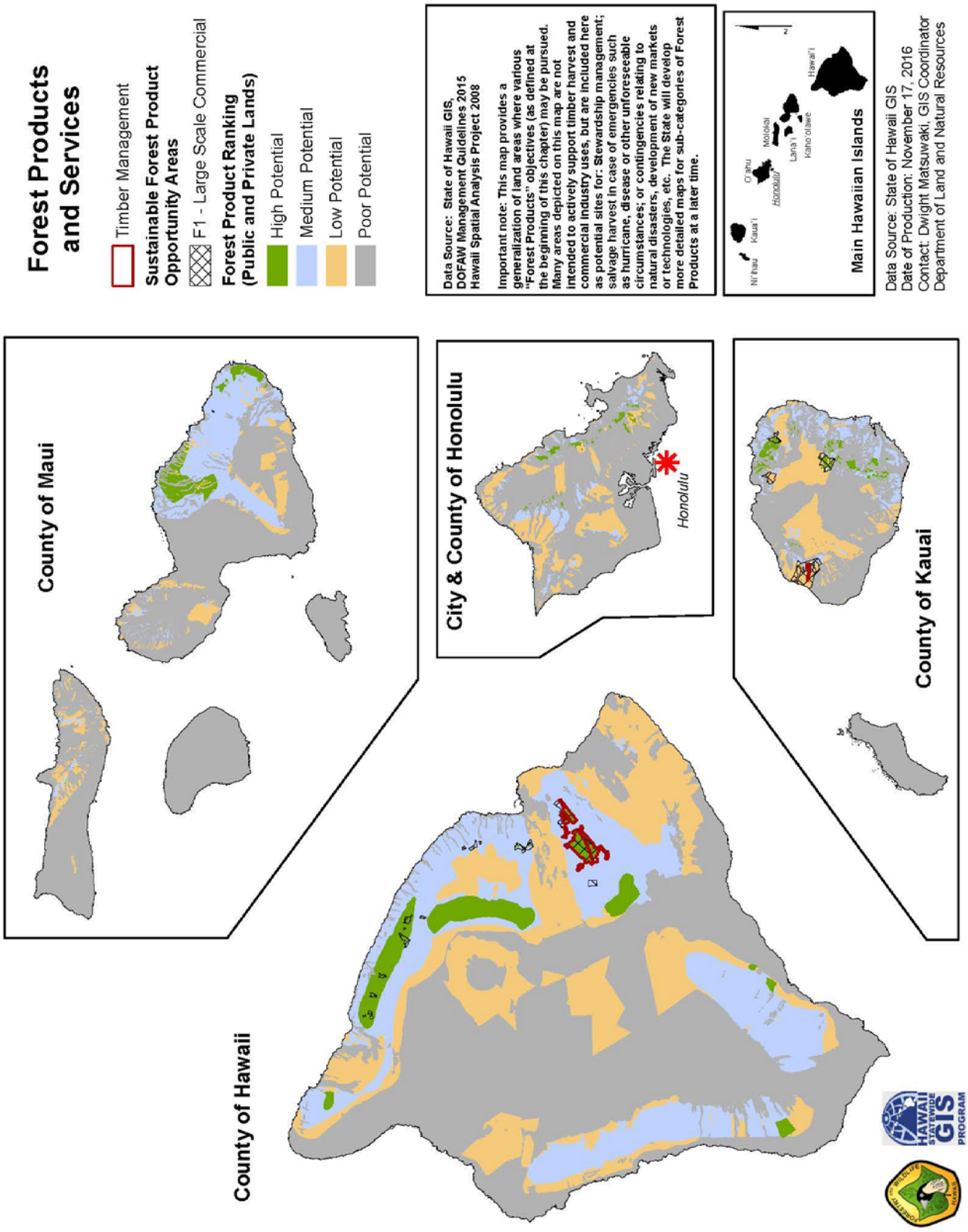
Priority Areas for Forest Products and Carbon Sequestration

Forests cover roughly 1.7 million acres (41%) of the state's total land area, and approximately 60% of this area is considered productive, healthy forest—mostly covered by *‘ōhi‘a*, *‘ōhi‘a-koa* mix and relatively pure *koa*. About 700,000 acres (50%) of the relatively productive forest land is considered to be timberland, capable of producing timber and wood products on a sustainable basis.[32] Of that, roughly 76,000 acres are tree plantations (Maps 8.1–8.5).

Areas that have potential for providing forest products and services have been mapped (Map 8.6) based on distribution and forest type, or potential to support forest vegetation, and by analyzing environmental factors such as rainfall, elevation, and soils. These forest areas are mapped for the entire state, including private and public lands, and are further categorized as having high, medium, low, or poor potential for forest products. [33] This map provides a generalization of land areas where various "Forest Products" objectives may be pursued. Many areas depicted on this map are not intended to actively support timber harvest and commercial industry uses; but are included here as potential sites for activities such as stewardship management; salvage harvest in case of emergencies such as hurricane, disease or other unforeseeable circumstances; or contingencies relating to natural disasters, development of new markets, or technologies. More detailed maps for sub-categories of forest products will be developed at a later time.

An area with high potential has soil capable of growing wood at a rate of 85 cubic feet or more per acre per year. Most of the high-potential timber-producing land, approximately 470,000 acres, is on the island of Hawai‘i. Non-native commercial timber plantation areas managed by DOFAW, roughly 48,000 acres, were automatically ranked as having high potential. An area with medium potential has soil capable of growing wood at a rate less than 85 cubic feet per acre per year, but can grow a high-value species, maintain soil productivity and protect water quality. An area with low potential has value and opportunities to be managed for ecosystem services, salvage of resources after natural disasters, invasive species control, and native species restoration. Other non-forested areas, such as pasture, croplands, and urban areas, are designated as having poor potential for forest products.

The Forest Products and Services Map also identifies the location of DOFAW-managed lands (cross hatching) identified for large scale commercial production. The policy guidance on how these lands are going to be managed to provide large scale commercial forest product is provided under DOFAW's Management Guidelines. The management of sustainable forest product opportunities is categorized into four classes: large scale commercial (F1), small scale commercial (F2), personal use (F3), and restricted (F4). Table 8.1 defines these classes and the management strategies that guide these classes. The lands classified as F1 are depicted on Map 8.6.



Map 8.6. Priority area for forest products and services in the State of Hawai'i.

Table 8.1. Draft Management Plan Guidelines (2015).

Forest Product Management		
Management of Sustainable Forest Product Opportunities		
Class Name	**Class Definition**	**Management Strategies**
F1 Large Scale Commercial	Forest products are a primary objective and large scale commercial timber harvesting or salvage is allowed. Permits and/or licenses are required with appropriate restrictions. Harvesting of non-timber forest products is allowed. All Timber Management Areas are designated as F1 areas.	To produce timber while allowing other uses such as recreation, hunting and gathering. Activities may include, but are not limited to, pre-commercial thinning, commercial thinning, and forest stand improvement. Harvesting activities should follow best management practices for maintaining water quality. Sustained yield management is encouraged and planting or revegetation must follow harvesting to ensure sustainability.
F2 Small Scale Commercial	Areas where limited small-scale (no more than 1% of the total acreage of a forest reserve annually) commercial timber harvesting or salvage is allowed. Harvesting of non-timber forest products is allowed. Permits and/or licenses are required with appropriate restrictions.	To ensure sustainability of forest product resources while minimizing impacts to non-target native species. Activities may include, but are not limited to pre-commercial thinning and forest stand improvement thinning. To distribute impacts of harvesting over the resource area through controlled seasons and harvest. Depending on the scale and impact of harvesting, planting or revegetation may be required, if deemed necessary by land managers. To encourage active management of culturally and economically significant forest products.
F3 Personal Use	Areas where limited non-commercial timber harvesting and commercial timber salvage is allowed. Harvesting of non-timber products will be considered on a case by case basis. Permits are required with appropriate restrictions.	To minimize human impacts to native species and native ecosystems. To encourage active management of culturally and economically significant forest products for sustainable personal use.

Forest Product Management		
Management of Sustainable Forest Product Opportunities		
Class Name	**Class Definition**	**Management Strategies**
F4 Restricted	Forest products are not a primary objective. Harvesting of timber products is not allowed. Harvesting of non-timber forest products is generally not allowed and will be considered on a case by case basis for improving forest health, watershed protection, cultural uses, and conservation efforts. Permits are required with appropriate restrictions.	To ensure protection of native species and native ecosystems. Permitted activities in these areas are minimally disruptive, and would be focused on improving forest health, watershed protection, and conservation efforts.

Data Gaps and Opportunities

1. Manage native forests for social and cultural objectives. For example, the state seeks to develop an *Acacia koa* canoe log production forest at Kapāpala on the Island of Hawai‘i.
2. Take necessary administrative steps that would allow the state’s forestry program to participate in the California compliance market or the voluntary carbon market to help generate revenue for state forestry lands and programs that are currently underfunded.
3. Investigate requirements and benefits for obtaining national and international certification of sustainable production and harvest practices for common market species such as *koa*, sandalwood, and *Eucalyptus*.
4. Develop a chain-of-custody certification program for sustainably harvested Hawai‘i forest products that will allow the users in the market to distinguish between products obtained from forests that are sustainably managed and those that are not.
5. Pursue certification of Hawai‘i-grown and -processed solid wood *Eucalyptus* products to meet local and national building code standards, for use in local construction.
6. Analyze the potential and opportunities to develop Christmas tree plantations on state lands as well as support such an industry on private lands. This would minimize the quantities of trees imported to Hawai‘i each year and also help mitigate the risk of introducing new invasive species that hitchhike on those trees.
7. Support establishment of mid-sized sawmill, biomass/biofuel, and veneer mill facilities. Identify loan programs to help private businesses obtain capital for field equipment, processing facilities, infrastructure development, and product marketing to develop the forest industry in Hawai‘i.
8. Develop genetically improved and/or disease-resistant seedling stock for non-native and native species, including *koa*, *‘ōhi‘a*, and *‘iliahi*.

9. Use commercial forestry as a way to convert lands dominated by weedy, invasive species to productive forests and native forests.
10. Develop new markets, both domestic and international, for common Hawai‘i commercial species. Near-term market opportunities appear to exist for export of sandalwood to U.S. essential oil markets as well as to China, *Eucalyptus* sawn lumber to Indonesia and the mainland Northwest, and *koa* to the U.S. mainland.
11. Complete comprehensive management plans for all State Forest Reserves (hawaii.gov/dlnr/dofaw/forestry/FRS/frplans). Investigate opportunities to develop additional forest product or timber management areas on state lands. Identify areas that have soils with high-enough productivity to produce wood products, have adequate accessibility for forest management and commercial harvest activities, and are not already committed for other high-priority purposes such as native species' critical habitat.
12. Develop survey and monitoring techniques, best management practices, and harvest protocols to avoid take of endangered Hawaiian hoary bats and other listed species that may be at risk during commercial forest management and timber harvest operations. Develop regulatory tools, approaches, agreements, and/or permits to enable the forest products industry to operate compatibly with management and conservation needs of protected species.
13. Implement studies or research to answer the following questions:
    a. How much forested and agricultural land is needed to produce adequate quantities of products to support processing plants for solid wood products, for electricity, or for biomass conversion to diesel or other fuels.
    b. How do existing stands of mature commercial forest on state lands fit into the long-term goal of a viable forest products industry?
    c. Where are timber resources located relative to potential markets, and what are the best ways to connect them?
    d. What are the characteristics of the existing industry, including logging infrastructure?
    e. What are the markets (expected price and depth) for various products, including high-, medium-, and low-grade hardwood lumber and other products?
    f. What opportunities exist to use or sell manufacturing and forest residue? How sustainable are the various components of the timber resource?
    g. What new products or services are suitable for Hawai‘i?
    h. What are the best restoration and silvicultural methods and practices for production of sandalwood for conservation and commercial purposes?
14. Implement studies or research recommended by the Koa Action Plan, such as:
    a. Investigate the potential to create silvi-pastoral systems that successfully integrate grazing animals with *koa* forestry.

b. Conduct replicated trials across a variety of environments to evaluate genetic variability and to identify superior families for continued selection and as seed sources for planting.
c. Expand field trials to test the durability of wilt resistance, as identified by seedling screening, and to develop resistant varieties for all affected ecotypes.
d. Quantify the current and future market value of *koa* products and the number of jobs created by *koa* forestry.
e. Quantify value of ecosystem services for *koa* forest restoration.
f. Quantify the supply of wood from old-growth trees that are available for harvest, and determine whether continued harvests are appropriate.
g. Conduct market research to investigate how to expand markets for plantation *koa* while maintaining prices.
h. Conduct research on *koa* wood quality from planted stands.
i. Develop grading system for *koa* wood quality.

Summary

The forests of Hawai‘i will continue to be critically important to the state’s water supply, unique plants and animals, the economy, clean energy supply, people, and their culture. Benefits from these forests go well beyond wood and fiber products and affect aesthetic values, recreational enjoyment, ecotourism, carbon sequestration, specialty non-timber forest products, water conservation, improved air quality, coral reef protection, and many other important resources.[34] Increased economic and development pressures that alter land use and management will continue to be challenges for the state’s forest industry.[34] It is important that forest industry potential in Hawai‘i be considered from a holistic perspective in order to sustain the growth and health of the forests over the long term and to provide for the services and benefits associated with healthy forests.

Forest industry in Hawai‘i has unique win-win opportunities to integrate the development and operation of a commercial forest industry based on the use of native and non-native species with other high-priority state goals to produce clean and renewable energy, provide jobs and economic growth in rural communities, restore native *koa* forests to underused lands, control invasive species such as albizia, integrate commercial forestry activities as a tool in the restoration and management of badly degraded forest ecosystems, and generate additional revenue to fund conservation management activities on all state lands. The Hawai‘i forest industry must look toward and integrate new technologies, programs, and cooperative opportunities that provide alternatives that are compatible with the unique resources of Hawai‘i.

Strategies for Issue 8: Forest Products and Carbon Sequestration

Forest Products and Carbon Sequestration: Support Development of a Forest Products Industry								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Foster the development of an integrated forest products industry in Hawai'i.	See maps.	Address solid wood products, non-timber forest products, carbon sequestration, biomass for energy and fuels reduction, economic growth, salvage, and invasive species control.	Rural development, FSP, EQIP, farm bill programs: biomass and biofuel, FSCG, Cooperative Fire Assistance.	Public and private forest landowners, TNC, OHA lessees.	HFIA, WFLC, HCA, TNC, IPIF, Hawai'i Legislature, FS.	Increased public and private lands under commercial forestry management; more leases executed for commercial timberlands; greater proportion of energy or raw materials produced locally versus imported.	1.1 1.2 3.1 3.4 3.5 3.6	1.3 1.5
2. Develop and implement strategic research plan based on existing symposia and research findings regarding forest products industry.	Statewide.	Inform investment strategy, improve best management practices, inform public.	Farm bill: biomass and biofuel programs, S&PF Rural Development Program, Ecosystem Services Program, FSP.	Private landowners, PICCC, USFWS, TNC, UH.	Same as above.	Hawai'i forest product literature made available at appropriate clearinghouses, websites, and research stations; new research projects initiated and completed.	1.1 1.2 2.1 2.2 3.1 3.4 3.5 3.6 3.7	
3. Improve opportunities for forest product entities doing business in Hawai'i. Provide career training for forest industry jobs.	Statewide.	Create economic opportunities, support solid wood, biomass, and biofuel production.	FRS, HCA, Special Technology Development Program, FSP, FLP, CREP, LLCP, FSCG, OHA.	HCA, NPS, HDOT, Office of Planning, HDOA, TNC.	Same as above.	Low-interest loans made available to private entities; cultural products made available throughout the year; export potential enhanced.	1.1 1.2 3.1 3.4 3.6 3.7	1.3 1.5
4. Develop regulatory tools and approaches to enable the forest products industry to operate compatibly with conservation of protected species and habitat.	Statewide.	Create economic opportunities, support biomass and biofuel production, conserve native biodiversity.	FRS, HCA, FSP, FLP, CREP, LLCP, FSCG, Native Biodiversity Program, Threatened and Endangered Species Program, PEPP, HIP.	HFIA, ESRC, USFWS, FS, public and private forest landowners, TNC, HCA.	HCA, TNC, USFWS, NARS, IPIF, ESRC, PEPP, HIP, DLNR, NPS.	Increased public and private lands under commercial forestry management; increased conservation of native flora and fauna.	1.1 1.2 2.2 3.4 3.5 3.7	1.2 1.3 1.5

Strategies for Issue 8: Forest Products and Carbon Sequestration

Forest Products and Carbon Sequestration: Explore the Feasibility of Carbon Credits on State Lands								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Research and develop a carbon market for Hawai'i.	Statewide.	Sequester carbon, identify cap and trade and voluntary carbon markets for landowners, protect and enhance watersheds.	FRS, HCA, Special Technology Development Program, FSP, FLP, CREP, LLCP, FSCG, OHA.	Resource managers, private landowners, OHA, TNC.	HCA, OHA, DOD, Office of Planning, TNC, WFLC, IPIF, HETF, HISC, UH, carbon brokers.	Discussions held with State Attorney General's office and various carbon credit companies; one or more carbon credit market demonstration projects established.	1.1 1.2 3.1 3.4 3.6 3.7	1.3.a, b, c
Forest Products and Carbon Sequestration: Research Hardwood and Native Trees								
Long-Term Strategy	**Priority Landscape Areas**	**Secondary Issues Addressed**	**Program Areas That Contribute**	**Key Stakeholders**	**Resources Available & Partners**	**Measures of Success**	**Supports National Objectives**	**Supports Hawai'i Environmental Literacy Plan Goals**
1. Conduct research focused on improving growth form and fusarium resistance for koa and resistance to wilt and rust diseases for ohia. Research restoration and sustainable commercial production of sandalwood. Include local schools and communities to collect data for research.	Statewide.	More deliberately plant native forest species (e.g., koa, sandalwood, milo, kou, and ohia) for forest production purposes as well as native biodiversity benefits.	FRS, HCA, Special Technology Development Program, FSP, FLP, CREP, LLCP, FSCG, OHA.	Resource managers, private landowners, OHA, TNC.	HCA, OHA, DOD, HDOT, Office of Planning, TNC, WFLC, IPIF, HISC, CGAPS, HAWP.	Improved genetic native tree stock distributed throughout the state; reduced dieback of koa and ohia; enhanced economic potential for koa due to more straight boles.	1.1 1.2 2.2 3.1 3.4 3.6 3.7	1.2 1.3 1.5
2. Identify invasive species vectors and pathways to reduce potential introductions, such as new plant diseases and *Erythrina* gall wasp.	Statewide.	Share inform literature with Pacific neighbors.	HDOT, HDOA, PIER, HEAR, FSCG, FSP.	Multi-state, international neighbors, HAWP, private landowners.	HCA, OHA, DOD, HDOT, Office of Planning, TNC, WFLC, IPIF, HISC, CGAPS, HAWP.	Improved biosecurity at sea and airports; reduced biosecurity threat to native flora and fauna.	1.1 1.2 2.2 3.1 3.4 3.6 3.7	

Strategies for Issue 8: Forest Products and Carbon Sequestration

3. Research social, cultural, and non-traditional forest products. Educate communities on gathering rights, responsible harvesting, and culturally appropriate protocols.	Statewide.	Elucidate cultural uses, benefits to human health, and recreational opportunities.	Conservation education, UCF, FSCG, TPL, TNC, land trusts.	Community groups, individuals, public and private landowners, recreation organizations.	OHA, DBEDT, DLNR, TNC, HCA, NPS, USFWS refuge system.	Reduced negative impacts on public lands, due to increased education; more implementation of Hawaiian land management practices.	3.1 3.2 3.4 3.5 3.6	1.2 3.1

Key:

CGAPS = Coordinating Group on Alien Pest Species
CREP = Conservation Reserve Enhancement Program
DBEDT = Department of Business, Economic Development & Tourism
DLNR = Department of Land and Natural Resources
DOD = Department of Defense
EQIP = Environmental Quality Incentive Program (of the Natural Resources Conservation Service)
ESRC = Endangered Species Recovery Committee
FLP = Forest Legacy Program
FRS = Forest Reserve System
FS = U.S. Forest Service
FSCG = Forest Service Competitive Grants
FSP = Forest Stewardship ProgramHAWP = Hawai'i Association of Watershed Partnerships
HCA = Hawai'i Conservation Alliance
HDOA = Hawai'i Department of Agriculture
HDOT = Hawai'i Department of Transportation
HEAR = Hawai'i Ecosystem At Risk
HETF = Hawai'i Experimental Tropical Forest
HFIA = Hawai'i Forest Industry Association
HIP = Hawai'i Invertebrate Program
HISC = Hawai'i Invasive Species Council
IPIF = Institute of Pacific Islands Forestry
LLCP = Legacy Land Conservation Program
NARS = Natural Area Reserves System
NPS = National Park Service
OHA = Office of Hawaiian Affairs
PEPP = Plant Extinction Prevention Program
PICCC = Pacific Islands Climate Change Cooperative
PIER = Pacific Island Ecosystems at Risk
S&PF = State and Private Forestry organization (FS)
TNC = The Nature Conservancy
TPL = Trust for Public Lands
UCF = Urban and Community Forestry Program
UH = University of Hawai'i
USFWS = U.S. Fish and Wildlife Service
WFLC = Western Forestry Leadership Coalition

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