

Issue 6: Conservation of Native Biodiversity

Overview

The Hawaiian Islands are the most isolated archipelago in the world, situated in the middle of the Pacific Ocean more than 3,200 kilometers (2,000 miles) from the nearest continent. Due to its extreme isolation and climactic conditions, Hawaii is characterized by high levels of endemism in both its native animals and plants, with over 10,000 species found nowhere else on earth. Although thousands of Hawaiian species have yet to be described, the estimated number of native species is thought to include more than 14,000 terrestrial, 100 freshwater, and 6,500 marine taxa. For more than 70 million years, the evolution of new species vastly exceeded losses to extinction. Yet after the arrival of humans to the islands, about 700 years ago, numerous extinctions have occurred and many more species are threatened. These losses include more than half of the endemic birds, including flightless ducks, rails, and ibis, hundreds of plant species, and possibly thousands of lesser known taxa such as terrestrial insects and spiders that were lost before they were ever described.

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

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

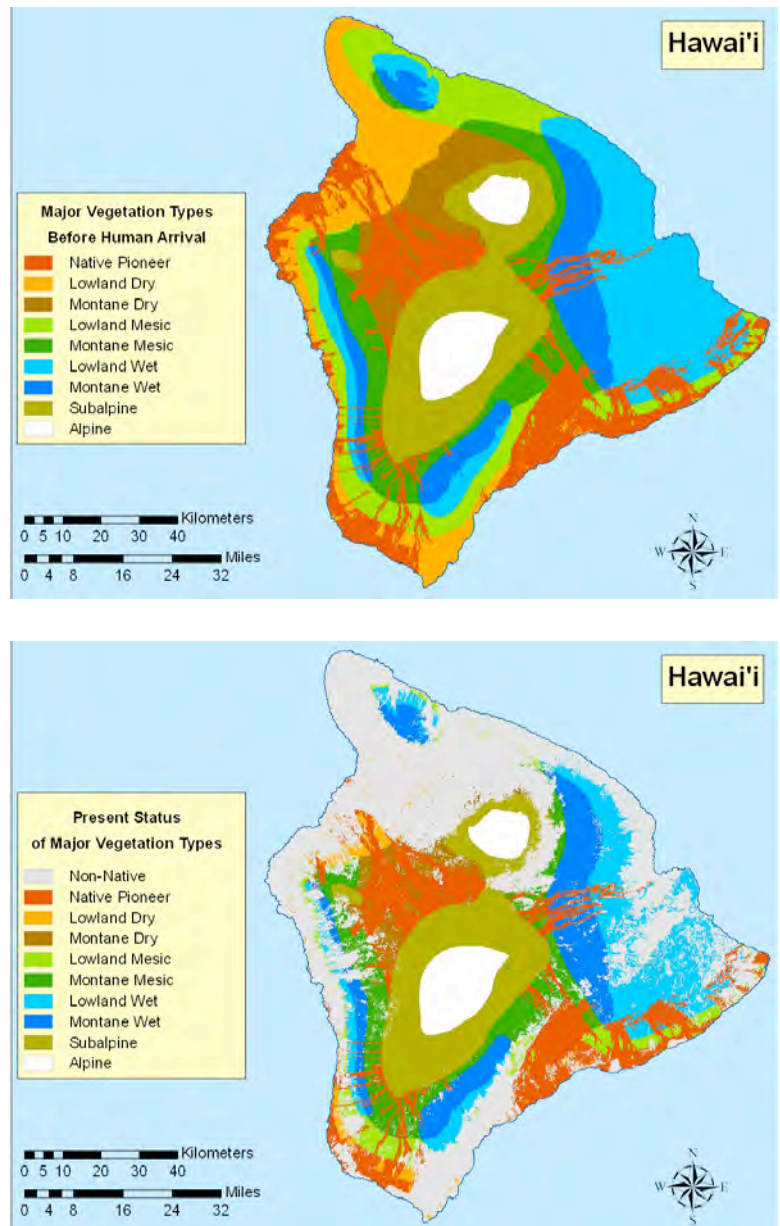
In 2005, Congress required all states to develop a Comprehensive Wildlife Conservation Strategy (CWCS).¹ The CWCS's are to be updated every five years. In Hawaii, this provides the opportunity for resource managers to develop and modify a comprehensive planning process to help manage all of Hawaii's unique native wildlife. The CWCS recognizes the importance of protecting all native terrestrial animals, all endemic aquatic wildlife, other aquatic species threatened with decline, and a broad range of native flora. On the ecological level, the CWCS takes a habitat management approach, adopting a landscape view that takes into account the complex inter-relationships between species and their habitats and the need for change and adaptability. This plan builds on and synthesizes information gathered from existing conservation

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

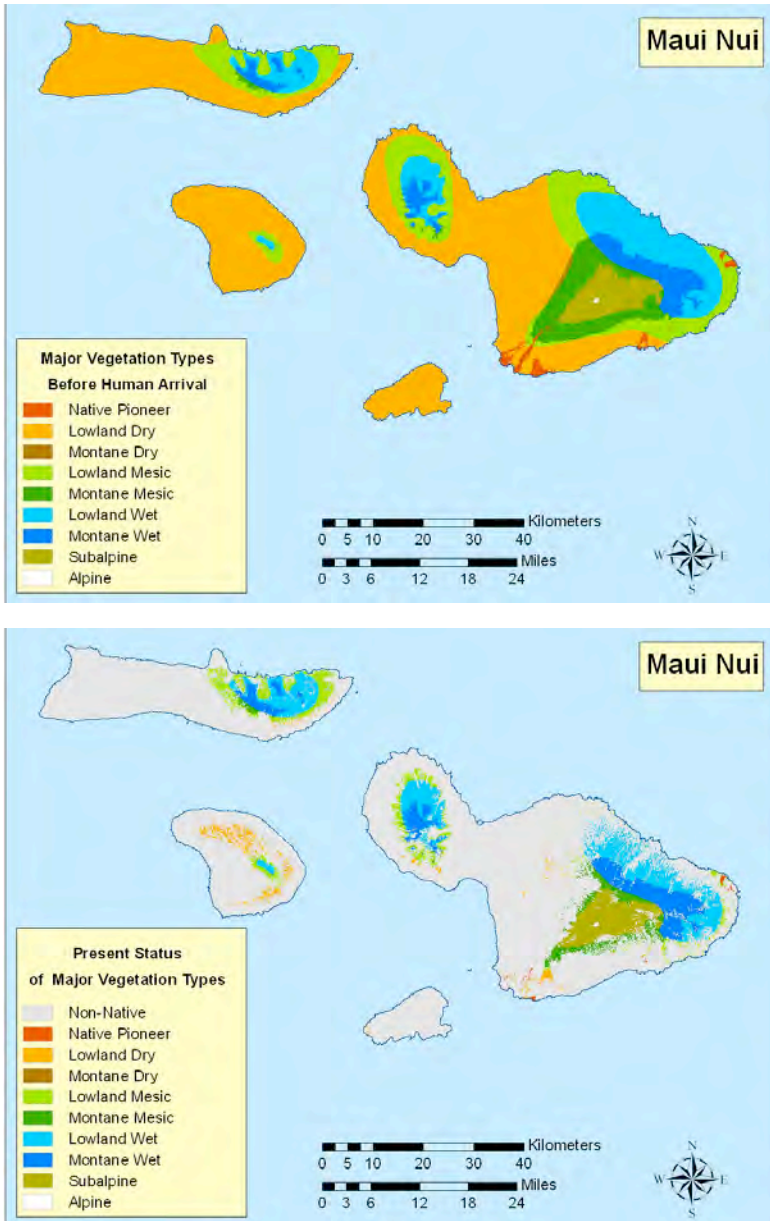
The DLNR coordinated the development of Hawaii's CWCS, with joint cooperation by the Division of Forestry and Wildlife (DOFAW) and the Division of Aquatic Resources (DAR), the divisions primarily charged with protecting the State's terrestrial and aquatic resources. The foundation for this assessment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

Benefits & Services

In present day Hawaii, the link between native Hawaiian culture and native species continues to be practiced in belief systems as well as traditional practices such as gathering of native plants and animals for hula, traditional medicines, food, structural materials, carving, weaving, tool making, jewelry, and ceremonies. For many native Hawaiians, the relationship with the land and native ecosystems is integral to their identity and sense of well-being. The special role and relationship native Hawaiians have with some native species and ecosystems in the islands is perhaps best reflected in their increasing role in natural resource management in places such as the island of Kahoolawe; Limahuli and Lumahai valleys on Kauai; Moomomi, Molokai; and Keauhou, Hawaii where traditional management practices such as *kapu* (taboo) and *ahupuaa* (watershed)-scale thinking predominate.



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



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

Native biodiversity is not only important to native Hawaiians, but also to many non-Hawaiian residents and to many outside of the islands. Active local lifestyles may include activities such as hiking, backpacking, snorkeling, boating, fishing, and hunting and are enhanced when interacting with native wildlife and ecosystems unique to the Hawaiian islands. Based on a 2004 survey “Wildlife Values in the West”, a large majority of Hawaii’s residents (71.4%) strongly agree that it is important to take steps to prevent the extinction of endangered species.² Economically, wildlife viewing opportunities have become an important part of the State’s \$10 billion a year tourism industry.³ Hawaii’s native wildlife and their habitats also provide essential goods and services to residents such as water quality, soil stabilization, carbon storage, and climate control. A University of Hawaii study of the economic value of these services estimated between \$7.4 to \$14 billion in the Koolau Mountains on Oahu alone.⁴ Other examples of ecological services provided by native habitats include coral reefs that protect beaches, homes, and businesses from erosion, storms, and tsunami waves; wetland habitats that filter the water supply, mitigate pollution, and slow storm runoff; and other natural areas that provide social and human health benefits through recreation, beauty and a spiritual

connection to nature.

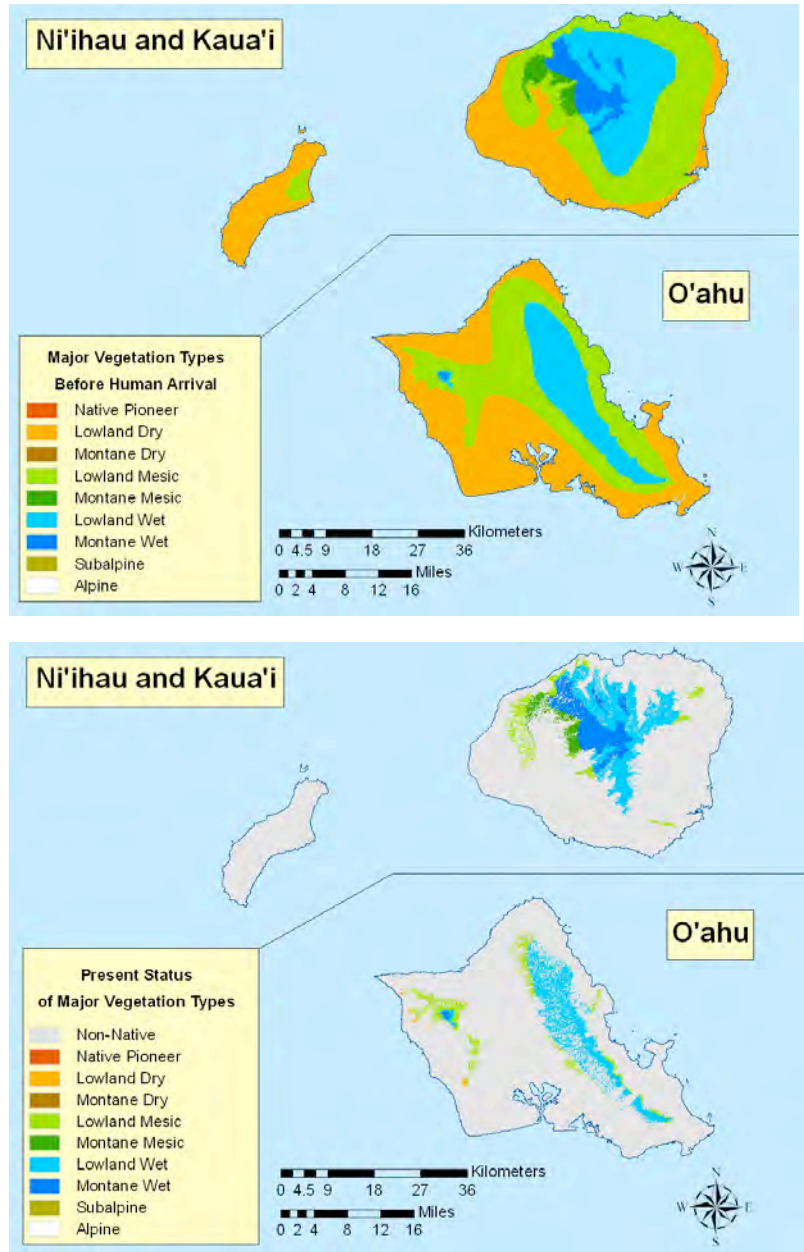
Forest conservation plays a critical role in maintaining the health of makai (ocean) resources such as coral reef ecosystems and limu (seaweed) beds. Local wisdom passed on by kupuna (elders) cautions that unless we take care of mauka resources, makai resources will suffer.

Current Conditions

The Hawaiian Archipelago possesses a wide range of habitats, from wet forests to extremely dry coastal grasslands and subalpine areas. With the arrival of humans and consequent clearing of native habitats for agriculture, the introduction of invasive species and more recently development, many of these habitats have declined. Maps 6.1, 6.2 and 6.3 depict major vegetation types before human arrival and their current extent. For example, an estimated 90 percent of Hawaii’s dryland habitat, 61 percent of the mesic habitat, and 42 percent of wetlands habitats have been lost. Today, native vegetation occurs over less than 40 percent of the islands’ land area. Similarly, much of the habitat for freshwater species has declined, with 58 percent of the perennial streams in the State having been altered in some way.

Terrestrial Habitats

The distribution of terrestrial habitats in Hawaii is influenced by elevation, climate, and substrate. Using elevation zones and moisture gradients, Hawaii can be classified into nine terrestrial habitat types. These nine habitat types can be further refined based on the dominant plants and structural characteristics of the vegetation. The Manual of the Flowering Plants of Hawaii⁵ recognizes 33 native forest communities, 36 native shrubland communities, eight native grassland communities, and four native herbland communities. Subterranean systems form a tenth habitat type defined by geology rather than elevation zones and moisture.



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

Aquatic Habitats

Aquatic habitats link together most of Hawaii's terrestrial habitats. Streams and groundwater flow play an important role in providing water for plants and animals throughout the ecosystem. The flow of water that rains down on the high mountaintops transports nutrients, and organic matter through the various forested and shrubland areas into estuaries and wetlands at low elevations and then finally into the ocean. Many of Hawaii's native freshwater aquatic animals migrate between the ocean, estuaries, and upper reaches of streams as part of their life cycle.

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

Native Taxa

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

The Hawaii CWCS⁶ selected a large cohort as Species of Greatest Conservation Need including: one terrestrial mammal, 77 birds, over 5,000 known terrestrial invertebrates, over 500 plants, six species of endemic terrestrial algae, 12 freshwater invertebrates, five freshwater fishes, 24 species of endemic freshwater algae, 20 anchialine-pond associated fauna, 26 marine mammals, six marine reptiles, 154 marine fishes, 197 marine invertebrates, and 79 species of endemic marine plants or algae.

Threats

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

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

Table 6.1. Terrestrial Habitats & Principal Threats to Native Ecosystems

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

extinction crisis. Since the establishment of forest reserves, during the first three decades of the 20th century, alien invasion—not direct habitat destruction by humans—has been the dominant threat to native species and ecosystems across the Hawaiian Islands.

Hawaii is extraordinarily vulnerable to human-accelerated alien species invasions due to: (1) its geographic isolation as the hub of Pacific travel and trade, and (2) an exceptional range of hospitable habitats for invaders to occupy. The estimated rate for successful, new colonization of the islands by a plant or animal species before human arrival was once every 25,000 - 50,000 years. In contrast, over the past 30 years, newly established species have been recorded in Hawaii at the rate of once every 18 days. The existing complement of established invasive aliens has the capacity to overwhelm most remaining native habitat if left unchecked.

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

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

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

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

For these reasons, successful conservation in Hawaii requires keeping remaining, relatively uninvaded native areas intact, stemming the establishment of new invasive species, restoring degraded areas needed for species-specific conservation goals, and devising practical strategies to limit the impact of widely-established species. Table 6.1 reveals that alien species such as ungulates and weeds are prominent and ubiquitous, with other threats active in specific locations.

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

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

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

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

been planted with eucalyptus species and are awaiting a viable logging industry for harvest. This could stimulate the harvest of more adult hardwood stands and strike the need for aggressive replanting and sustainable harvest practices. (See Issue 8: Forest Products and Carbon Sequestration for additional information.)

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

Overharvesting: Most minor forest and stream “commodities” (plant materials for lei making, flower arrangements, and herbal use; stream fishes and invertebrates for food) can be harvested for home and cultural use on a sustainable basis. These activities are not sustainable at the commercial scale, however, and are restricted by permit systems. Similar issues prevail in the seaweed and fishing industries.

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

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

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

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

Stream diversion: Native stream communities are highly dependent on continuous stream flows to the sea that support the diadromous life cycles of their dominant aquatic animals. Most of the state's streams are already partially or fully altered (channelized, diverted, or de-watered via groundwater pumping), and those that remain are vulnerable as the demand for fresh water outstrips the current yield of harvesting. The new Hawaii State Water Code⁷ provides mechanisms for protecting stream flow, but these mechanisms await their first test cases.

Wildfire: Wildfire is an uncommon natural occurrence in Hawaii, where ground-strike lightning is rare and wet plant communities cover large areas. Fire-adapted aliens (especially grasses and short-lived shrubs) are established in lower, leeward slopes and some subalpine areas. When ignited these weeds fuel major wildfires that can carry into native forests. Native forests are destroyed and replaced with fire-adapted weeds in a trend that increases the range and intensity of these fires. This grass/fire cycle perpetuates itself and without intervention can render native ecosystems permanently altered and unable to be restored to a natural state.

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

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

Trends

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

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

Table 6.2. Threat Assessment Summary by Geographic Landscape¹¹

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

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

Collaborative Working Groups

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

- The Hawaiian Bat Research Cooperative, a partnership composed of government agencies, nonprofit organizations, and private landowners, was formed to prioritize and fund needed bat research.
- The Hawaiian Forest Bird Recovery Team, a cooperative effort involving multiple government agencies and nonprofit organizations guide forest bird conservation work, including the development of the Draft Revised Recovery Plan for Hawaiian Forest Birds⁸ and five-year implementation plans for identified critical species, captive propagation, annual forest bird surveys, as well as other identified research and management projects.
- Dryland Forest Working Group (DFWG) is an ad hoc partnership formed in the early 1990’s. It was the driving force behind restoration science at Kaupulehu dryland forest. In 1993, the DFWG began to advise and participate in a cooperative restoration project and agreement between the Hawaii Forest Industry Association (HFIA) and the USFWS.

Table 6.3. Principal Threats to Native Aquatic Habitats

Aquatic Habitat	Principal Threats
Streams	Sedimentation caused by grazing animals, development, water diversions: dams, channelizing/concreting stream bottom & sides, introduced gamefish. Lack of vegetation along banks reducing shade, nutrient inputs from decaying plant matter and shelter provided by tree roots. Excessive vegetation adjacent to streams leading to decline in native aquatic organisms.
Estuaries	Similar to streams: sedimentation, development, & invasive species boat harbors & other sources of human disturbance.
Sandy Bottom	Pollution, human impacts.
Coral reefs	Human impacts, non-point source pollution from terrestrial land use practices, excessive inundation with freshwater during storm events which can inhibit successful establishment of coral larvae, invasive species of algae, disease and global climate change.
Bathypelagic, Mesopelagic, and Pelagic	Offshore aquaculture is a potential new threat to these areas.
Additional Marine Habitats	Direct and indirect human impacts due to proximity to the coast.

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

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

Innovative Management Techniques

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

Funding for Conservation

Since the arrival of humans more than half of the Hawaiian archipelago’s known endemic bird taxa have been lost. Of the taxa that remain, 31 are federally listed under the U.S. Endangered

Species Act and 17 have populations of less than 1,000 individuals. Previous studies have documented a geographic disparity in recovery expenditures on listed species, but none have specifically focused on Hawaiian birds. To draw attention to this disparity with the aim to improve Hawaiian bird conservation, DOFAW staff Wildlife Biologist David Leonard summarized recovery expenditures on listed birds from 1996 to 2004 comparing mainland and Hawaiian taxa in the context of their degree of endangerment. Federal and state spending on the 95 listed bird taxa over this nine year period totaled \$752,779,924. Hawaiian birds comprise a third of the listed bird taxa (n = 31), yet dedicated recovery expenditures was only \$30,592,692 or 4.1% of the total spent on all listed birds. Despite similar priority ranks assigned by the U.S. Fish and Wildlife Service, listed mainland birds received over 15 times the funding of Hawaiian birds. In general, the threats to island taxa are unlike those of mainland taxa (e.g., non-native predators), management actions are expensive, and in many cases they must be conducted in perpetuity. Because of the status of many Hawaiian birds and the threats facing them, current recovery expenditures are inadequate to prevent additional extinctions.⁹

Hawaii ranks near the bottom (48th) in the nation for state spending on fisheries and wildlife, though the state forest reserve system ranks 11th in size and the state boasts the largest marine protected areas in the United States. In Fiscal Year 2006, the State Department of Land and Natural Resources was allocated approximately \$76.8 million of the State's \$8.9 billion dollar executive budget. With less than one percent (0.86%) of the state's budget, the DLNR must manage the state's marine and freshwater resources (e.g., commercial fisheries, aquaculture, aquatic resources protection, recreational fisheries), protect threatened and endangered species, manage State-owned lands (both those for lease and those set aside as forest reserves, natural areas, plant and wildlife sanctuaries, and parks/recreation), manage statewide ocean recreation and coastal areas programs (i.e., boating), oversee permitting associated with the Conservation District, implement the state's historic preservation mandates, maintain the statewide recording system for title to real property, and enforce the Department's rules and regulations.

A conservative estimate of the amount of state funds actually dedicated solely to conservation of native wildlife and their habitats was approximately \$23 million dollars for Fiscal Year 2006. Though no comprehensive cost estimates exist for the protection and recovery of wildlife in Hawaii, the inadequacy of current funding levels is obvious based on costs included in recovery plans for endangered species. For example, the recently published Draft Revised Recovery Plan for Hawaiian Forest Birds (2003) estimates the cost of recovering 21 species of forest birds at nearly \$2.5 billion dollars over the next 30 years – an annual cost (\$83 million) that exceeds the budget for the entire DLNR. Costs associated with the recovery for endangered whales, sea turtles, seabirds, waterbirds, invertebrates and plants would add tens of millions more per year.

Funding levels from federal sources are also inadequate and inequitably apportioned. With more than 30 percent of the nation's imperiled species, Hawaii receives less than 15 percent of the national appropriation under the Endangered Species Act, the traditional Section 6 Program and only one percent of the national appropriation under the State Wildlife Grants Program. In recent years, through related competitive grant programs within the Section 6 program, additional

funding for conservation on private lands and for land acquisition (see *Appendix C: Forestry Related Assistance Programs*) has become available. Though Hawaii has been successful in securing a portion of these grants because of extensive and progressive partnerships with landowners, lack of sufficient overall funding to implement recovery programs, especially on state lands, leaves both critically endangered species and lesser known native species (e.g., terrestrial invertebrates) with little support.

Loss and Degradation of Habitat

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

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

Priority Areas and Issues for Conservation of Native Biodiversity

Public Education

There is a lack of awareness about Hawaii's avifauna. Mainland U.S. visitors and birdwatchers generally have little or no acquaintance with Hawaiian birds. Unlike most mainland areas, many listed Hawaiian birds are restricted to remote, high-elevation forests where access is difficult or impossible, so the opportunities to see native birds are limited. Similarly, many Hawaiian residents have little connection to, or knowledge, of native taxa, and without this connection, there is little demand from the public for increased funding.

Improve Information Access & Management

Huge gaps in knowledge exist for many native species. Gaps in information are often magnified by the challenges inherent in sharing information across institutions. Building on existing efforts to centralize information storage in a spatial database could better identify data gaps, provide a more comprehensive view of the status of a particular species or habitat, and allow management decisions to be made using the most up-to-date and accurate information.

Geospatial Data

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

Category 1: Intact Native Ecosystems, Highest Biodiversity

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

Category 2: Intact Native Ecosystems, High Natural Biodiversity

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

Category 3: Rapidly Degrading Ecosystems

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

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

Category 4: Threatened Native Ecosystems

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

Category 5: Degraded Ecosystems

This class presents opportunities for localized native habitat restoration. Lands in the Degraded Ecosystems class are dominated by non-native species, and are not located adjacent to substantial native vegetation areas. These areas may or may not contain native elements or pockets of native biodiversity, but at a large scale, they have potential for improving their capacity to providing ecosystem services such as nutrient cycling, soil and moisture retention and pollination. Degraded Ecosystem areas also include secondary areas for protecting waterbirds and coastal vegetation.

Category 6: Native Ecosystems No Longer Exist

This class of lands are areas where habitat conversion is severe enough to minimize chances of restoration of native biodiversity, due to paving over, contamination, and interruption of natural processes in the area. Alternative habitat uses like development and agriculture have destroyed seed banks, soil composition, and/or natural processes needed for native biodiversity. The very limited opportunities for restoration in these areas would require extensive reconditioning of the area before restoration could be possible. These areas are currently absent of substantial native biodiversity value (e.g., developed areas, intensive current and former agriculture, and managed tree plantations).

Priority Areas for Conservation of Native Biodiversity

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

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

Summary

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

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

Successful conservation in Hawaii requires keeping remaining, relatively uninvaded native areas intact, stemming the establishment of new invasive species, restoring degraded areas needed for species-specific conservation goals, and devising practical strategies to limit the impact of widely-established species.

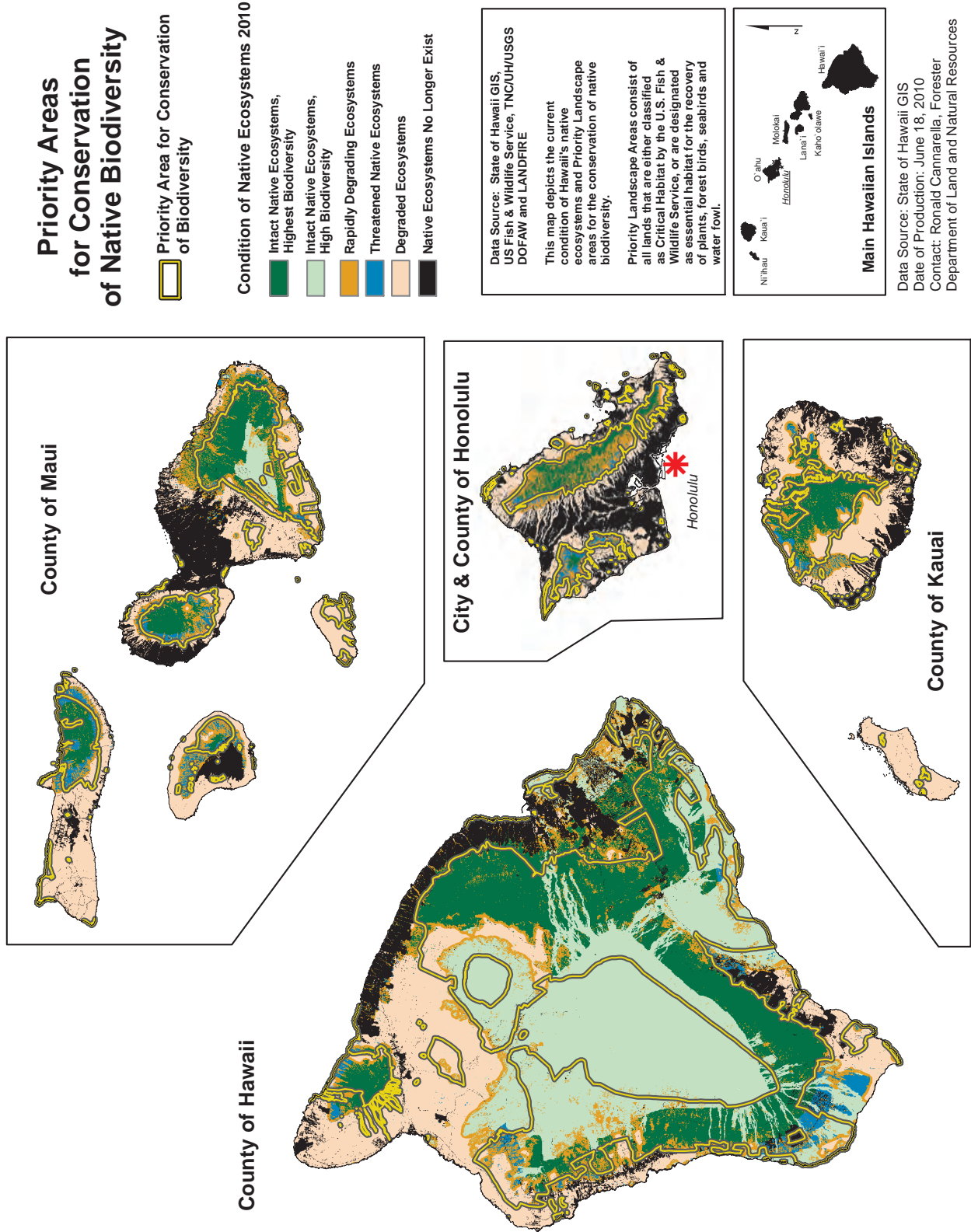
Hawaii continues to face major conservation challenges in protecting its over 10,000 native wildlife species.

Data Gaps

Limited Information & Insufficient Information Management

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

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



Map 6.4 Priority Landscape Areas for the Conservation of Native Biodiversity

accurately reflect a population's full distribution or abundance. Accurate population estimates for many Hawaiian waterbirds, seabirds, fishes, and for most non-threatened or endangered invertebrate populations are not available. Large numbers of native invertebrates have not even been described, making assessment of their populations and consideration of the consequences of proposed management actions problematic at best.

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

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

Strategy Matrix for Issue 6: Conservation of Native Biodiversity.

Strategy: Issue 6: Conservation of Native Biodiversity

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

Biodiversity Objective/Management Strategy for Lands with Intact Native Ecosystems (Map 6.1)							
Long Term Strategy	Priority Landscape Area(s)	Secondary Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available & Implementing Partners	Measures of Success	Supports National Objectives
I) Engage in conservation to maintain intact native ecosystems and species.	All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery Habitat.	Other ecosystem services including water quality and quantity, flood control, carbon storage & sequestration. Open space, ecotourism, information & education dissemination.	Forest Health Protection & Monitoring, Coop Fire, Forest Stewardship, Forest Legacy, Conservation Education, S&PF Redesignated Competitive Grants	Public and private landowners, TNC, NAPP, NARS, FSP clients, Forest Legacy clients, USFWS, OHA, National Park Service, etc.	FSCG, NRCS, FWS, DAR, non-profits, NOAA, DOD Army, Watershed Partnerships, Forest Legacy Program (FLP), Bishop Museum, Duke Foundation, etc. Facilities and infrastructure including (e.g. captive breeding facilities, seed storage, nurseries); research and monitoring technologies and partnerships (e.g. aerial imagery, IPIF, PEP, PICCC, HAWP, Private Landowners; S&WCD	Invasive species removed; Acres of fenced, ungulate free habitat created and maintained; Acres of predator controlled habitat; Acres protected by fuel breaks created and/maintained; Native species re-introduced; Plant genetic materials secured in seed storage facilities; Long-term monitoring of rare plant and animal populations; Acres of land under conservation easements that limit habitat altering activities.	1.1 1.2 2.1 2.2 3.1 3.5 3.6 3.5

Strategy: Issue 6: Conservation of Native Biodiversity

<p>2) Maintain native dominated ecosystems (50 to 100% native), including waterbird habitat & intact coastal sites.</p>	<p>All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery Habitat. Areas with FWS designated core waterbird concentrations; Any coastal area designated by TNC as good to very good</p>	<p>See above</p>	<p>See above</p>	<p>See above</p>	<p>See above</p>	<p>In addition to the measures detailed above, this strategy would also measure: Acres of habitat maintained for waterbirds; Acres of land under conservation easements that limit habitat altering activities; New policy providing incentive programs for private landowners to engage in this type of land management.</p>	<p>1.1 1.2 2.2 3.1 3.5 3.6</p>
<p>Biodiversity Objective/Management Strategy for Lands with Rapidly Degrading Ecosystems (Map 6.1)</p>							
<p>1) Enhance native dominated habitat with formerly wide-spread plant species that are now limited in range.</p>	<p>All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery Habitat.</p>	<p>See above</p>	<p>See above</p>	<p>See above</p>	<p>See above & CREP</p>	<p>See # 1 above; Establishment of two or more rare plant nurseries on each of the main Hawaiian Islands, more seed storage facilities and fully operational Plant Extinction Protection programs.</p>	<p>1.1 1.2 3.1 3.4 3.5</p>
<p>Biodiversity Objective/Management Strategy for Threatened Native Ecosystems (Map 6.1)</p>							
<p>1) Restoration of landscapes with high potential for successful restoration due to their proximity</p>	<p>All lands designated by the U.S. Fish & Wildlife Service as Critical Habitat, Essential Habitat and/or Recovery</p>	<p>See above</p>	<p>See above</p>	<p>See above & CREP</p>	<p>Invasives removed; Natural native plant regeneration; Length of barriers created to control the introduction of habitat modifying weeds and predators; Miles of fuel break created and/maintained; Native species re-introductions; Rare plants cultivated in nurseries for</p>	<p>1.1 1.2 2.2 3.5</p>	

Strategy: Issue 6: Conservation of Native Biodiversity

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

Acronyms Used:

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

Strategy: Issue 6: Conservation of Native Biodiversity

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

Section References

- ¹ Mitchell, C., Christine Ogura, DW. Meadows, A. Kane, L. Strommer, S. Fretz, D. Leonard and A. McClung. Hawaii's Comprehensive Wildlife Conservation Strategy, 2005.
- ² Teel, T.L., A.A. Dayer. Preliminary State-Specific Results from the Research Project Entitled "Wildlife Values in the West 2004". Fort Collins: Human Dimensions in Natural Resources Unit, Colorado State University. 2005.
- ³ U.S. Department of Interior Fish & Wildlife Service. Bulletin 20-983, 2003
- ⁴ Kaiser B, Krause N, Roumasset J. 1999. Environmental valuation and the Hawaiian economy. Honolulu: University of Hawaii Economic Research Organization.
- ⁵ Warren L. Wagner, Derral R. Herbst, S.H. Sohmer ; Yevonn Wilson-Ramsey, illustrator University of Hawaii Press : Bishop Museum Press, 1990 [Honolulu]
- ⁶ Mitchell, C., Christine Ogura, DW. Meadows, A. Kane, L. Strommer, S. Fretz, D. Leonard and A. McClung. Hawaii's Comprehensive Wildlife Conservation Strategy, 2005.
- ⁷ "HRS Chapter 174c - the Water Code", <http://www.hawaii.edu/ohelo/statutes/HRS174C/HRS174C.html> (accessed April 2010).
- ⁸ U.S. Fish & Wildlife Service, Pacific Islands Fish and Wildlife, "Draft Revised Recovery Plan for Hawaiian Forest Birds " <http://www.fws.gov/pacificislands/recoveryplans.html>.
- ⁹ Leonard, Dave L., Jr. "Recovery Expenditures for Birds Listed under the US Endangered Species Act: The Disparity between Mainland and Hawaiian Taxa." Biological Conservation 141, No. 8 (2008): 2054-2061.