EXHIBIT "I-9"

PART L

CHAPTER 6

Source Water Protection

In this Chapter

Key Points

- Lana`i is unusually dependent upon its mauka watershed, because Lana‘i is dependent upon fog drip. Over 65% of the recharge in the primary high level aquifer for Lana‘i is believed to be attributable to fog drip. Loss of fog drip from Lana‘i Hale would lead to the loss of over 50% of the water levels in the Central aquifer, essentially the only viable water source for the island. Estimates from studies elsewhere indicate that fog drip interception by mountain forests increase precipitation by as much as 30%, and recharge by 10-15%.

- The watershed on Lana'i is a low elevation cloud forest, with a strong mix of mesic species. Maintaining native cover becomes especially important in light of its role in the water budget for Lana'i and the rising inversion layer. Yet less than 30% of the native cover in the cloud forest remains.
- Threats to the watershed include: habitat alteration by feral animals, human activity and invasive species; continuing intrusion of exotic plant and animal species which can trample, prey on or out-compete native species; loss of critical populations; loss of native pollinators and other keystone species; introduced pathogens and insects; erosion; drought, and; high vulnerability to fire due to mesic conditions combined with the spread of fire inducing weeds.
- Key management measures include: fencing the most valuable watershed; eliminating feral animal ingress to fenced areas; removal of non-desirable weed and animal species; planting of desirable native species; erosion and fire prevention measures; and limiting human activities in key areas. More specifics are provided.
- Where drinking water is concerned, prevention of pollution is less expensive and more efficient than cleaning it up. One of the first tasks in any effective prevention program is to identify and inventory wells to be protected, areas that feed them and activities or sources of pollutants that pose a potential risk or could degrade water quality.
- Drinking water wells on Lana'i were mapped, and a computer model was used to evaluate the area surrounding each well which could contribute to its water withdrawals within a 2, 5, 10, 15, 20 and 25 year time periods.
- Water that can reach a well within two years can contribute bacteria and viruses to the drinking water in that well. Although chemical contaminants may be persistent well beyond 10 years, this is the time frame broadly used in wellhead protection programs, as it is assumed that within that time frame protective measures may be taken in the event of a spill.
- Among the potential contaminant sources identified were the following: Wells 1, 9 and 7 are located in or near former pineapple fields. Well 9 is also near some former underground storage, and Well 7 near some old above ground storage. Traces of atrazine have been found in Well 1 in the past. Well 8 is within 1,000 feet of the Koele golf course. A list of contaminants that may be generated by the types of activities found is provided.
- Potential management strategies and measures are described. These include regulatory measures such as overlay zones and prohibitions, non-regulatory measures such as purchase of easements or incentivization of best management practices, guidelines, education and others.
- The recommended wellhead protection strategy involves an overlay zoning ordinance which either prohibits or prescribes best management practices for various uses at different times of travel. Also included in the strategy are non-regulatory measures, such as guidelines for mixed use developments, protective land agreements, incentives and education for best management practices or protective measures, and measures to improve well siting. Implementation of this ordinance would require coordination between the DWS and other agencies, particularly the Planning Department.
- If water levels in pumping wells reach half their initial head level, this is now grounds for designation proceedings, based on a January 31,1990 decision by the CWRM. CCR has also offered voluntary guidelines which set action levels at about 2/3 of initial head. These are delineated in

the well operating guidelines section. Upon reaching a designation trigger or lowest allowable level, pumpage in a well is expected to stop. Upon reaching an action level, a well is to receive scientific review and investigation, as well as some public scrutiny.

- Action levels and lowest allowable levels from CCR's voluntary well operating and management guidelines, as well as designation triggers, are provided on page 6-121.

Watershed Protection

The Role of the Forest in Water Production

The Hawaiʻian Islands are unique in their geology, their geographic isolation, their species endemism and their beauty. Rising 16,000' from the ocean floor at sea level, the tallest island rises nearly another 14,000' more, while the smallest barely tops the surface.

The Hawaiʻian archipelago is a 1,500 mile chain of volcanic islands and atolls, created over more than 20 million years. The oldest islands are Kure atoll and Midway at the northwest extent of the archipelago. Rock formations on Kauaʻi have been dated between 5 and 6 million years old, while the islands of Hawaiʻi and Loʻihi are still growing.

Formed by volcanic eruption, shaped and molded by winds, wave action, erosion, rain and even ice (Mauna Kea sported an ice cap during the Pleistocene era), Hawaiʻi is also unique in its hydrologic qualities. Volcanic basalts include some of the most permeable formations on earth. Given the steep, mountainous terrain of much of the islands, highly permeable rocks and soils are an especial boon to water recharge in some areas. In other areas, denser lava flows, ponded lava, deposits of alluvium or volcanic ash, and rifts and dikes help to contain water, even creating warm, high elevation brackish water pockets in some places.

Surrounded by water and blessed with some of the wettest places on Earth, Hawaiʻi nevertheless is located in a fairly arid area, with rainfall in the open ocean surrounding the islands averaging only 25" to 30" per year. Yet Mount Waiʻaleʻale on Kauaʻi receives over 400" of rain per year.

The secret to Hawaiʻi's natural abundance of water lies in a convergence of winds upon its richly forested mountains. Northeasterly trade winds gain moisture and warmth as they flow for thousands of miles over the tropical Pacific. As these winds reach the islands they are deflected upslope, cooling as they rise and causing moisture to condense. From equatorial regions to the south, air heats and rises, flowing toward the poles. Meanwhile high, cold air from polar regions sinks and flows toward the equator. High elevation cool winds traveling from the northeast subside toward the ocean surface. This subsiding air forms a layer that blocks the rise of the trades up the mountains. The result is a subsidence inversion known as the trade inversion. The trade inversion causes a layer of warmer air to form between 4,800' and 7,000'. When the warm, moisture laden trades rise up the mountains, the rising air is held down by this inversion layer. This convergence of moisture laden air leads to the condensation and release of moisture in Hawaiʻiʻs cloud forests.

If not for Hawaiʻi's mountain forests, most of this moisture would simply run off immediately to the sea. Instead, as this moisture condenses, it adheres to thousands of stems, leaves, twigs, lichens and other surfaces in the watershed.

FIGURE 6-1 Cloud Forest

The multi-leveled, thickly vegetated nature of Hawai‘ian cloud forests provide abundant surface area to help capture and collect large amounts of water. The mosses, lichens, ferns, leaf litter and soils of the forest floor also help to increase the collection and storage value of the forest. The mist laden air surrounding the forest, and the abundant shade from multiple levels of vegetation, help to decrease evapotranspirative losses that would normally occur in a warm, highly vegetated region.

By breaking the impact of heavy rains, holding large quantities of water with surface tension and absorption, and thus allowing a slower, more manageable impact to the ground via stem and leaf drip, Hawai‘ian cloud forests not only reduce the erosive impacts of freshets, but also enable higher and more sustained quantities of recharge. The sponge-like ability of the mosses and fern layers, as well as root-zone soil strata, help to facilitate recharge and minimize water loss during dry periods, holding moisture and keeping the ground shaded.

Hawai‘i’s watershed forests contribute to the high quality of the islands’ waters. Forests have been compared to the kidneys in the body, which filter impurities out of the blood. Particles are removed by adhering to leaves, stems and soils. Certain compounds, especially nutrients, can be absorbed by leaves or root systems. Leaf matter and well graded soils also help filter particles of water.

Hawai‘ian cloud forests are particularly good water managers, and perform the five functions discussed above, namely: 1) collection of water, 2) storage of water, 3) regulation of the discharge of water, 4)erosion control and 5) improving water quality.

Collection of Water

As moisture laden air travels over the ocean and up the mountains, it comes into contact with the abundant plant cover in the forest. The moisture condenses, adheres to, and is absorbed by vegetation and forest litter. Every stem, leaf, twig and bit of moss helps to collect water.

Storage of Water

Hawai‘ian forests are characterized by a dense understory of ferns and mosses, and by multiple levels of plant surfaces. The multidimensional layers and dense understory, and especially the carpet of moss and ferns that typify Hawai‘ian watersheds serve, not only as excellent collection systems but also as storage reservoirs for water. Abundant surface area and multiple surface layers help to absorb and hold more water and to reduce evapotranspirative losses even where large amounts of plant materials are present. Mosses, lichens and ferns are also able to hold large quantities of water.

Regulation of the Discharge of Water

During a heavy rain, the forest canopy and dense under- layers break the impact of falling raindrops, while the sponge-like abilities of mosses and forest floor plants, as well as root-zone soil strata help to hold the water. The understory and groundcovers also help to keep the air and soil in the watershed moist, while facilitating continued recharge and minimizing water loss during dry periods.

Control of Erosion

Erosion control results from the ability of the canopy and other vegetative layers to break the impacts of heavy rain, as well as from the soil holding capacities of the roots. The roots and dense growth serve to keep soil aerated and penetrable, helping to prevent run off, and also preventing the soil from becoming so dry and exposed that it becomes powdery and blows away. In this way, the healthy forest cover helps to promote recharge and minimize soil loss.

Improvement of Water Quality

The watershed forest helps to keep water clean. Impurities in water are removed by adhering to leaves, stems and soil particles. Certain compounds, especially nutrients, can also be absorbed or taken up by both leaves and root systems. The leaves and well graded soils found in a healthy watershed also help to filter particles out of the water.

The effects of Hawai‘ian forests on island recharge are profound. Perhaps the most dramatic example is the island of Lana`i, one of the least forested of all the main islands, with relatively low rainfall and a sustainable yield of only 6 MGD.

FIGURE 6-2 Role of Forests in Hydrologic Cycle

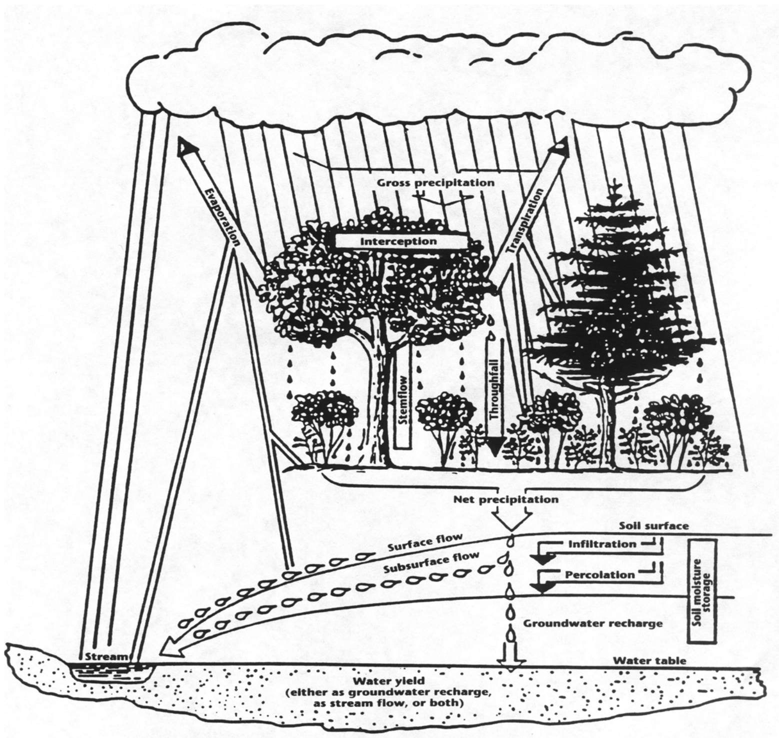


Illustration of the role forests play in the hydrological cycle and watershed protection. (Source: Cassells, Hamilton & Saplaco)

A 1967 State Land Bureau study investigated soils and vegetation on Lana‘i Hale and concluded that they were more typical of an area receiving 60" / year of annual rainfall - or nearly double the amount received on most of Lana‘i - than of the 35-40” that actually fall on Lana‘i Hale. More recently, *A Numerical Groundwater Model for the Island of Lana`i, Hawai‘i* (CWRM-1, Hardy, ‘96) estimated that over 65% of the recharge in the primary high level aquifer for Lana‘i was attributable to fog drip, and that the loss of fog drip from Lana‘i Hale would lead to the loss of over 50% of the water levels in the Central aquifer, essentially the only viable water source for the island. Lana`i is unusually dependent upon fog drip. Estimates from studies elsewhere indicate that fog drip interception by mountain forests increase precipitation by as much as 30%, and recharge by 10-15%.

The mauka cloud forests are as vulnerable as they are important to the water budget of the islands. Hawai‘ian forest ecosystems evolved in extreme geographic isolation, over 2,400 miles from the nearest continent, with an estimated species introduction rate of one in every 10,000 years, Hawai‘ian species were not exposed to the same pressures and competition as continental species. The result is that many Hawai‘ian species are not well equipped to defend against invasive weeds from more competitive environments, nor from exotic animal pressures such as grazing, browsing, trampling and imported diseases, pests and pathogens. Introduced species can over-run native ecosystems.

Lana`i has suffered the ravages of such introductions. In his 1993 article, "Lana`i - A Case Study: The Loss of Biodiversity on a Small Hawai'ian Island"; *(Pacific Science*; Vol.. 47, no. 3; pp 201-210, University of Hawai`i Press, © 1993), Robert Hobdy estimated that, of the original plant communities on Lana`i, more than 2/3 have been lost. This circumstance is particularly worrisome on Lana`i, where sustainable ground water yield is less than 10% that of Molokai, and less than 2% that of Maui.

Theoretical, empirical, anecdotal and modeling evidence indicate that loss of forest cover, and associated loss of fog drip, has likely impacted water recharge on Lana`i.

The State Land Study Bureau (Sahara et. al '67, quoted from CWRM-1, Hardy '96) studied the vegetation and soils on and around Lana`ihale and concluded that the vegetation and soils of the forest were more typical of one receiving 60" per year than 35 or 40". They attributed this apparent anomaly to the continuous cloud cover. Hardy, in *A Numerical Ground Water Model for the Island of Lana`i, Hawai'i*, describes several such investigations into fog drip on Lana`i. Given repeated, essentially undisputed conclusions that the forest cover contributes to fog drip, it is a short step to the conclusion that loss of forest cover will alter effective precipitation, and hence, via the water budget, recharge.

In "*The Hydrological Importance of a Montane Cloud Forest in Costa Rica*", (Chapter 2.3 of Tropical Agricultural Hydrology, John Wiley & Sons, ©1981), F. Zadroga describes preliminary data from a 5 year experimental catchment research project in the Monteverde Cloud Forest Reserve. Comparing rich montane forest cover with deforested watersheds, he notes a differential effect in wet season direct run-off as compared to dry-season flows. Deforested areas experienced higher run-off during wet seasons, but were unable to sustain flows during dry seasons. On the other hand, forested watersheds continued to yield flows above "rainfall" levels even during the dry season. Areas lacking in forest vegetation had substantially lower yields in terms of percent of direct rainfall over time. The preliminary findings seemed to indicate that the presence of montane cloud cover makes a significant contribution to sustained flows / recharge. Potential reasons mentioned for increased ability to sustain flows in forested areas included increased precipitation from cloud mist or cloud droplet catchment in forested areas, low evapotranspiration due to low insolation from closed canopy, high air-moisture content, and increased ability to intercept clouds.

This finding seems to echo Lana`i's experience as summarized by Hobdy ('93). In an excellent chronology of human activities leading to denudation of the slopes, he describes accounts and observations of witnesses in the late 1800s and early 1900s, and early efforts to preserve or recover forest. *(This narrative is summarized in the timeline/Figure following this introduction.)* Lawrence Gay, in his *True Stories of the Island of Lana`i* noted that the Maunalei stream traveled a mile from its source, but that older Hawaiians remembered it flowing all the way to the sea. In the late 1800s, taro production in Maunalei had to be discontinued, because goats on the cliffs above had denuded the land to such a degree that it had become dangerous to work below. Traditional wetland taro terraces, or lo`i may still be found in Maunalei Valley. George C. Munro, in *Story of Lana'i*, also described hearing from an old Hawai'ian that Maunalei Stream once ran all the way to the ocean. Stearns noted that Maunalei Gulch was perennial prior to the development of Maunalei Tunnel around 1940, although apparently it was not perennial all the way to the sea. Combined, these comments give us the picture that flows at Maunalei Stream had once been sufficient to support taro, and that flows had diminished even before the remainder was essentially eliminated with development of the tunnels. Bowles ('74) and Hardy ('95) both indicate that the loss of recharge resulting from loss of forest cover may have contributed significantly to drawdowns in the wells (CWRM-1, Hardy, '96, pg. 125)**.**

Such conclusions are also supported by Hardy's *Numerical Groundwater Model for the Island of*

Lana`i, Hawai'i (CWRM-1, Hardy, 1996). The model uses a fog drip to rainfall ratio of 0.72, arrived at by averaging studies quantifying precipitation collected in open areas as compared to under forest cover. It uses empirical and / or calculated data for elements such as rainfall, direct run-off, evapotranspiration, and soil characteristics to arrive at water level and draw down estimates assuming various pumping and recharge scenarios. One of the model runs examines the loss of fog drip from the island. The greatest impacts are observed in the areas over 2,000', under which the primary high-level water source is located. In this area it is estimated that 8.87 MGD is attributable to fog drip, vs. a total recharge estimate of 13.5 MGD.

The model scenarios indicate that loss of fog drip alone, with no pumping, would have a greater regional effect on the Central Aquifer Sector than pumping existing wells to 6 MGD (CWRM-1, Hardy, 1996, p. 112). In this high level aquifer area, the loss of fog drip would lead to the loss of over 50% of water levels. Since the model used is unable to account for additional loss of recharge due to erosion and compaction of soils that would be associated with loss of watershed, this may even be a conservative estimate. "...The results clearly indicate that the reduction of forest cover would affect ground water levels drastically,....[and]... make.. a strong case for the maintenance of fog drip efficient vegetation above the 2,000' elevation. "...Recharge should be protected and enhanced to guarantee a reliable ground water resource..."It is important to remember that the overriding factor for governing actual fog drip...is providing the medium upon which fog drip can condense and be harvested from the air. Therefore, changes in the type and density of the forest cover are more likely to change actual fog drip on Lana`i than changes in the surrounding ocean or global climate." (Hardy pgs. 126, 95 & 26)

A recent study by Pacific Environmental Engineering, (Final Report: Lana'i Fog Drip Study, May 29, 2009), found even higher precipitation under Cooke Pine than had been previously estimated. This study did not compare Cooke pine to native vegetation, nor analyze differences in subsurface soil characteristics such as moisture and compaction, but it did highlight the importance of fog drip. While Cooke pine seem to have much to offer in terms of increasing effective precipitation, it cannot and should not be concluded that they are more effective than, nor that they should replace, native vegetation. Nor is this suggested in the Lana'i Fog Drip Study. The concern is raised here because Figure 50 in that document, labeled "Potential Acreage for Cooke Pine Restoration (by Suitability Class)" indicates a candidate Cooke Pine planting area which overlaps the extent of the best remaining native habitat. The map merely indicates areas where Cooke Pine could be effective at fog drip catchment, and where slopes, terrain, wind characteristics, etc. were likely to be suitable for Cooke Pine. This is all valid as far as it goes. It simply does not address the question of native habitat at all. Caution should be taken not to misinterpret this as a recommendation that remaining native vegetation be replaced by Cooke pine.

A more recent article "Hawai'ian Native Forest Conserves Water Relative to Timber Plantation Species and Stand Traits Influence Water Use", Kagawa, Sack, Durate and James, Ecological Applications 19(6), 2009, pp. 1429-1443 studied native 'ohi'a forest versus invaded eucalyptus and evergreen ash, and found that native forest was the better water manager.

Despite abundant evidence pointing to the importance of forested watershed in sustaining the small, susceptible water resources of this island, multiple accounts attest to the fact that Lana`i's watershed has been both degraded and reduced dramatically over the past two centuries. Hobdy ('93) estimated that only 30% or less of the original cloud forest cover in Lana`i remains.

Lanaʻi Water Advisory Committee Process in Watershed Plan Development

Given that forested watershed is critical to maintaining water availability, and that Lana`i's forested watershed is diminishing, it was determined that the Water Use & Development Plan would not be complete without a skeletal plan for watershed protection and implementation measures. The following section represents a peer reviewed cooperative, consensus effort at developing the basis for watershed protective efforts over the planning time frame.

The group started by identifying two existing plans, the CCR's proposal for a stewardship plan at that time (not the same as the present plan) and a species recovery plan for Lana`i, entitled *Lanaʻi Plant Cluster Recovery Plan*, published by the US Fish & Wildlife Service, September 1995. These two plans were sent to a panel of over 20 resource managers, most of whom had experience in Lana`i, with the request that each be reviewed as a potential watershed plan to incorporate by reference, and that each panel member offer suggestions for the top priority actions needed to protect the Lana`ihale watershed. Written comments were followed up with a three island skybridge meeting, in which priorities for forest management were discussed. The results of these efforts are incorporated in the proposed plan, by unanimous agreement of the Lanaʻi Water Advisory Committee.

The proposed plan reflects certain principles to which the Lanaʻi Water Advisory Committee was committed. Specifically, the group unanimously agreed that any plan should afford maximal protection for the water resource, protecting biodiversity to the greatest extent possible. The group concluded that preservation of native biodiversity would be the most protective for the watershed, given that systems are more stable and able to withstand challenges when their inherent parts are intact.

There are multiple, complex inter-dependent relations between species in any system, and it has been noted that there also appear to be keystone species, without which entire systems unravel. In matters of biodiversity, the committee determined that the most cautious approach for the watershed would be to encourage the maximum preservation of native biodiversity.

Finally, the committee determined that respect for cultural resources and consistency with community values should help to guide the plan. Management of ecosystems has to account for lifestyle and needs of the community. For example, there are roughly 400 hunting licenses out of a population of roughly 2,500 in Lana`i. There are also gathering rights which will be eliminated if the species gathered disappear. Given the need to balance community values, lifestyles and concerns, a series of public meetings were held in which several alternatives were presented and discussed.

Concurrently, a second committee, of which several advisory committee members were a part, met to determine the best path for biodiversity preservation on the island of Lana`i. Although these two groups met separately and for somewhat different purposes, they ended up reaching similar conclusions regarding the management of Lana`ihale, and presented suggestions at a public forum hosted together, and ultimately formed a partnership with other agencies to protect Lanaʻi's forest and watershed.

Setting

Lana`i is an 89,280 acre (361 sq. km.) island, nearly 2,500 miles (4,022.5 km) from the nearest continent (2,400 miles from California, 4,000 miles from Japan, 2,400 miles from the Marquesas, Samoa & Fiji).

The summit of Lana`i is about 3,370' (1,027.85 meters) high. Lana`i was created by a single shield volcano, built by eruptions at the summit along 3 rift zones, (Stearns & MacDonald, 1983), and possibly a fourth, northern rift zone. (CWRM-1, Hardy, 1996), referring to gravity survey by Krivoy & magnetic survey by Malahoff). The principal rift zone trends northwest-ward, the other rift zones trend southwest toward Kaholo Pali and Kaunolo Bay; and the last south-southwest-ward, toward Manele. Palawai basin is the remnant of a caldera. Just to the west of Palawai, Miki Basin is a nearly filled pit-crater. Cross sections of several additional subsidiary cones and pit craters have been identified.

Lana`i stone has been dated from 0.81 million to 1.46 million years old. The lavas are *theolitic basalts*. These are igneous rocks composed of calcic plagioclase feldspar and pyroxene, relatively rich in silica, and poor in sodium and potassium. Some contain olivine as well. Basalts are low viscosity lavas that form in volcanoes with gently sloping flanks. Basalt lava flows are the *Pahoe-hoe*, which means "ropey", and indeed looks like smooth ropes or layers, or *A'a*, which means "hurt" and is sharp and fragmented.

Because Lana`i lies to the lee of Maui, precipitation is low. The summit receives roughly 38" (96.52 cm) of rain per year, as compared to over 400" (1,016 cm) per year on parts of the neighboring island of Maui. This orientation has also given the island a somewhat unusual topology. What would normally be the "windward" slopes of the island are relatively sheltered from wind, precipitation and wave action. As a result, Lana`i does not have the dramatic windward facing sea-cliffs of Maui or Molokai. However, the southwest is fully exposed to both waves and south-westerly storms, which has allowed the formation of high sea cliffs on her "leeward" side, and a wind-formed dune ridge to the southeast. Pinnacled rocks on the north of the island are also the result of erosion by northeasterly winds.

The hydrogeology of Lana`i is unusual in terms of the predominance of high level water, including the presence of high-level brackish water in at least one location, accompanied by geothermal heating. High level water occurs within 3.8 miles (6.1142 km) of the coast line all around the island. In addition, the north west rift zone is quite wide, possibly as much as 4 miles (6.436 km) across at some points. Such features, as well as numerous dike and fault boundaries have introduced some difficulty in monitoring and understanding the shape of the aquifer and fresh /salt water interface. The south side of the island has essentially no cap rock, but thick alluvial deposits or possibly cap-rock on the north side may serve to deter discharge of water to the ocean and saltwater intrusion.

FIGURE 6-3 Chronology of Land Use Conservation & Water in Lana'i

1400 AD -	Hawai`ians arrived - peak population prior to Cook was estimated at between 3,000 - 3,250 people. Fire, wood, thatch used, some ag - some clearing, some burning for ag and use of wood, etc.
1675 -	Kahuna named Kawelo maintained perpetual bonfire - kept burning for many years, must have cost a lot of trees - the site is one of the worst examples of erosion today
1778 -	Few months before Cook's arrival, warring raid from King of Hawai`i Kalaniopu`u, and his Chief Kamehameha (who eventually united the Hawai`ian islands) (Kamehameha was about 25 yrs old) Kalaniopu`u was upset because he had been defeated by the king of Maui Kahekili. His army descended on Lana`i and destroyed the entire population, ate the food and crops, burned all the houses and other improvements
1778 -	Cook arrived in Hawai`i
1779 -	Clerke recorded Lana`i's existence while departing

Watershed Protection

1778 -	Goats and European hogs introduced to Hawai`i
1791 -	Sheep introduced to Hawai‘ian islands
1793 -	Cattle introduced to Hawai‘ian islands
early 1800s -	Goats introduced to Lana`i - causing noticeable damage within 30 years Before the introduction of goats, there was apparently an extensive and unique forest of `akoko covering upland basins of Palawai and Miki (Succulent bark with good moisture, goats stripped the bark - killing the trees. `akoko = (Chamaesyce celastroides, var. lorifolia) At first, goats didn't penetrate the summit - there was plenty of good eating below.
1823 -	First known visit of caucasian to Lana`i - Reverend William Ellis to Hawai`i Estimated population of the island 2,500
1823 -	Lana`i island population about 2,500
1848 -	The Great Mahele in Hawai‘i. Government heard peoples claims for land, and awarded it to chiefs and commoners. Lana`i had 13 ahupua`a
1852 -	First distribution of land to commoners in Lana`i
mid 1800s -	Sheep to Lana`i (probably in connection with small colony of Mormons that settled in Palawai basin) later under Walter Murray Gibson, decision was made to raise goats for skins and sheep for wool
1865 -	Lana`i Ranch started
1867 -	Gibson estimated 18,000 goats and 10,000 sheep on Lana`i.
1867 -	Peck vs. Bailey, 8 Hawai‘i 658 Determined appurtenant rights, right to amount of water used on the land at the time of the Great Mahele.
1870 -	Botanist Dr. William Hillebrand visited Lana`i with J.M. Lydgate. Lydgate described the island as “pretty well denuded of its forest cover:” and observed that “only on the summit of the island ridge was that mantle really intact and undisturbed” (Lydgate 1920)
1875 -	First two Norfolk Island pine planted on Lana`i.
1876 -	Gibson noted that “the isles are becoming naked at a fearful rate”.
1880s	Late 1880s European hogs introduced, but succumbed to a virulent hog cholera epidemic a few years later.
1886 -	Complaint was filed against Gibson by 5 Hawai‘ian families, for placing undue pressure on their livelihoods by charging / limiting access to gathering, fishing and water resources necessary for the subsistence lifestyle of the day. Many water sources were controlled by Gibson, including Waipa‘a. The Waipa‘a Tunnel was not drilled until 1924, so this must have referred to a spring source nearer the shoreline.
1888 -	Gibson passed away and left Lana`i lands to his daughter and her husband, Frederick Hayselden. Hayselden focused primarily on sheep ranching.
1895 -	Lonoaea vs. Wailuku Sugar Co., 9 Hawai‘i 651 (1895) determined prescriptive rights - rights obtained by adverse use of water for statutory period of adverse possession.
1898 -	Munro estimated 50,000 sheep and a large but undetermined number of goats. Lowland already mainly destroyed. Animals wandering up into mesic and cloud forest areas and denuding mid-elevation canyonlands on the windward side. Human population about 174.

Source Water Protection

	Attempts made to control rampant erosion by planting Bermuda grass. Eucalyptus and Norfolk pine also planted in Koele.
	WATER RESERVOIRS BUILT AT KOELE AND KAIHOLENA GULCH.
1898 -	Maunalei Sugar Co. started by Heyselden.
late 1800's	Taro production in Maunalei Gulch discontinued because rocks dislodged by goats from denuded cliffs above.
1899 - 1901 -	Epidemic among Chinese workers on sugar plantation reduces company employee population from 710 to 12. This, combined with brackish water helped to guarantee the end of the sugar plantation.
1900 -	GAY WELL A CONSTRUCTED.
1902 -	Heyselden destroyed a local well in KAUNOLU, by damaging the traditional Hawaiʻian plaster work. The well went brackish. The wells he depended upon for sugar production in KEOMOKU were also too brackish to continue using for irrigation.
1902 -	Charles Gay purchased ⅔ of Heyselden's holdings at auction.
1902 -	Charles Gay arrived on island and began more controlled operations focusing on cattle and some agriculture. In 1965, Gays eldest son, Lawrence Gay was noted to recall that mid elevations had extensive areas of tree skeletons on the northern plateau and in the central basin above 1000'. (305 m) around the period (1902) they had arrived on Lana`i.
1902 -	Island population less than 100. Droughts resulting from loss of forest cover - brought reduced productivity and famine to Lana`i residents in the first decade of the twentieth century. Gays arrived on the island. Gays began intensive goat and sheep eradication efforts.
1903 -	Gay purchased Hayselden's remaining interests in Lana`i.
1905 -	The two-story company store and hotel at Keomoku was dismantled and floated across the channel to Lahaʻina, where it became the Pioneer Inn.
1907 -	Gays purchased Kaa & Kaohai ahupua`a. At this time more than half of the lands of Lana`i were still in the hands of Hawaiians, but this percentage was diminishing rapidly.
1908 - 1911 -	Drought
1910 -	Gays invited Territorial Forester Ralph S. Hosmer to help them with a long term recovery plan. Hosmer wrote a 27 page report, recommending more fencing and animal eradication, followed by tree and grass planting to speed the revegetation on the lower slopes.
1910 -	Gays forced to sell most of their holdings Lana`i Company - formed by a group of bankers Initial plan was to focus on sugar beets
1911 -	Small piggery started at Waiapa`a on the slopes above the Palawai basin. Unsuccessful because of non-dependability of water supply remaining hogs released and became feral Munro noticed signs of forest damage in the summit cloud forest, and mounted a successful effort to rid the island of hogs
1911 -	Lana`i Company hired George C. Munro to run the ranch 799 head of cattle present, but sheep count was estimated at 20,558 Munro recommended transition from sheep to cattle; this recommendation was approved

Watershed Protection

1911 -	MAUNALEI TUNNELS 1 & 2 CONSTRUCTED
1911-1921 -	Munro spent much time shooting sheep and goats completed fenceline around the mountain started by the Gays
1911-1937	Munro introduced many species of plants for erosion control and reforestation some of which became pests, choking out native species Melinis minutiflora - molasses grass Paspalum dilatatum - dallis grass Panicum maximum - guinea grass Atriplex semibaccata - Australian saltbush Araucaria columnaris - Cook Pine Leptospermum scoparium - manuka Cauarina glauca - longleaf ironwood Myrica faya - firetree
1916 -	By this time large scale sheep farming was finished
1917 -	Baldwins purchased Lana`i from the Lana`i Company of the time Baldwin's focused on cattle ranching. 4,000 head of cattle in 1917.
1918 -	50 acres of Kanepu`u dry forest fenced by Gay et al
1918 -	MOUNTAIN HOUSE TUNNEL DRILLED
1920 -	Two bird species: `akialoa (Hemignathus obscurus lanaiensis), and Lana`i hook-billed finch (Dysmorodrepanis munroi) gone by 1920. Both birds primary habitat had been the `akoko forests.
1920 -	12 axis deer introduced to Lana`i from Molokai. Multiplied in the Palawai basin, hunted for sport and meat. Munro later mentioned that he regretted this. Population at this time estimated at 185.
1920-	GAY TUNNEL CONSTRUCTED
1921 -	By this time, only 208.25 acres out of the entire island were still owned by Hawaiians.
1921 -	First crop of pineapples planted on Lana`i by Gay.
1922 -	Baldwins sold Lana`i to James Dole, who immediately began preparing Palawaii Basin for pineapple growing. Razing and destroying an enormous non-native invasive cactus population in the process.
1922 & 1926	Munroe makes systematic fog drip observations. ***Letter to the Editor,*** <u>Hawai‘ian Forester and Agriulturist</u> 19(2) pp. 45-46. Unpublished analysis by Munro also given to company as late as 1954
1924 -	Dole Company started planting pineapple fields.
1924 -	Waiapa‘a TUNNEL CONSTRUCTED
1925 -	By this time over 2,000 laborers, including many immigrants, had moved to Lana`i to work in the pineapple fields. Brought considerable numbers of poultry and other birds with them.
1926 -	First pineapple harvest on Lana`i. Kaumalapau Harbor was opened, and the crop shipped by barge.

Source Water Protection

1927 -	Territorial Forester Charles S. Judd made a visit to Lana`i. Noted that forest was making a substantial recovery under Munro's management.
1929 -	Munro noticed a sudden decline in numbers of forest birds, which had previously seemed to be recovering.
1929 -	Munroe, *Norfolk Island Pine for the Wet Forest*, Hawiian Forester and Agriculturist 26(3), pp 126-127.
1930 -	Hogs eradictaed. Human population had exploded to 2,356, more than 10x the number of a decade before. The vast majority, about 78% were either Japanese or Filipino,. The remaining 22% were a mix of Hawaiians, Koreans, Puerto Ricans, Chinese, Haole and Portuguese (in descending order of population).
1930 -	W.O. Clark recommended tunneling in Maunalei Gulch.
1931 -	Three more species of birds gone: `o`u (Psittirostra psittacea), Lana`i Creeper (Paroreomyza montana montana), and Lana`i Thrush (Myadestes lanaiensis lanaiensis). Munro believed that there must have been an inadvertent introduction of some avian disease against which the native birds had no defense.
1931 -	9 month drought.
1936 -	MAUNALEI SHAFT 1 & 2 CONSTRUCTED
1937 -	`i`iwi (Vesstiaria coccinea) gone
1937	Munro retired. Deer numbers still low at this time, but in 1950 reminiscences, regretted the introduction.
1940 -	H.T. Stearns estimated 6.46 recharge for high level aquifer; 21.26 MGD for entire island. 6,150 acres (24.89 $km^{2)}$ were set aside as the Maunalei Forest Reserve through a surrender agreement between the Hawai'ian Pineapple Company and the Territorial Government.
1945 -	WELL 1 DRILLED
1946 -	WELL 2 DRILLED
1948 -	George Munro wrote a letter to Colin G. Lennox (president of the Board of Agriculture and Forestry) seeking his assistance in persuading Hawai'ian Pineapple Company to additionally fence of the Kanepu`u dry forest to protect it from cattle and deer. He recounted his long efforts to do so, but registered frustration that it "all has been to no effect".
1950 -	Cattle completely gone from the island. (Cattle ranching discontinued when pineapple began).
1950s	Several hectares of pine trees were planted on the summit to enhance fog drip, but little else in the way of forest management was initiated by government or company during this period.
1950 -	WELLS 3 , 4, & 5 DRILLED.
1950 -	KAIHOLENA TUNNEL HOLE 3 CONSTRUCTED.
1953 -	H.T. Stearns estimated sustainable yield at 3+ MGD.
1954 -	Mouflon sheep introduced as potential game animal.

Watershed Protection

1954 -	SHAFT 3 CONSTRUCTED.
1955 - 1958	Fog Drip Study by Ekern, published 1964 Direct Interception of Cloud Water on Lanaʻi Hale, Hawaiʻi, Soil Science Society of America Proceedings, vol. 28, n. 3, pp. 319-421.
1957 -	Hawaiʻian Pineapple Company rescinded the surrender agreement & terminated forest reserve status.
1959 -	Hawaiʻi Water Authority publishes study on development of Lana`i groundwter and fog drip importance.
1960 -	Pronghorn antelope introduced - did not adapt well.
1960 & 1961 -	K.E. Anderson estimated safe yield at 2.2 and 2.3, respectively. Ultimate high level aquifer supply estimated at 3.6 to 4.8 MGD. At the time appreciable amounts of Maunalei Tunnel water flows bypass the water system, are not accounted, and probably flow into the sea.
1961 -	Carlson, N.K.; *Fog and Lava Rock, Pine and Pineapples*, American Forests 67(2); pp. 8-11, and 58-59.
1961 -	Groundwater Use Act , Hawaiʻi Revised Statutes, §177.
1963 -	Otto Degener published warning concerning the future of Lana`i's native flora.
1964 -	P.C. Ekern estimates that rainfall precipitation is augmented by 30″ per year beneath a mature Norfolk Pine.
1970s -	Castle & Cooke and State wildlife managers decided to eradicate goats from the island.
1971 -	Spence & Montgomery documented diminishing forest diversity at Kanepu`u dry forest.
1973 -	Hobdy sends report to State Forester documenting diminished forest diversity at Kanepu`u. Document calls for fencing, deer removal, enrichment plantings of rare species.
1973 -	W.M. Adams estimates that optimum drilling sites for high quality water are in the southeast area between Lopa and Naha. Lower quality between Kiolohia and Lopa.
1973 -	McBryde vs. Robinson 54 Hawaiʻi 173 N 15.
1974 -	S.P. Bowles estimates infiltration recharge of 6.5 gpd.
1976 -	Last sighting of the `amakihi (Hemignathus virens wilsoni).
1981 -	Goats eliminated.
1983 -	J.F. Mink estimates recharge at 9.3 MGD; sustainable yield of 6 MGD. Sets a primary recharge area of 14 square miles, and a secondary recharge area of 10 square miles.
1982 -	Pronghorn antelope gone.
1983 -	K.E. Anderson suggests that a freshwater supply estimate of 4.1 - 5.5 MGD be used for planning purposes.
1984 -	Heteropsylla cubana - the Leucaena psyllid - infested and defoliated haole koa in lowlands, deer began migrating upland - deer numbers began to increase rapidly.
1985 -	K E. Anderson reviews water supply and concludes existing infrastructure is capable of supplying 2.7 MGD.

Source Water Protection

1986 -	Ordinance 1578 establishes Manele Project District. Initial project configuration includes 395.34 acres of Single Family, Multi-Family, Commercial, Golf Course, Hotel, Park & Open Space Uses.
1986 -	Ordinance 1580 establishes Koele Project District. Initial project configuration involves 468.3 acres of Single Family, Multi - Family, Commercial, Golf Course, Hotel, Park & Open Space Uses.
1986 -	Well 6 DRILLED.
1987 -	Well 7 DRILLED.
1988 -	Government deer census estimated over 3,700 deer on the northern half of the island alone.
1989 -	Lana`i Company publishes Water Resources Development Plan for the Island of Lana`i, Hawai'i, by M&E Pacific.
1989 -	Well 10 DRILLED (aka Lana`i 10) . This was drilled in response to suggestion that an exploratory well be drilled in the southwestern sector of the Palawai Basin, outside the range of the high level aquifer, and outside the primary and secondary recharge zones. This was an attempt to test whether the basal aquifer could deliver any viable supply. If chlorides were low enough it could prove economical to utilize - and if this had been the case, there would have been a viable source outside the high level aquifer. Instead, high level, geothermally heated and highly brackish water was found.
1989 -	Lana`i Company filed a petition with the State Land Use Commission to reclassify 138.577 acres from Rural and Agricultural Designations to Urban in order to develop the Manele golf course and related facilities.
1989 -	K.E. Anderson estimates recharge at 8.89 MGD, S.Y. at 6.22 MGD.
1990 -	State Water Resources Protection Plan by JF Mink includes discussion of Lana`i aquifers. Further update 1993.
1990 -	County Water Use and Development Plan published. Key issues for Lana`i involved how to accommodate the combined resort and pineapple economy with limited water. Alternate water sources for golf-course irrigation were proposed.
1990 -	Petition to Designate Lana`i as a State Groundwater Management Area filed by a group of citizens on Lana`i. CWRM finds that reasonable estimates are recharge: 9 MGD, and sustainable yield : 6 MGD.
1990 -	WELLS 8, 9, 12 & 13 DRILLED. Well 9 is on the border between Mink's "primary" and "secondary" recharge areas. Wells 12 & 13 were a further test to see if the basal aquifer could deliver practical supply. They are located in the island's southeast rift zone. The wells are basal with 4 - 5 feet of head. Chlorides were 900 - 1400 mg/L. Well 12 tested at 100,00 gpd, and Well 13 at less than 42,000.
1990 -	Dole Company announced the closing of pineapple operations.
1991 -	Ordinance 2066 prohibits use of potable water on all golf courses.
1991 -	Land Use Commission issued a Decision and Order, granting the reclassification for Manele, pursuant to several conditions; one of which was that no potable water from the high level groundwater aquifer would be used for the golf course irrigation, and that instead only alternative, non-potable sources of water would be used.
1992 -	Coastal and strand community had been largely destroyed - 3% remained

Watershed Protection

Arid grassland & shrubland ~ 20% remained, mostly in N. & E., Much species diversity eliminated
Dry forest community - 2% remained
Mesic forest community - 3%
Cloud forest community - 30%
threatened with Myrica, Psidium or Leptospermum thickets, Melinis grass, etc.

1992 - Ordinance 2132 increases Manele Project District from 395.34 acres to 556.34 acres. Major changes are addition of 201 acres of golf course, and reduction of 25 acres of Open Space.

1992 - Ordinance 2139 increases Koele Project District from 468.3 acres to 618 acres. Major changes are addition of 332.4 acres of golf course and reduction of 201.5 acres of Open Space.

1992 - County Water Use and Development Plan Draft - Revisited Lana`i issues given the new economic direction of the island. Key issues were the need for better water auditing and control - there seemed to be wide unexplained swings in consumption, high water losses and overall need for better monitoring and conservation. This recommendation applied not only to systems, but was also put forth with regard to hydrologic data gathering. Dual potable and non-potable water systems were also recommended for the Manele Project District.

1993 - Council Chair requests stop work at Manele golf course pursuant to violation of condition of County Code §19.70.85 prohibiting use of water from the high level aquifer for Manele. Three months later, council elects to defer, enforcement of §19.70.085 is deferred given certain conditions. 750,000 gpd allowed for the interim, with some restrictions, in Resolution 93-42.

1993 - State Land Use Commission issued an Order to Show Cause because it believed that Lana`i Co. had failed to comply with Condition 10 of it's District Boundary reclassification for Manele, prohibiting the use of high level water for irrigation of Manele Golf Course.

1993 - County Council Resolution 93-42 also establishes Lana`i Water Subcommitee, with sunset at the end of the year to monitor the use of water from the high-level aquifer. Subcommittee has 9 members. 3 from company, 3 from Lanai‘ans for Sensible Growth, and 1 each from CWRM, Planning Commission and State Water Commision.

1994 - Bill is proposed to amend §19.70.85 to allow withdrawal of 650,000 gpd. Heard first by Planning Commission. Planning Director recommends total allowance fo 650,000 gpd; and that subcommittee be impaneled as a subcommittee of the Human Service, Water and Ag Committee. Recommended subcommittee composition includes 3 from Company, 3 from Lanai‘ans for Sensible Growth, 1 each from CWRM, Planning Commision and State Water Commission as before, with the addition of the Directors of Public Works and of Water Supply.

Mid 1990s - Goats re-introduced.

1995 - Council Subcommittee Established with the following membership: 2 from Company, 2 from Lanai‘ans for Sensible Growth, 1 Councilmember, Lana`i Planning Commission Chair, Planning Director, Public Works Director, the Water Supply Director as an ex-officio non-voting member, and one additional non-voting member from Lanai‘ans for Economic Growth and Stability.

1995 - Ordinance 2410 increases Manele Project District from 556.34 acres to 872.25 acres. Major changes are additon of 258 acres more single-family development, reduction of 29 acres of golf course, reinstatement of 45 acres of open space and addition of 21.4 acres of multi-family development.

1995 - WELL 14 DRILLED.

1996 - State Land Use Commission issued cease and desist order requiring Lana`i Company to stop using water from the high level aquifer for golf course irrigation, and to file a plan with the LUC within 60 days saying how it would comply.

1996 - CWRM publishes a Numerical Ground Water Model for the Island of Lana`i, Hawai‘i ; by Roy Hardy ; CWRM-01.

Source Water Protection

1996 - An additional Lana'i Water Resources Management Plan is published by the Company, in response to the State Land Use Commissions May 17th 1996 Decision and Cease & Desist Order. It essentially stated that since efforts to develop a practical basal source with wells 10, 12 and 13 had failed, it was impractical to continue to rely on purely non-potable, non-high-level sources. It notes that Time Domain Electrormagnetic Resistivity surveys performed by Black Hawk had indicated that the extent of the high level aquifer was larger than previously expected. It stated that principal recharge to the basal lense is leakage from high level groundwater compartments beyond the rim of the Palawai. The recharge itself was considered too brackish for use. The report concluded that brackish water from the high-level aquifer was the only practical source for alternate irrigation.- A month later, the company filed a supplement with additional cost information. There were no alterations to the conclusions.

1996 - State Commission on Water Resource Management establishes a Lana`i Water Working Group to try to reach consensus on water issues. Composition is identical to that of the council subcommittee, which was scheduled to dissolve at the end of the year.

1996 Council Subcommittee sunset December 31st.

1997 - Water Working Group established by the State Commission on Water Resource Management sunsets.

1997 - In January and again in April, the Board of Water Supply resolves to continue working with the Working Group until the County Water Use and Development Plan is completed, and to consider establishment of ongoing committee to work on unresolved issues. Board continues discussions on pros and cons of this decision and on what form the committee should take until 1999.

1997- Final Report of the Lana`i Water Working Group established under CWRM is submitted. Board moves to accept this report as the "interim" draft WUDP until the Lana`i WUDP chapter is approved through the usual process.

1996 - Ordinance 2515 amended County Code Section 19.71.055 relating to irrigation of the Koele Golf Course. Amends section D on Irrigation by changing phrase from no high level groundwater to no high level aquifer groundwater . Then proceded to establish conditions under which the Director of Public Works and Waste Management may authorize use of the high level aquifer for golf course irrigation. Events that trigger such allowance include but are not limited to: chemical contamination of a non-potable source, resulting in chemical concentrations not approved for golf course application; a water transmission line break in the non-potable line; failure of non-potable pumping systems, failure in sewage reclamation systems, draw down of reservoirs and irrigation water features for fire fighting or other emergencies or electrical power failure in delivery facilities. In no case is drought to be deemed an unanticipated event warranting issuance of such permit. Prior to such emergency approvals, the golf course owner shall have provided to the director supporting documentation of relevant facts and events, a plan showing that no continuous physical connection will be made between potable and non-potable systems, a remedial plan to restore non-potable water use including schedule; and a plan detailing how other critical uses will be accommodated, source to be used, distribution priority to residents, etc. Such permit when issued to be valid for only 30 days, with provision for longer lasting permits if deemed necessary by director and council. Failure to comply with remedial plans warrants refusal of extensions, weekly progress resorts must be submitted by golf course owner, amounts not to exceed 250,000 gpd.

1996 - Ordinance 2516 further amends County Code 19.71.055 by adding Section E, entitled re-seeding or re-grassing, enabling a golf course owner to apply for use of up to 27,000 gpd PER FAIRWAY to supplement non-potable irrigation sources in order to establish new plantings. One fairway to be irrigated at a time. No more than 4 fairways per calendar year. Re-seeding or re-grassing allowable only between May and October; each fairway to be re-seeded or re-grassed NO MORE THAN ONCE under this provision. Reiterates several conditions listed above: no permanent interconnections; provision for other priority uses; if irrigation emergency occurs during already-permitted re-seeding or regrassing, the replanting activity may continue, but only such that the combined total of re-grassing or re-seeding and the other emergency use does not exceed 250,000 gpd.

1997 - Lana`i Water Working Group Report passed February '97.

1998 - Ordinance 2743 decreases Manele Project District from 872.25 to 868 acres. Major change is reduction of 51 acres of single family, addition of 25 acres of multi-family, addition of about 19 acres of open space, and addition of 6.6 acres to hotel site.

1999 - Board Resolution No. 5 (1999) establishes the Lana`i Lana‘i Water Advisory Committee. Composition: 2 voting members from Lana`i Company, 2 voting members from Lanai‘ans for Sensible Growth; 1 voting member from the Lana1i Planning Commission; councilmember from the island of Lana`i, with voting rights; 3 residents of Lana`i who are not affiliated with any of the aforementioned entities; 1 non-voting member from Lanai‘ans for Economic Growth and Stability, DWS as the lead agency and staffing source, and other county and state agencies such as Planning, Public Works, CWRM, DLNR-DOFAW or others to participate as desired, but without voting privileges. Executed on March 16th, 1999.

2001 - Lana`i Forest and Watershed Partnership MOU signed. Efforts to construct fence and management undertaken by multi-entity partnership.

200 - First increment of Lana‘i Hale Summit Fence completed.

2008 - WELL 15 (briefly aka Well 11) - drilling permit issued. Well is not yet drilled as of 2009 update.

Sources:

Hobdy, Robert; “Lana`i - A Case Study: The Loss of Biodiversity on a Small Hawai‘ian Island”; *Pacific Science*; vo. 47, no. 3; pp 201-210, University of Hawai`i Press, © 1993
Lana`i Community Plan (1998); prepared for the Maui County Council by the Lana`i Planning Commission; the Maui County Department of Planning; the Lana`i Citizen Advisory Committee; and Consultants; Community Resources, Inc. & Michael T. Munekiyo Consulting, Inc.
CWRM; Numerical Ground Water Model for the Island of Lana`i, Hawai‘i ; by Roy Hardy; CWRM-01; State Commission on Water Resources Management; well data base dated 2001

Lana`i Plant Communities

Range: The Lana`ihale Cloud Forest ranges from about 2,100' (700 meters) to the summit at about 3,370' (1,023 meters) in elevation, along the ridgetops and gulches of the mountain summit in Lana`i. The Lana`ihale forest covers all or part of the Kealiakapu, Kealia Aupuni, Palawai, Kamao, Kaohai, Pawili, Kaunolu, Kalulu, Maunalei, and Kamuku ahupua`a. Access from town is achieved via the Lana`ihale summit road, and by various 4 wheel drive roads to the northeast end.

Because of the low elevation of this cloud forest, it contains a strong mix of mesic species and is immediately surrounded by mesic forest and shrubland. These communities, where contiguous, are not entirely distinct. Therefore, it is recommended that management measures be extended to the buffering mesic areas. The Lana`ihale mesic forest ranges from 900' (300 meters) to 2,400' (800 meters) in steep gulch lands surrounding the summit cloud forest, and extends into the summit forest.

Plant Taxa and General Plant Community Types:

Native species commonly found in the area include `ohi`a, pukiawe, `olapa, a`ali`i, mamane and uluhe.

A list of flowering plants, indicating endangered, proposed, candidate and SOC (Species of Concern) plants of Lana`i is provided in Figure 6-5. Also provided are lists of the ferns, lichens and hepatics, of Lana`ihale.

Native plant communities have been classified by Dr. Samuel Gon, III of The Nature Conservancy according to an adaptation of the method used by Wagner, Herbst and Sohmer in the Manual of the Flowering Plants of Hawai`i. According to this classification, predominant plant communities in Lana‘ihale include a mixture of:

Metrosideros polymorpha / Cheirodendron sp. (‘Ohi`a / `Olapa or Lapalapa)
Metrosideros polymorpha / Dicranopteris spp. (`Ohi`a/Uluhe)
Dicranopteris sp. lowland wet shrubland (Uluhe)

Also present are:
Dodonaea spp / Stypelia tameiameiae (`A`ali`i / Pukiawe)
Osteomeles anthyllidifolia (`Uulei)
Acacia koa (Koa)
Diospyros sanwicensis (Lama)
Nestegis sandwicensis (Olopua or Lapalapa)

Loss of Plant Communities

According to Hobdy (93) About 30% of native Hawai‘ian vascular plants have been recorded in Lana`i, roughly 345 species. Of these, about 70 have disappeared, including 8 endemics. The Bishop Museum Flowering Plant Checklist lists 205 endemic and indigenous species. The U.S. Fish & Wildlife Service lists 36 endangered, 3 proposed, 3 candidate and 25 “species of concern” (hereinafter SOC).

The attached Figure 6-5 lists these endangered, proposed, candidate, and SOC plants, of which 35 are found in Lana‘ihale. Hobdy has developed a user-friendly classification of native plant communities on Lana`i based on moisture, elevation, plant community and soil type. The following Figure, from his 1993 article (*Case Study*), paints a dismal picture of what has already happened to biodiversity on Lana`i. This Figure more or less answers the question “What have we lost so far” (or “what have we not yet lost”)?

Vegetation Community	Annual Moisture	Percent Remaining	Percent of Island
Cloud forest	35-50" (875-1250 mm)	30% remains	2%
Mesic forest	27-35" (675-875 mm)	3% remains	7%
Dry forest	20-27" (500-675 mm)	2% remains	36%
Arid grassland & shrubland	8-20" (200-500 mm)	20% remains	49%
Coastal and strand	8-18" (200-450 mm)	3% remains	6%

Source: Hobdy, 1993

Status of Remaining Plant Communities

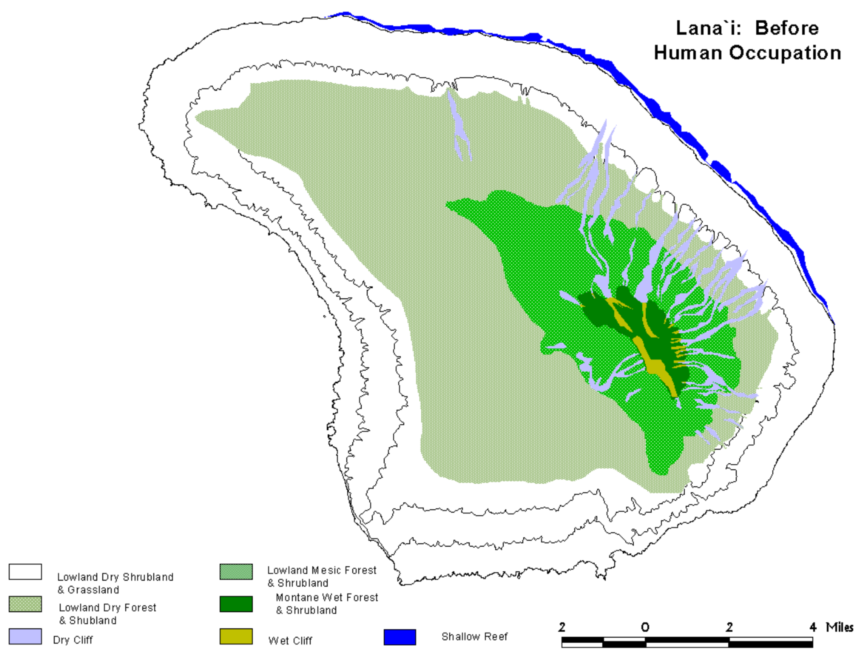
The Nature Conservancy, using a classification with more segregation of categories, but based on the same sorts of considerations, divides the island into seven main types of communities. This Figure does not look at the overall percent of native community remaining, but rather asks the question, within the remaining pockets of native plant communities, what percent of plants is actually native? In other words, the Figure below answers the question “How pristine is the remaining native cover?”

VEGETATION COMMUNITY	ELEVATION RANGE	PERCENT NATIVE
wet cliff	2,700-3,300'(823.5 - 1,006.5 m)	75%
montane wet forest & shrubland	2,800-3,300'(854 - 1,006.5 m)	75%

lowland mesic forest &shrubland	1,500-3,300(457.5 - 1,006.5 m)	50%
lowland dry forest & shrubland	1,600-1,800'(488 - 549 m)	25%
dry cliff	400-3,300'(122 - 1,006.5 m)	75%
lowland dry shrubland & grassland	500-3,200'(152.5 - 976 m)	50%
non-native	0-3,100' (0 - 945.5 m)	5%?

The map below shows estimated ranges of the pre-contact extent of the communities listed above.

FIGURE 6-4 Lana'i Vegetation Before Human Occupation



Threats to Lana'i Hale Plant Communities

Prior to Polynesian colonization, Lana`i was covered with native vegetation. The introduction of Polynesian agriculture and fire modified the vegetation primarily in the coastal and lowland areas. The arrival of Europeans accelerated the destruction, with the introduction of ranching, cattle, sheep, pineapple, cane, goats, pigs, etc, axis deer, mouflon sheep.

Although the Lana`ihale ecosystem is unique, many of the threats to the watershed affect the entire island. The major threats include habitat alteration, invasive plants & animals, erosion, pathogens, human activity and drought. These are further described in Figures 6-7 and 6-8, which follow.

FIGURE 6-5 Flowering Plant Species on Lana`i - Endangered, Candidate, Threatened, Species of Concern

found in Lana`ihale	Status	Family	Genus	Species	SubSpecies (var. if indicated)	Description
	E	Amaranthaceae	Achyranthes	splendens	var. rotunda	
	E	Apiaceae	Spermolepis	hawaiiensis		tiny, seasonal shrub in the Parsley family. found in dry areas 1,000-2,500'
Y	E	Asteraceae	Bidens	micrantha	kalealaha	erect, perennial herb in the Sunflower family. found in dry to mesic forests and shrublands. 1.5-5' tall. Lana`i Hale.
Y	E	Asteraceae	Hesperomannia	arborescens		small, shrubby tree in the Sunflower family, 5-15' tall. slopes and ridges of wet forests. (1,000'-2,200')
	E	Asteraceae	Tetramolopium	lepidotum	lepidotum	white flowered daisy in the Sunflower family found in dry lowland areas (500'-1,000')
	E	Asteraceae	Tetramolopium	remyi		shrub in the Sunflower family found on dry exposed ridges or flats in lowland & dry shrubland areas (500'-2,500')
Y	E	Camapanulaceae	Clermontia	obliongifolia	mauiensis	terrestrial shrub or tree in the Bellflower family, with dark, smooth glossy green leaves, and white calyx type flowers with white or purple stamens. 6-21' tall. orange berries. mesic valleys to wet forests, 1,200-3,600'.
Y	EX	Camapanulaceae	Cyanea	lobata	baldwinii	four to seven foot tall palm-like shrub in the Bellflower family. mesic to wet forest (2,000' - 3,000') , extinct. a single plant was found in 1919 by Munro. The same plant was still alive as of 1935. Munro propagated seeds from this plant, and they survived around his home site until at least 1940.
Y	E	Camapanulaceae	Cyanea	gibsonii		was Cyanea macrostegia gibsonii. palm-like lobeliad tree in the Bell-flower family, 3-21' tall. bird-pollinated, found in wet to mesic areas (2,490-3,180')
Y	E	Campanulaceae	Brighamia	rockii		}lula, h~h~. succulent in the Pink family. has stout, unbranched stem, thicker at base. 3-15' tall. calyx type flower has white corolla with green to yellowish green tube. grows on windward sea cliffs to 1,400'. also found in Maunalei valley.
Y	E	Caryophyllaceae	Silene	lanceolata		subshrub in the Pink family. small flowers at end of stems, in clusters, with smooth white petals. reddish brown seeds. dry to mesic areas, 900'-5,490'. Maunalei Valley .
	E	Convolvulaceae	Bonamia	menziesii		
	E	Cyperaceae	Cyperus	trachysanthos		
Y	E	Cyperaceae	Gahnia	lanaiensis		tufted, perennial Sedge, 980'-3,020' range, first described at 2,919' elevation
Y	E	Cyperaceae	Mariscus	fauriei		low-growing Sedge found in mesic shrubland (1,000'-2,500')
Y	E	Fabaceae	Caesalpinia	kavaiensis		uhi uhi, k~wa`u, kea shrub or tree in the Pea family. 12-30' tall, thick rough dark gray bark, pinate (divided) leaves, red flowers. dry to mesic forests 240'-2,760' . Hawaiians made spears and fishing implements from the hard, durable wood.
	E	Fabaceae	Sesbania	tomentosa		prostrate shrub in the Pea family found in lowland coastal areas 50'-1,500'
	E	Fabaceae	Vigna	owahuensis		twining vine in the Pea family, found in dry lowland areas 50' - 1,500'
	E	Gentianaceae	Centaurium	sebaeoides		ephemeral herb in the Gentian family, found in coastal habitats 50'-750' elevation
Y	E	Gesneriaceae	Cyrtandra	munroi		shrub in the African violet family found in lowland wet forest (980'-2,202')
	E	Gooeniaceae	Scaevola	coriacea		dwarf naupaka. prostrate perennical herb in the Goodenia family.
Y	E	Lamiaceae	Phyllostegia	glabra	var. lanaiensis	perennial herb in the mint family lowland mesic to wet forest 2,490' - 3,180' gulch bottoms & sides, steep areas
	E	Malvaceae	Abutilon	eremitopetalum		shrub in the mallow family, bird pollinated lowland dry forest, historical range 690'-1,710' currently only at around 1,100'
	E	Malvaceae	Abutilon	menziesii		shrub in the mallow family, bird pollinated found in low, dry shrubland (500-1,400')

	E	Malvaceae	Hibiscus	brackenridgei	brackenridgei	sprawling, deciduous shrub found in dry, lowland areas (500'-2,000')
	E	Poaceae	Cenchrus	agrimonioides	agrimonioides	
	E	Poaceae	Panicum	fauriei	var. carteri	
	E	Portulacaceae	Portulaca	sclerocarpa		perennial herb in the purslane family. pale, grayish-green leaves. clusters of 3-6 flowers at the end of stems, white or pink metals about 10 mm long, with tufts of hair underneath. likes dry habitats, 3,090'-4,890'. Found on Po`opo`o islet off the coast of Lana`i.
	E	Rhamnaceae	Gouania	hillebrandii		
Y	E	Rubiaceae	Gardenia	brighamii		small tree in the coffee family, up to 15' tall. dry forest species. 1,050' -1,560'. Kanepu‘u.
	E	Rubiaceae	Hedyotis	mannii		subshrub in the Coffee family. mesic to wet forest.
Y	E	Rutaceae	Zanthoxylum	hawaiiensis		moderate sized tree in the Rue family. found in mesic forest habitats. 2,000' - 4,500'
Y	E	Santalaceae	Santalum	freycinetianum	var. lanaiensis	small gnarled tree (Sandalwood) w/ bright red flower clusters, bird pollinated, lowland dry to high-elevation mesic, or wet
Y	E	Solanaceae	Solanum	incompletum		pÇpolo kã mai. shrub in the Nightshade family. Up to 9' tall. reddish prickles on stem. mesic to dry forest. 1,800' - 6,100'.
Y	E	Urticaceae	Neraudia	sericea		9' - 15' shrub in the Nettle family. Mesic to dry forest. 2,000'-3,000'.
	E	Violaceae	Isodendrion	pyrifolium		
Y	E	Violaceae	Viola	lanaiensis		subshrub in the Violet family, lowland wet forest to lowland mesic shrubland 2,200' - 3,200'
Y	PE	Loganiaceae	Labordia	tinifolia		k~makahala. Shrub or small tree in the Logania family. 3.5 - 30' tall. Mesic to wet forest, ridges, slopes or understory of open canopy. 900' to 2,300'.
Y	PE	Rubiaceae	Hedyotis	schlechten-dahliana	var. remyi	trailing herbaceous shrub in fern understory. Coffee family. 2,500' - 3,000'
Y	PE	Rutaceae	Melicope	munroi		
Y	C	Caryophyl-laceae	Schiedea	pubescens	var. pubescens	
	C	Fabaceae	Canavalia	pubescens		found in mesic to dry areas, bird pollinated
Y	C	Laminaceae	Phyllostegia	imminuta		sub-erect perennial shrub in the Mint family. mesic gulches of Lana`i Hale. 2,040' - 2,190'
Y	SOC	Asteraceae	Bidens	campylotheca	campylotheca	erect perennial herb in the Sunflower family. 2 ' - 12' tall. wet to mesic areas 300'-3,600'.
	SOC	Asteraceae	Bidens	mauiensis		decumbent perennial herb in the Sunflower family 0.3' - 1' tall. coastal bluffs, dunes and dry slopes. 150' - 1,800'.
Y	SOC	Agavaceae	Pleomelde	fernaldii		small, branched tree in the Agave family w/palm-like leaves mesic to dry forest 1,600' - 3,000'
Y	SOC	Araliaceae	Tetraplasandra	kavaiensis		tallish (24' - 75') tree in the Ginseng family. mesic to wet forest. 1,950' - 4,800'.
	SOC	Asteraceae	Tetramolopium	conyzoides		
	SOC	Brassicaceae	Lepidium	bidenatum	var. owahiense	
Y	SOC	Campanulaceae	Delissea	lanaiensis		four to six foot tall palm-like shrub in the Bellflower family. mesic to wet forest (2,000' - 3,000') , extinct?
	SOC	Capparaceae	Capparis	sandwichiana		
	SOC	Caryophyl-laceae	Schiedea	menziesii		Sprawling subshrub in the Pink family. Found in Maunalei valley. dry forest ledges and cliffs. 90' - 1,020'
	SOC	Euphorbiaceae	Chamaesyce	celastroides	laehiensis	
	SOC	Fabaceae	Acacia	koaia		smallish, gnarled tree in the Pea family. less than 35' high. mesic and dry, open habitats. wood is harder and pods narrower, than those of Acacia koa. 180' - 6,180'
Y	SOC	Gesneriaceae	Cyrtandra	lydgatei		shrub in the African violet family. 2' - 8.5' tall. flowers at ends of stalks, in dense clusters. leaves in unequal pairs. white berries. wet forest (1,500' - 2,700'). Maunalei Valley and Hale.
	SOC	Lamiaceae	Haplostachys	munroi		
Y	SOC	Malvaceae	Hibiscadelphus	crucibracteatus		tree up to 18' tall in Mallow family. rounded crown. trunk about 16 cm. diameter. Puhielelu Ridge in Lana`i about 2,250'.
Y	SOC	Poaceae	Dissochondrus	bifloris		tall, perennial Grass with narrow, spike-like tufted flowers. sharply keeled, flat blades. diverse mesic forests, often on slopes. 1,400' - 3,150'.
	SOC	Poaceae	Eragrostis	deflexa		
	SOC	Poaceae	Eragrostis	mauiensis		
	SOC	Poaceae	Panicum	ramosius		
	SOC	Portulacaceae	Portulaca	molokiniensis		`Ihi. stout perennial herb in the Purslane family. older stems have a pale, corky layer of second-ary growth. headlike clusters of flowers with white or pink petals, 10 mm long. dark brown seeds. coastal areas, sea cliffs and steep, rocky slopes. 30-345'.

	SOC	Portulacaceae	Portulaca	villosa		perennial herb in the Purslane family. erect sub-shrub. pale, grayish-green leaves. dark, reddish-brown seeds. clusters of 3-6 flowers at the end of stems, white or pink metals 8- 10 mm long, with tufts of hair underneath. dry rocky or coralline areas, 0-1,200'.
Y	SOC	Rubiaceae	Morinda	trimera		
Y	SOC	Rutaceae	Melicope	hawaiensis		Mokihana, kãkae moa, manena. 9' - 30' tall shrubs or trees in the Rue family. smooth, pale brown bark. dry to mesic areas, 1,830' - 3,660'.
	SOC	Santalaceae	Exocarpos	gaudichaudii		Heau, a`u, sandalwood tree. small tree or shrub 4.5 - 21' tall. found on ridges in mesic forest and shrub land. 750' to 1,075'. bears small fruit with hard seed.
	SOC	Solanaceae	Nothocsestrum	latifolium		
Y	SOC	Thymelaeaceae	Wikstroemia	bicornuta		}ki`a, kauhi. straggling shrub to small tree in the }ki`a family. Dark green leaves, lighter on lower surface. 3'-7' tall. 2,700' - 3,150' elevation. wet forest. highest ridge of Lana`i.
	E		Ctentis	squarmigera		endangered terrestrial fern found in Lana`i Hale.

FIGURE 6-6 Two Native Lana'i Species: Kawau and Cyrtandra

The left column indicates whether the species is found in Lana`ihale. Descriptions are provided for Lana`ihale species.

This Figure was compiled from the Bishop Lists, US F&WS list, the Manual of Flowering Plants of Hawai'i (Wagner, Herbst and Sohmer, 1990), with guidance and assistance from Robert Hobdy, formerly of the State DLNR Division of Forestry and Wildlife.

FIGURE 6-7 Threats to Lana'i's Flowering Plant Species

Threat	Explanation of Problems Caused by Threat
Habitat Alteration	The small size of remaining populations of certain species can leave them vulnerable. Loss of numbers can lead to loss of genetic vigor, increased susceptibility to disturbances & diseases and other problems. The small extent of remaining intact ecosystems may prove too small to support certain target species Introduction of exotic species, particularly if these are invasive, can destroy large tracts of land very rapidly Poorly planned management efforts can inadvertently alter habitat.
Invasive plants	A list of invasive plant species needing control in and around Lana'ihale is provided in Figure 8. This Figure also describes some of the problems associated with these plants.
Invasive animals	examples below
Axis Deer (Axis axis)	Axis deer were introduced 1920s. After elimination of goats in 1981, deer moved upland and numbers have increased dramatically. It is possible that a psyllid leafhopper of koa haole contributed to this movement upland, since koa haole had been major source of food for deer in the lowlands. In 1988, the deer population reached 10,000. The majority of deer are noted just mauka of the kiawe belt on the north east side of the island. DOFAW staff also notes that there appears to be evidence that there may be two somewhat distinct populations of axis deer on Lana`i: one makai (in the kiawe belt) and the other mauka (in and around Lana'ihale and upper elevations). This theory is based on observations of game trails that extend upward from the kiawe and downward from the mesic forest, but seem to be discontinuous at or about mid-elevation. Axis deer are considered the primary threat to the watershed at this time, largely due to their behaviours of browsing, trampling and rubbing, described further below.
	Browsing damages or destroys plants by eating green portions
	Trampling removes vegetation, removes leaf litter important to soil-water relations promotes erosion, compacts soils, opens areas to invasive plants and animals (carried as seed in digestive tracts, droppings, fur, etc.)
	Rubbing destroys cambium layer of trees, esp. from bucks rubbing felt off antlers
Mouflon Sheep (Ovis musimon)	Browse on native vegetation, trample, etc. Introduced in 1954. Well adapted to ridge and gully lands
Sheep (Ovis aries)	catastrophically large numbers of sheep around the turn of the century (50,000) Greatly reduced by 1920, eliminated entirely from Lana`i by the late 1950s.

Goats (Capra hircus)	introduced in early 1800s eliminated 1981 trampling, grazing, erosion, etc.
Cattle (Bos Taurus)	eliminated about 1950 trampling, grazing, erosion, etc.
Pigs (Sus scrofa)	first piggery 1911, pigs eradicated in 1930 by George Munro trampling, wallows, grubbing, erosion, etc.

Birds	Loss of native pollinators (birds, insects) causes threat to remaining habitat Introduction of pest birds that feed on native insects that pollinate native plants Introduction of pest birds that compete with native birds for food, nesting sites, etc. Examples include the Japanese White Eye and the Japanese Bush Warbler, which compete for food & nesting sites, or Cardinals, believed to feed on sandalwood fruits. More information is found in Figure 13. Introduction of bird diseases including avian malaria (protozoan), avian pox (virus) Introduction of insects carrying avian diseases, especially mosquitoes, which carry avian malaria and avian pox
Rats (Rattus rattus rattus, Rattus exulans Rattus norvegicus)	Rats feed on fruits, flowers and seeds of native plants, girdle or strip branches, and prey on native birds. Rattus rattus rattus, the arboreal black rat, believed to have had the greatest impact among rats and mice on flora and fauna.
Mice (Mus domesticus)	Like rats, mice feed on fruits and flowers of Hawai‘ian plants, and/or girdle and strip branches. Sandalwoods are especially vulnerable to rodent damage. Predation on seeds reduces reproductive viability.
Slugs	Slug damage and live slugs have been observed on native species, such as Viola lanaiensis). Seedlings and young tender shoots are especially susceptible
Insects	Descriptions of problem insect species are found in Figure 9.
Pathogens	Spike disease - affects sandalwood in India, believed to be in Hawai‘i Santalum heart rot - affects sandalwood (mostly dry to mesic, but some in Lana‘ihale) Santalum seed fungus - affects sandalwood (mostly dry to mesic, but some in Lana‘ihale)
Humans	Human and animal traffic in and around remaining communities Example - roughly half of the remaining plants of a certain species (Gahnia lanaiensis) grow adjacent to the Munro Trail. conversion of native ecosystems to agricultural uses , pasture Ex: Most of dryland habitat long ago cleared for pasture, harming Abutilon eremitopetalum, Abutilon menziesii, Tetramolopium remyi) pineapple cane vandalism illegal collection fires resulting from human activities or spread by human-introduced species inadvertent damage from poorly executed management efforts

Erosion	Self-perpetuating cycle. Animals lead to compaction of soils, loss of plants, and erosion. Erosion leads to more loss of plants. Loss of plants leads to more erosion
Drought	May be exacerbated by diminishing fog drip. Exacerbated by loss of ground cover in the forest - ground dries quickly & stays dry longer can also lead to viscious cycle . Die back of plants leads to less fog drip. Less moisture leads to more die back of plants. This cycle increases threats from fire and erosion.

A list of invasive plants that pose threats to the watershed is provided in Figure 6-8. Typical invasive behaviors include crowding out other vegetation, displacement of understory, allelopathy or release of compounds that inhibit growth of other plants, and provision of fire fuel or stimulation. Among the more damaging are christmas berry (*Shinus terebinthifolius*), strawberry guava (*Psidium cattleianum*), manuka (*leptospermum scoparium*), guava and *Tibouchina herbacea.*

FIGURE 6-8 Invasive Plants in Lana'ihale and Surrounding Mesic Areas

Genus	Species	Common Name	Description
Andropogon	viginicus	broomsedge	boggy open mesic and dry habitats, releases allelopathic substances. fire stimulated, and fuel for fires. Dormant during rainy season. May enhance erosive properties.
Asclepias	physocarpa	balloon plant	erect shrub in the milkweed family. grows up to about 6' in height. highly invasive in disturbed areas. seeds dispersed by wind.
Hedychium	gardnerianum	kahili ginger	agressive invader of wet forests, especially well lit areas and streambeds. dispersed by birds. also spreads vegetatively. forms large continuous clumps, displaces understory.
Lantana	camara	aggressive grass. crowds out other species. carries fire, fire stimulated. seeds dispersed by wind. affects mostly dryland areas. Introduced to Lana`i in two places, on the north end and on the golf course. Known populations were removed, but follow-up is needed.	thorny shrub, forms impenetrable thickets, crowding out other plants. biological controls have reduced aggressiveness somewhat. especially bad in dry lowland areas. normally does not grow over 15' hight, but can get to 40' if supported.
Leptospermum	scoparium	manuka	New Zealand shrub. Crowds out native vegetation, especially on Lana`i Hale.
Leucacaena	leucocephala	koa haole	nitrogen fixing tree, forms dense thickets, excludes other vegetation, esp bad in low, dryland areas,but also affects mesic to wet areas.
Melinis	minutiflora	mollasses grass	dry mountain ridges, mesic to wet forests. forms dense mat, smothers other plants. fuel for fires. spreads fires.
Myrica	faya	firetree	rapidly growing, invades mesic and wet habitats. Forms dense, monotypic stands. Nitrogen fixing, capable of altering ecosystems. Suspected of allelopathic activity. Grows from 984' to the summit. Colonizing. Lana`i Hale south slope has one of the major infestations in the state.
Panicum	maximum	guinea grass	drougt resistant, allelopathic, carries fire under dry conditions, highly invasive. Especially problematic in dry areas.
Paspalum	conjugatum	Hilo grass	low growing grass. spreads in shady partial openings and occupies distrubed areas in forst understory. not as habitat-altering as molasses grass
Pennisetum	clandestinum	kikuyu grass	invades dry, mesic and wet forest habitats. forms thick mat that prevents reproduction of native taxa.
Pennisetum	setaceum	fountain grass	aggressive grass. crowds out other species. carries fire, fire stimulated. seeds dispersed by wind. affects mostly dryland areas. Introduced to Lana`i in two places, on the north end and on the golf course. Known populations were removed, but follow-up is needed.
Pluchea	symphytifolia	sourbush	forms dense thickets in dry to wet habitats
Prosopis	pallida	kiawe	highly invasive tree to dry areas and lowlands. Overtops other lowland vegetation.
Psidium	cattleianum	strawberry guava	one of the most agressive exotic invasive species. forms dense stands, capable of displacing all other palnt species. Has allelopathic properties. Fruit is dispersed by birds.
Rubis	rosifolius	thimbleberry	low to mid height, weak-stemmed shrub. Has small red berry and prickles on stems. Grows in mesic to wet areas
Schinus	terebinthifolius	christmas berry, brazilian pepper	tree. forms dense monotypic stands. found in Kanepu`u and on the lower slopes of Lana`i Hale. Massive dispersal by birds follows fruiting in Nov.-Dec. Christmasberry invades dry to mesic sites
Tibouchina	herbacea	aggressive grass. crowds out other species. carries fire, fire stimulated. seeds dispersed by wind. affects mostly dryland areas. Introduced to Lana`i in two places, on the north end and on the golf course. Known populations were removed, but follow-up is needed.	wet forest invader, crowds out native species. Especially invasive where native cover has been disturbed

FIGURE 6-9 Native Lana'i Ferns - Amau and Uluhe

Ferns

Native Hawai'ian ferns help to collect and hold water, and to improve water holding capacity of the soils. They help to limit loss of water through evapotranspiration by keeping the forest floor cool.

Native ferns serve as nesting sites for certain native birds. Munro records certain native Lana`i bird species nesting in and amongst ferns, possibly to help hide themselves from the predatory Pueo (native owl).

Like all other species, ferns also contributed to the general biomass and level of soil nutrients.

The following Figure describes some of Lana'i's native ferns.

FIGURE 6-10 **Pteridophytes (Ferns) Native to Lana`i**

Family	Genus	Species
Psilotaceae	Psilotum	nudum
		complanatum
Lycopodiaceae	Phlegmariusrus	filiformis
		phyllanthus
	Huperzia	erosa
		x. gillettii
		serrata
		x sulcinervia
	Lycopodium	venustulum
	Palhinhaea	cernua
Selaginellaeae	Selaginella	arbuscula
Botrychiaceae	Sceptridium	subbifoliatum
Ophioglossaceae	Optioglosum	petiolatum
		polyphyllum
	Ophioderma	pendula
Marattiaceae	Marattia	douglasii
Gleicheniaceae	Dicranopteris	linearis
	Diplopterygium	pinnatum
	Sticherus	owhyhenis
Schizaeaceae	Schizaea	robusta
Pteridaceae	Adiantum	capillus-veneris
	Coniogramme	pilosa
	Pteris	cretica
		excelsa
		x hillebrandii
		irregularis
	Doryopteris	decipiens
		decora
		subdecipiens
	Pellaea	ternifolia
Vittariaceae	Haplopteris	zosterifolia
Hymenophyllaceae	Gallistopteris	baveriana
	Gonocormus	saxigragoides
	Mecodium	recurvum
	Sphaerocionium	lanceolatum
		obtusum
	Vandenboschia	cyrtotheca
		davallioides
		draytoniana
Cyatheaceae	Cibotium	chamissoi
		glaucum
		menziesii
Dennstaedtiaceae	Hypolepis	hawaiiensis
	Microlepia	strigosa
	Pteridium	decompositum
Lindsaeaceae	Lindsaea	repens var. macroaeana
	Odontosoria	chinensis
Thelypteridaceae	Pseudophegopteris	keraudreniana
	Cyclosorus	cyatheoides
		hudsonianus
		interruptus
		sandwicencis
	Thelypteris	globulifera
Blechnaceae	Dodia	kunthiana
	Sadleria	cyatheoides
		pallida
		souleyetiana
		squarrosa
Aspleniaceae	Asplenium	acuminatum
		x adiantum-nigrum
		aethiopicum

		contiguum
		cookii
		horridum
		lobulatum
		macraei
		nidus
		nomale
		sphenotomum
	Hymenasplenium	excisum
		unilaterale
	Diellia	erecta
Woodsiaceae	Athyrium	microphyllum
	Deparia	fenzliana
		marginalis
		prolifera
	Diplazium	arnottii
		molokaiense
		sandwichianum
Dryopteridaceae	Ctenitis	latifrons
		squamigera (endangered)
	Cyrtomium	caryotideum
	Dryopteris	fusoatra
		glabra
		mauiensis
		sandwicensis
		unidentata
		wallichiana
	Nothoperanema	rubiginosa
	Tectaria	cicutaria var. gaudichaudii
	Elaphoglossum	aemulum
		crassifolium
		paleaceum
		parvisquameom
		pellucidum
		wawrae
	Nephrolepis	cordifolia
		exaltata ssp. hawaiiensis
Grammitadaceae	Adenophorus	abietinus
		hillebranii x. tripinnatifidus
		hymenophylloides
		tamariscinus
	Grammitis	hookeri
		tenella
	Lellingeria	saffordii
	Oligadenos	pinnatifidus
Polypodiaceae	Lepisorus	thumbergianus
	Microsorum	spectrum
	Polypodium	pellucidum
Courtesy of Herbarium Pacificum, Bishop Museum		

Hepatics, Mosses and Lichens

The health of a watershed, and therefore its water catchment ability, can be rapidly assessed by the abundance of pendulous lichens and mosses on the branches of the trees.

Lichens and mosses are excellent interceptors of moisture from fog. Hanging *Thalli* have a high surface area to volume ratio, which means more surface area to intercept rainfall. Mosses and lichens help to keep the temperature in the cloud forest cool, allowing for more water condensation.

The diversity of a healthy epiphyte and bryophyte community also lends stability. A monotypic plant community is ultimately unstable and more vulnerable to outside threats.

Mosses and lichens provided food and home to various species. For instance, *Usnea* species are often inhabited by rare, cryptic spiders. *(Personal communication: Dr. Cliff Smith of UH Botany Dept.)*

Figures 6-11, 6-12 and 6-13 list native mosses, lichens and hepatics of Lana`i, respectively, based on information provided by Bishop Museum. Dr. Christopher Puttock, Collection Manager of Botany for the Bishop Museum, has indicated that the list of hepatics is likely a vast underestimate, and suggests that the true list "will probably be similar to that of Molokai (91 taxa) and perhaps half of Maui (137)".

Threats to Mosses and Lichens and Algae

Threats to ferns, mosses, lichens and algae are largely similar to those facing the flowering plant communities described in the Figure above. Of particular concern for the survivial of these specific communities are:

- trampling, browsing, ungulate traffic
- insect pests such as the Chinese two-spotted leaf- hopper
- exotic weeds
- loss of critical population size / habitat size
- predation by introduced rodents, snails, slugs, birds
- erosion
- fire damage
- introduced pathogens

(Sources: Personal communications, Dr. Cliff Smith of UH Botany Dept., and Dr. Christopher Puttock of Bishop Museum Dept. of Natural Sciences)

FIGURE 6-11 Mosses on Lana`i

GENUS	SPECIES	VARIETY	BAUTHOR	TAUTHOR
Acroporium	fusco-flavum	fusco-flavum	(Par.) Broth.	
Aerobryopsis	wallichii		(Brid.) Fleisch.	
Anoectangium	euchloron		(Schwaegr.) Mitt.	
Baldwiniella	kealeensis		(Reichardt)Bartr.	
Bryum	angustirete		Broth.	
Campylopus	fumarioli		C. Mull.	
Campylopus	hawaiicus	hawaiico-flexuosus	(C. Mull.) Jaeg.	(C.Mull.) Frahm
Campylopus	hawaiicus	hawaiicus	(C. Mull.) Jaeg.	
Campylopus	umbellatus		(Arnott) Par.	
Daltonia	contorta		C. Mull.	
Dicranella	hochreuteri		Card,	
Distichophyllum	freycinetii	freycinetii	(Schwaegr.) Mitt.	
Distichophyllum	paradoxum		(Mont.) Mitt.	
Ectropothecium	sandwichense		(Hook & Arnott.)	
Ectropothecium	viridifolium		Bartr.	
Entosthodon	subintegrus		(Broth.) Miller, H.	
Eurhynchium	vagans		(Jaeg.) Bartr.	
Fissidens	bryoides		Hedw.	
Fissidens	delicatulus		Angstr.	
Fissidens	elegans		Brid.	
Fissidens	hoei		Pursell	
Fissidens	kilaueae		Hoe & Crum	
Fissidens	lancifolius		Bartr.	
Fissidens	nothotaxifolius		Pursell & Hoe	
Glossadelphus	zollingeri	filicaulis	(C. Mull.) Fleisch.	(Fleisch.) Fleisch.
Glossadelphus	zollingeri	filicaulis	(C. Mull.) Fleisch.	(Fleisch.) Fleisch.
Holomitrium	seticalycinum		C. Mull.	
Homaliodendron	flabellatum		(Sm.) Fleisch	
Hookeria	acutifolia		Hook. & Grev.	
Hookeria	acutifolia		Hook. & Grev.	
Isopterygium	albescens		(Hook.) Jaeg.	
Leucobryum	gracile	gracile	Sull.	
Leucobryum	pachyphullum		C. Mull.	
Leucobryum	seemannii	seemannii	Mitt.	
Macromitrium	brevusetyn		Mitt.	
Macromitrium	emersulum		C. Mull.	
Macromitrium	piliferum		Schwaegr.	
Macromitrium	reinwardtii		Schwaegr.	
Palamocladium	wilkesianum	wilkesianum	(Sull.) C. Mull.	
Palamocladium	wilkesianum	sciuroides	(Sull.) C. Mull.	(C.Mull.) Wijk &
Philonotis	hawaica		(C. Mull.) Broth.	
Philonotis	turneriana	turneriana	(Schwaegr.) Mitt.	
Pogonatum	tahitense		Schimp. ex	
Racopilum	cuspidigerum		(Schwaegr.)	

Rhizogonium	pungens		Sull.	
Rhizogonium	spiniforme		(Hedw.) Bruch	
Sematophyllum	hawaiiense		(Broth.) Broth.	
Taxithelium	mundulum		(Sull.) Bartr.	
Thuidium	hawaiense		Reichardt	
Tortella	humilis		(Hedw.) Jenn	
Tortella	tortuosa		(Hedw.) Limpr.	
Trichosteleum	hamatum		(Dozy & Molk.)	
Trichosteleum	bartramii		Mill	
Vesicularia	perviridis		(Angstr.) C. Mull	
Weissia	ovalis		(Williams) Bartr.	
Courtesy of Herbarium Pacificum, Bishop Museum				

FIGURE 6-12 Lichens of Lana`i

GENUS	SPECIES	VARIETY	BAUTHOR
Anaptychia	sorediifera	colorata	(Muell. Arg.) Du Reitz & Lynge
Anthracothecium	sandwicense	convexum	Zahlbr.
Anthracothecium	sandwicense		Zahlbr.
Arthonia	cinnabarina		(DC.) Wallr.
Arthopyrenia	phaeoplaca		Zahlbr.
Arthotelium	macrothecum		(Fee) Mass.
Bacidia	alutacea		(Kremp.) Zahlbr.
Bacidia	alutacea	minarum	(Kremp.) Zahlbr.
Bacidia	choriciae		Zahlbr.
Bacidia	medialis		(Tuck.) Zahlbr
Bacidia	personata		Malme
Bacidia	sandwicensis		H. Magn.
Bombyliospora	domingensis		De Not
Buellia	subcallispora		H. Magn.
Catillaria	cuvatula		H. Magn.
Catillaria	intermixta	trachonoides	(Nyl.) Am.
Catillaria	vacillans		H. Magn.
Chiodecton	perplexum		Nyl.
Cladina	sylvatica		(Hoffm.) Nyl.
Cladonia	angustata		Nyl.
Graphina	sulphurella		Zahlbr.
Graphis	illinata	apoda	Eschw.
Graphis	leptocarpa		Fee
Graphis	lineola		Ach.
Gyrostomum	dactylosporum		Zahlbr.
Lecidea	granifera	leucotrapa	(Ach.) Vain.
Leptogidium	byssoides		(Carrahlbr.)
Microthelia	albidella		Muell. Arg.
Ocellularia	exnthismocarp		(Leight.) Zahlbr.
Ocellularia	multilocularis		Zahlbr.
Ochrolechia	pallescens		(L.) Mass.
Opegrapha	prosodea		Ach.

Opegrapha	subcervina		Zahlbr.
Pannaria	lurida		(Mont.) Nyl
Parmelia	tinctorum		Despr.
Parmentaria	lyoni		Zahlbr.
Phaeographis	dentritica		(Ach.) Muell. Arg.
Phaeophysica	UN		UN
Phaeotrema	rocki		Zahlbr.
Physcia	picta		(Sw.) Nyl
Physcia	picta		(Sw.) Nyl
Physcia	servediosa		(Vain.) Lynge
Pleurotrema	rocki		Zahlbr.
Pseudocyphellaria	flavicans		(Hook.) Vain.
Pseudopyrenula	octomera		H. Magn.
Pyrenula	sublateritia		Zahlbr.
Pyxine	retirugella	capitata	Nyl.
Ramalina	extenuata		H. Magn.
Ramalina	faurieana	contracta	Zahlbr.
Ramalina	faurieana		Zahlbr.
Ramalina	microspora		Kremp
Ramalina	sideriza		Zahlbr.
Ramalina	subpollinaria		Nyl.
Sphinctrina	microcephala		(Sm.) Nyl.
Sticta	weigelii		Isert
Usnea	australis		Fr.
Usnea	condensata		Mot.
Usnea	dasycera		(Nyl.) Motyka
Usnea	rubicunda		Stirt
Xanthoparmelia	subramigera		(Gyeln.) Hale
Courtesy of Herbarium Pacificum, Bishop Museum			

FIGURE 6-13 Hepatics of Lana`i

GENUS	SPECIES	BAUTHOR
Frullania	neurota	Taylor
Jubula	hutschinsiae	(Hooker) Dumortier
Courtesy of Herbarium Pacificum, Bishop Museum		
* Bishop Museum staff suggest that this list probably under-represents		
Hepatics on Lana`i, and that the true list would probably be more		
similar to those of Molokai (91 taxa) and perhaps half of		
Maui (137 taxa).		

FIGURE 6-14 Native Lana'i Snails

Terrestrial Mollusks of Lana`i

Estimates of the number of species of terrestrial mollusks in Hawai'i vary. Loope ('98) quotes S. Miller of the US F& W Service as stating that there are about 1,263 historically described species of Hawai'ian Land Snails, of which about 900 species, or 71% are extinct. (Mac, M.M.; P.A. Opler; C.E. Puckett Haecker; and P.D. Doran "Status and Trends of the Nation's Biological Resources", 2 volumes; U.S. Department of the Interior, U.S. Geological Survey; Reston, Va.; Chapter on Hawai'i & the Pacific Islands by Lloyd Loope, 1998). A review of the U.S. Fish & Wildlife Service Species List from February 1st, 2000 indicates 640 endangered, threatened, candidate or species of concern snail taxa. Hobdy ('93) estimates that there were once roughly 780 species of snails endemic to the Hawai'ian islands ("Lana`i - A Case Study: The Loss of Biodiversity on a Small Hawai'ian Island"; *Pacific Science*; vo. 47, no. 3; pp 201-210, University of Hawai`i Press, © 1993). According to Severns (personal communication 1999), there were 763 species of taxonomically valid species of snails recognized as Hawai'ian, of which all but 2 to 4 are endemic. Most were single-island endemics. An additional 16 species questionably belong to Hawai'i, and a further 14 are possibly senior synonyms (prior descriptions under a different name).

Earlier articles have estimated that there were once 42 species of native land snails on Lana`i. However, more recent work estimates 71 species. (See Figure prepared by Mike Severns, based on Cowie, Catalog of Native Land & Fresh Water Molluscs of the Hawai'ian Islands, Backhuys Publishers, Lieden, 1995 and others. These are listed in Figure 6-15.

Although native snail fauna is among the more diverse groups of native species, some experts believe that most species of Hawai‘ian snails radiated from members of a single genus of progenitors, *Tornatellides*, which has been found on bird feathers throughout the Pacific islands. (Personal communications, Dr. Michael Hadfield, Mike Severns).

Snails were and integral and abundant part of the original, uniquely endemic ecosystems of Lana`i. Most native snails are single island endemics, existing no where else on Earth. Snails in Hawai‘i mainly eat fungus, lichens and algae off leaves of trees. It is not clear whether this could have any beneficial impact on the trees, or how important this role was. Snails, like other abundant life forms, were part of the nutrient cycle, contributing to the total biomass, soil nutrients, and so forth. They were a dietary component of certain native birds. The endangered Po`ouli (Melamprosops phaeosoma) eats snails (Gon), and it is believed that certain extinct species of large flightless birds ate snails (Severns), although apparently the larger snails were not eaten. (Severns, personal communication; Pilsbry, Manual of Conchology, Storrs & James, Ornithological Monographs 45 & 46, James Juvik, Atlas of Hawai‘i, 3rd Edition).

Severns has explained a phenomenon noticed during the time when sheep were on Lana`i, in which mollusc populations seem at first to increase with disturbance of native communities, though in the long run they may be adversely affected. He believes that invasive mammals, such as sheep ate lower stature plants / trees at the edge of the forest, exposing large, shallow-roooted `ohi`a trees to winds which they were not capable of withstanding. When the trees fell, they extended the range of the fringe (semi-forest, semi-scrub) habitat, and certain populations adapted to inhabit fringe areas expanded.(Severns, personal communication, information from article in preparation for Pacific Science)

Snail species are described in Figure 6-15.

FIGURE 6-15 Native Snails of Lana`i

Family	Sub Family	Genus	Sub Genus	Species	Preferred Habitat, Food,Habits, Elevation Ranges and Other Notes	Max Size mm	Description
Helicinaidae		Pleuropoma	Pleuropoma				have opercula (trap door)
				kaaensis	Dry land, W. Lana`i	3.10	
				lacinosa		3.20	
				piliformis	Found on Lana'i Hale.	3.50	
Achatinelli-dae	Achatinellae	Partulina	Eburnella		Eburnellas live in Lana'i Hale and fringe forest. live in trees, feed on lichens & algae. nocturnal		
				variabilis	Scrub `ohi`a areas, likes habitat that gets some light, vegetation not too dense, not usually found in the tops of trees. may be adapting to live on guava	18.00	semi-gloss shell
				lactea	Variation of variabilis	22.00	
				semicarinata		18.00	
				hayseldeni	Variation of semicarinata	18.00	well defined, sharp ridge around body keel that runs around periphery of the last whorl.
			Partulina		Lana'i Hale & fringe forest, uluhe & scrub `ohi`a areas feeds on lichens and algae, nocturnal, lives in trees. lives at somewhat lower elevations than other Partulinas (2,000-4000' on W. Maui) , but found on Hale		dull, rough shell,
				crassa		22.00	
	Auriculelli-nae	Auriculella			Tree dweller, feeds on lichens and algae, noctur-nal.		
				brunnea		8.00	
				lanaiensis		5.80	
	Pacificellinae	Lamellidea	Lamellidea				
				gracilis		3.75	
	Tornatellidi-nae	Tornatel-laria					
				cincta		5.00	
				trochoidea		4.00	
		Tornatel-lides	Tornatel-lidides				
				acicula		3.00	
				macromphala		2.75	
				perkinsi		3.00	
				procerulus		3.50	
				terebra		3.00	
Amastridae	Amastrinae	Amastra	Amastra		Lana`i once had large Amastras. These tend to be more ground-dwelling. They live under rocks, under ferns and other ground vegetation, and in leaf litter. Can live in mesic and fringe, down to dry-forest. Somewhat lower elevation than Partu-linas, but lived in Hale.		
				aurostoma		25.00	

				balteata		23.60	
				biplicata		23.00	
				durandi		20.00	
				grayana	Found in Lana`i Hale on ground	21.50	
				longa	Disappearance noted in 1912.	12.00	
				magna		36.00	largest known Amastra in Amastra genus. (Corelia is in a different genus)
				moesta		15.80	
				nucula		12.00	
				obscura		16.50	
				pusilla		8.50	smallest amastra on Lana`i
				rubristoma		19.30	
		Amastra	Heteramas-tra	fraterna		10.00	
		Laminella			Tree dwellers, feed on lichens and algae, noctur-nal		
				concinna	Found on koele side of summit, about 3,000'	11.20	
				circumcinta	Color variation of concinna	12.00	striped. this is the only striped Laminella.
				gracilor		15.50	
				remyi	Very similar to tetrao. Found behind koele.	14.00	
				tetrao	Very similar to remyi. Found behind koele.	17.20	
		Tropi-doptera					
				alata	Found behind koele	8.50	
				lita		10.00	
	Leptachatini-nae	Leptacha-tina	Leptachatina		Fringe to grassy areas	14.00	bullet shaped, shiny shells
				impressa	Found behind koele	7.00	
				lanaiensis		8.00	
				longiuscula		10.50	
				perkinsi	Found on ridges of gulches	10.50	
				semipicta	Found behind koele	8.00	
				smithi	Found in mountains behind koele	9.25	
				subovata	Was once abundant	7.30	
				supracostata		6.30	
Pupillidae	Nesopupinae	Lyropupa	Lyropupa				
				lanaiensis		2.50	
				rhabdota		2.50	
			Lyropupilla				
				sparna		2.20	
			Mirapupa				
				costata			
		Nesopupa					
			Limbatipupa				
				newcombi		1.65	
			Nesodagys				
				rhadina	Likes damp rocks, smooth, barked trees	1.95	
				thaanumi	Found in moss on tree trunks	2.75	
				wesleyana	Likes damp rocks, smooth, barked trees	2.00	

			Nesopupilla				
				baldwini	Found on top of Lana`i Hale	2.50	
				dispersa	Found freshly dead in mahana gulch	1.53	
		Pronesop-upa					
			Pronesopupa				
				boettgeri			
				hystricella			
Endodontidae		Cookecon-cha			Found on the ground, live in cracks between rocks, fallen logs, etc.		
				lanaiensis	Found in Koele and on Hale	4.77	flat rounded spire
				ringens	Likes wet forest. Found on Koele and on Lana'ihale	4.61	
		Endodonta		concentrata	Found on the ground, live in cracks between rocks, fallen logs, etc.	5.43	flat angular spire
Succineidae	Succineinae	Succinae	Succinae	caduca			
		Succinea	Truella	rubella	Fringe to drier areas		fingernail-thin
Helicarioni-dae	Euconulinae	Euconulus	Nesoconulus				
				kaunakakai	Under talus	2.33	
				subtilissimus	Ground dwelling	2.36	
	Mycrocysti-nae						
		Hiona	Hionella				
				perkinsi	Likes ground moisture, high elevations	6.50	
		Philonesia	Haleakala		Live in wet forest, like forest understory, very susceptible to dessication, typically likes higher elevations and wetter areas than Partulinas.		have thin, almost transparent shells, charcoal gray to black,
				diducta	Found under lichens on a`alii shrubs	4.81	
				interjecta		6.28	
				turgida	Found under lichens on trees	5.50	
			Philonesia	maunalei	Found in talus under kukui tree	6.33	
Zonitidae	Gastrodonti-nae	Striatura	Pseudohy-alina	discus		3.40	
	Zonitinae	Nesovitrea		pauxilla		5.00	
		Philonesia	Haleakala		Live in wet forest, like forest understory, very susceptible to dessication, typically likes higher elevations and wetter areas than Partulinas.		have thin, almost transparent shells, charcoal gray to black,
				diducta	Found under lichens on a`alii shrubs	4.81	

Figure courtesy of Mike Severins

Sources: Cowie, Catalog of Native Land & Fresh Water Molluscs of the Hawai'ian Islands, Backhuys Publishers, Leiden, 1995, and others

Threats/ Concerns to Native Snail Populations

Threats to snails in Lana`i include predation by rats, other snails, and possibly birds; altered and diminished habitat, introduced pathogens, and the risk of damage from human activities. These threats are delineated below. (*Source:Personal communications, Dr. Michael Hadfield and Mike Severns*)

- **Predation by other snails**

Oxachilus aliaris

Introduced predatory snail, eats natives.
Believed by Severns to have been introduced during WWII.
By the 1960s, most ground-dwelling snails were extinct.
Mucous coating smells of garlic.
Eats young snails when hatched.

Euglandina Rosea

Introduced predatory snail from the Florida swamps.
Not yet reported on Lana`i ,
Due to its agressive nature, forest managers should be on the alert for this predatory snail.
Introduced to the islands intentionally in 1958 to control another species of introduced snail.

A comparison of the life cycle of the predatory *Euglandina* to that of native snails such as *Achitinella* and *Partulina* highlights the vulnerability of the native snails. Whereas Achitinella and Partulina mature slowly (6-7 years), and live to a maximum of about 20 years, producing only 1 to 7 offspring per year, the introduced Euglandina takes less than a year to mature, produced more than 600 eggs per individual per year, and has a life span of up to 5 years. (Loope, 1998, in Mac, M.M.; P.A. Opler; C.E. Puckett, Haecker; and P.D. Doran *Status and Trends of the Nation's Biological Resources*, 2 volumes; U.S. Department of the Interior, U.S. Geological Survey; Reston, Va..; Chapter on Hawai‘i & the Pacific Islands by Lloyd Loope, quoting Mike Hadfield et al 1986) - (Hadfield, M.G.; *Extinction in Hawai‘ian achetelline snails*; Malacologia; 27:67-81; 1986)

- **Possible predation by other animals such as introduced birds**

- **Habitat of choice:**

  Native snails remaining are found living in low vegetation. This makes them more vulnerable to predators loss of natural habitat and possible introduction of diseases by introduced snails or slugs.

- **Invasion of non-host plant species**

  For example, Eucalyptus or other species that eliminate natural habitat species and which do not provide host for native snails.

- **Poorly planned management efforts**

  Even well-intentioned attempts to help retain and enhance habitat could pose a threat. Proposed fence lines or other forest management facilities should be surveyed to insure that snail populations are not disturbed.

FIGURE 6-16 Native Birds of Lana'i

Family	SubFamily	Genus	SubGenus	Species	Sub species	Common Name	Description
Fringillidae		Himatone		sanguina		apapane	Only remaining endemic forest bird in Lana`i. adult has crimson body with white belly and under-tail coverts, and black tail and wings. first plumage on the young is brown. strong flier, flies high in small groups from one part of the forest to another. keeps mainly to tree tops. wings vibrate loudly in flight. active in tree tops, hopping from one flower to another. food, nectar, insects and caterpillars.
Fringillidae		Paroreomyza	maculata	montana		Lana`i creeper, alauwahio	Wilson called this Paroreomyza maculata montana. Hawai`ian names: Alau-wahio, Alauwi, Lauwi. short flights, food in bark of tree trunks and branches. pretty, chirping call. yellowish green upper body with lemon-yel-low under body. about 5" long. nest was compact ball of fine grass stems and skeleton leaves, 1.75" across the bowl, 0.75" deep, 0.5" thick. last seen in 1937 per Munro.
Antidae		Branta		sandwicen-sis		Nene	Listed as Nesochen sandwichensis by Munro, but not mentioned by him as being on Lana`i. Ornithological monographs list as Branta sandwicensis. Both refer to it as nene. black, brown and buff with greyish parts. hind neck, cheeks, chin and throat black, also black ring around lower throat. 23"-28". webs on feet smaller than other geese. feeds on berries. lived and fed mainly in dry upland country; wintered and raised young in lowland lava flows. noted as living from sea level to 2,200' by Munro. nest was a hollow in the ground, or eggs laid on surface and surrounded by pieces of brush. Munro reported laid 3 to 6 cream white eggs. eggs 3.36"x2.35", but usually only 2 chicks. Nene on Maui typically lay about 4 eggs. Hawaiians used to hunt nene for food, esp. during molting season.
Fringillidae		Dysmoro-drepanis		munroi		hookbilled finch	Perkins called it Dysmorodrepanis munroi. Not clear if Munro thought it was finch or drepanid? Endemic to Lana`i. nearly extinct per Munro in 1944. bird found in 1913 by Munro had upper body light grey with tinge of green, white mark over the eye, but it was molting. found in Kaiholena Valley in 1913, and later in Waiakeakua. beak unusual in that mandibles curved toward each other so that only the tips touched. Retiring bird. Munro believed that this bird used to live in the akoko forest (Euphorbia lorifolia) that originally covered the Lana`i plains. Munro took one feeding on the fruit of an opuhe (Urera sandwichensis), which has fruit about the same size. lived in upper forest and plains of Lana`i. between the islands.
Fringillidae		Hemegnathus		obscurus	lanaien-sis	Akialoa	Munro calls it Hemignathus obscurus lanaiensis (Rothschild). Rothschild described male as black olivaceous green, with dirty yellow breast and cream white under tail covers. However both Munro and Perkins thought that this must have been either a younger bird or if an adult, one not in its breeding stage, as they found it to be quite yellow. The female was a dull greayish olive, with yellowish abdomen. By 1944, Munro felt it was probably extinct, as it had not been seen in many years. It was seen hunting for insects on an o`hi`a. Munro believed it had also inhabited the akoko forest. it hunted for insects on the trunks and limbs of trees, and Perkins noted that the one he saw seemed rather tame, continuing to hunt for food at times not 5 yards dis-tant.

Fringillidae		Hemignathus		virens		Amakihi, honey creeper	Bishop museum printout lists Hemignathus virens. Ornithological monographs list Loxops virens. Munro calls it Chorodrepanis virens chloroides. Known as the Lana`i amakihi. Type of honeycreeper. Looks not described specifically, but Munro mentions that the species vary little in size, with total length varying from 4.2 to 4.75 inches. He noted that Perkins felt that the species inhabiting Hawai‘i, Molokai, Maui and Lana`i were essentially the same. He describes the Kaua‘i and Hawai‘i amakihis, and foregoes description of the appearance of the Molokai, Maui or Lana`i species. The Kaua‘i species had bright green upper parts, with yellowish under parts. The Hawai‘i species was described as being much yellower than the Kaua‘i species, with a smaller bill. Kihi means curved, and describes the shape of the bill. One assumes that the Lana`i species was also green on top and yellow underneath. The Lana`i amakihi was once very common in the forest, but numbers were reduced by introduction of bird diseases. Munro says that they were plentiful prior to 1923, when the town was built. By the writing of his 1944 book, he says that they were very much reduced in numbers as of a few years ago and their chance of survival slight. The forest was small and of no considerable elevation, and its proximity of the town lent little protection through isolation. Munro observed a nest and noted that it was 3.75" wide by 3.5" deep, with a 1.75" hollow at the top, with the characteristic odor of the Drepanine birds. The Lana`i amakihi had this odor so stronly that, "A bird flying past to windward left the odor plainly perceptible in the air." Munro saw a nest in a small tree 12' from the ground. The female approached and tried to lure him away by scolding and fluttering. The nest overhung the steep valley side, but was hidden by the trees above from owls. It was made of grass and fiber from the ieie vine, and lined with rootlets and some sheeps wool.
Fringillidae		Loxops		virens		Amakihi, honey creeper	
Fringillidae		Psittirostra		psittacea		O`u	Munro lists as Psittacirostra psittacea (Gmelin). Bishop lists as Psittirostra psittacea. Munro notes that Temminck, Rothschild and Henshaw all referred to it as Psittirostra. He seems to credit Temminch with the name, but states that Psittacirostra as used by Perkins is more grammatically correct. Munro states that the male was known as the O`u poolapalapa, or yellow-headed O`u; and the female as O`u laueo, or leaf green O`u. The bird has a bright green body, and the male of the species has a yellow head. The female and young did not have a yellow head, and the younger birds were not quite as bright. The bill was parrot-like and hooked, possibly facilitating scooping fleshy flower bracts and picking ripe fruit from the upright spadix of the ieie vine. The O`u had a beautiful voice, with clear whistling notes leading in to a plaintive call. Munro noted that the birds were common in 1923 and seemed to be doing well, but by 1944 he felt that they were near extinction. O`u naturally fed on the fruit and flowers of the ieie vine, and on the berries of arborescent lobelias, and other upland fruits but they were also seen feeding on guava and mulberries. Unfortunately, Munro believed this is part of the reason they became extinct. The O'u had a habit of coming to the low level areas for food, which exposed the species to introduced bird diseases which they could then carry back to their forest habitat. No nests were seen. Munro thought they were probably well hidden in staghorn ferms and ieie vines. O`u feathers were used in Hawai‘ian featherwork..

Fringillidae		Vestiaria		coccinea		I`iwi, honey creeper	Munro lists as Vestaria coccinea (Forster). Type of honey creeper. Bright scarlet wings and tail. Also black wings. Rose colored bill. 5.75" long. According to Munro, in 1891 the i`iwi and apapane were so numerous that they raised a continual buzz. Lived in `ohi`a and Pelea trees. Lived at all elevations from the seashore to the mountaintop, whereever flowering ohi`a forest reached. Munro noted, "It semed to me that the `ohi`a honey had a stimulating effect as these birds were full of life and gaiety when frequenting the profusely blooming ohi`a trees." I`iwi fed on nectar, caterpillars and insects. They flitted from flower to flower and hopped among twigs and leaves in search of caterpillars. The call apparently varied. When feeding it was a sharp chirp, at other times a longer call. Munro described it as "like the creaking of a wheelbarrow, but a little more musical". Apparently the call was more discordant in lower elevation trees, and more musical among the treetops. Munro also noted, "...in a great assembly of birds the medley of sounds produced by hundreds of apapane, i`iwi and other birds produced a pleasing chorus and cheerful effect." Although I`iwi liked `ohi`a nectar, the main food was thought to be caterpillars. Nests were built of dry stems, leaves and rootlets, and some skeletonized capsules of Poha. They were usually placed in tall ohi`a trees. The feathers were used in Hawai'ian featherwork.
Muscicapidae		Myadestes		lanaiensis		Lana`i thrush, Amaui, (olomau - molokai species)	Munro lists as Phaeormis obscura lanaiensis. Bishop Museum and Ornithological Monographs list as Myadestes Lanaiensis (family Muscicapidae). Munro quotes Wilson as noting that the Lana`i Thrush "resembles P. obscura and P. myadestina, but is smaller than either while the bill is distinctly intermediate in size between those of the two species.". The outer pair of tail feathers have slight white markings at the tip, while the abdomen and undertail feathers are nearly pure white. Top was brown. Wing from carpal joint to tip was 3.65". Lana`i thrush differed from those of the other islands in its call. The other thrushes were great singers, but the Lana`i thrush had only 2 or 3 notes which it used constantly. It inhabited the forest and frequented the low trees and underbrush. It nested in the thickest underbrush amongst 'ie'ie vine and staghorn fern. It was a retiring species, more often heard than seen. It ate berries and insects. Munro also reported finding a small landshell in one. The thrush had the habit of trembling and quivering its wings when approached or excited. When disturbed, it flew upward into the trees. Munro believed the Hawai'ian name for all of the thrushes was Amaui (from Manu a Maui?). The Hawai'i thrush was called Omao or Amaui. The Molokai thrush was called Olomau or Amaui. Munro cites as his source "the very old Hawai'ian whom Perkins consulted".

Procellarii-dae		Pterodroma		phaeopygia		U`au, dark-rumped petrol	Only remaining Munro lists as Pterodroma phaeopygia sandwichensis (Ridg-way). Hawai‘ian name was Uau, Uaau, or Uwau. The back was a brownish slate, with darker wings and tail. The forehead, cheeks and underparts were white, and the head was black. Length was about 15.5". The call was a long drawn out u-a-u. The flight was a darting zig zag, interspersed with sailing. It nested in the mountains of all the main islands, in holes under the roots of trees and stones at elevations ranging from 1,500' to 5,000' (the latter obvi-ously not on Lana`i.). It was killed off the mongoose in Hawai‘i, Maui and Molokai. Munro believed that cats and pigs killed it on Lana`i. The eggs were glossy white and laid in April - May. The young birds were considered a delicacy by Hawaiians, and were kapu to common people, reserved for chiefs. Older birds were eaten after they had been salted. By 1944 Munro commented that it was in danger of extinction, though it seemed from his text that it was already gone completely from Lana`i.

Recurviro-stridae		Himantopus		mexicanus		Hawai‘ian stilt	Listed by Munro as Himantopus himantopus knudseni. Listed by Bishop museumas Himantopus mexicanus. not listed in ornithological monograph. Hawai‘ian names `Ae`o, and also kukuluaeo (Kukuluaeo was the word for stilts, or for a person walking on stilts. it signifies one standing high or set up like an aeo). The back and upper body are blue-black, the underparts white, the tail smoky gray, with white markings over the forehead and around the eye and long thin pink legs. The young are brown/grey above and lighter below. The length is about 16.5". The flight is flapping with legs stretched out behind. Feeds on larvae of dragon flies, small fish, worms, seeds and roots of water plants. The cry is short and sharp. The nest is a hollow in dry mud bordering shore lagoons in summer. Eggs are laid in May with 8-12 in a clutch. Eggs brown with large black spots, 1.9"x1.36", thicker at the large end, pointed at the small end, and ovoid. Adult birds are very agressive at trying to lure intruders away from nest and young.
Strigidae		Asio		flammeus		Owl	Asio flammeus sandwichensis (Bloxam) per Munro. Hawai‘ian name Pueo, probably from one of its calls according to Munro. Tawny ocraceus to buffy white, plentifully striped with dark brown. Immature birds are much darker. The birds are about 15.25" long. The Hawai‘ian owl was spread through all the islands, and numerous in open grassy country. Though a day hunter, it is more active at dusk or in early morning. It was common in the late nine-teenth century on Lana`i, but by 1944 Munro commented that its territory had been so taken over by agriculture that numbers had decreased. Nests in grass tufts in a hollow in the earth. Eggs are white and almost round. The Hawai‘ian owl eats mostly mice, but it also eats smaller birds. On Lana`i some hunted over trees in the forests, searching for other bird nests. Most Lana`i species of birds hid their nests from owls. The owl has several cries. The cries of the yound sound something like hissing, and the cries of the old can sound like a muffled dog bark. The owl will spread its wings when approached in a threatening manner. It is fierce enough with its claws that it will fight off cats and dogs.
		Thambe-tochen					

Native Birds on Lana`ihale

FIGURE 6-17 Apapane

Sixteen species of native birds have been recorded in Lana`i, not including non-resident seabirds and seasonal migrants.

Of eight species of native forest birds once known to inhabit Lana`i, the only one known to remain is the apapane (*Himatone sanguinea*). The apapane eats both nectar and insects. Its primary food source is `ohi`a blossom. The amakihi is believed extinct, but a systematic survey should be undertaken to determine status.

Lana`i also has two native seabirds, the Newell's shearwater, and the endangered Dark-rumped petrol. Dr. Fern Duvall recently found a fresh-killed carcass (cat-kill) in Kaiolena gulch while looking for *Hedyotis schlechtendahliana var. remyi* with Bob Hobdy.

Many species casualties among native birds were associated with specific ecosystem niches. The o`u was closely tied with mesic `ie`ie (*Freycinetra arborea*) forest areas. (`ie`ie is a climbing pandanus found in mesic areas) The Lana`i hookbill and akialoa were once plentiful in lowland *akoko* forest (*Chamaesyce celastroides v. lorifolia*). The i`iwi, extinct from Lana`i, was associated with endangered lobeliads. These endangered, bird-pollinated lobeliads in turn were required food for the i`iwi.

The decline of visiting sea bird populations may also have adverse impacts to the Lana'ihale forest. With loss of native trees and habitat, visiting sea birds don't come to Lana`i as much. Bird guana from these birds was thought to once have been an important source of forest nutrients in the islands. Fewer visits by these birds in turn causes diminishing forest nutrients. With diminishing nutrients, forest maintenance and recovery become more difficult. (*Source: Personal communication, Dr. Fern Duvall, 2005.*)

Various species of birds known from fossil records or historical accounts are also gone from Lana`i. Lana`i once had a flightless Ibis species, believed to have lived in Lo`ulu palm habitat. It also had a Moa nalo, a large, flightless grazing bird with a turtle-like head. The extinct Lana`i Hookbill was so fantastic looking that when it was first discovered, its authenticity was questioned. Apparently at some point in history the Hawaiians developed a pastime of sewing skins of different birds together to make fantastic creatures, and upon first discovery, the Lana`i Hookbill was believed to have been one such creation. There were also two species of flightless rail, a flightless owl, a nene and two relatives of the nene. (*Source: Personal communication, Dr. Fern Duvall*)

A list of the bird species once found in Lana`i is found in Figure 6-18 This Figure contains observations by the naturalists of the time on possible causes of extinction.

Importance of Birds In Lana`ihale

Birds serve(d) several important & specific functions in the watershed on Lana`i, including:

- direct pollination of native plant species
- seed dispersal (ex: amakihi ate fruit and insects, spread seeds in feces)
- source of nutrients (especially from sea-bird feces)

Nutrient cycles, especially as affected by seabirds, are now being understood to effect soil and plant health more than previously recognized . It is believed that a contributing cause of progressive degradation of the forest is the loss of sea birds returning nutrients to the soil via guano (Dr. Fern Duvall, referring to research by Storrs Olsen of the Smithsonian Institute).

Birds were an integral part of the pristine ecosystem, so there may have been additional functions which we would not be able to study in the absence of the system intact.

Bird Species Descriptions

A list of native birds once found in Lana`i is provided in Figure 6-19. This list was compiled from the Bishop Museum Bird Checklist, Birds of Hawai‘i (George C. Munro, 1960, 1982), and communication with Dr. Fern Duvall of the State DLNR Division of Forestry & Wildlife.

Threats to Birds on Lana‘ihale

One of the primary threats to remaining birds on Lana`i is the loss of habitat. Although threats to birds are listed below, it should be noted that the threats to plant communities listed above are also among the key threats to bird populations.

FIGURE 6-18 Threats to Birds in Lana‘i Hale

Loss of habitat	Examples, akoko, lobeliads, etc. Direct loss of food source Inadequate space to support and sustain healthy breeding populations If `ohi`a is lost, apapane would probably be lost also
Loss of native pollinators	Loss of pollinators of habitat, (birds, insects) causes threats to remaining habitat. Introduction of pest birds that eat native insects that pollinate native plants.
Introduction of pest birds	Competition with native birds for food, nesting sites. Destruction of native pollinators Introduction of bird diseases including: avian malaria (protozoan), avian pox (virus) Direct agression Examples: White eye - competes for food, nesting sites Japanese bush warbler - compete for food, nesting sites Cardinals - feed on sandalwood fruits Java sparrow

Rats, Cats	Predation. Rats & mice also eat seeds of native habitat trees & plants.
Introduction of insects	Carry avian diseases, for example, mosquitoes carry avian malaria and avian pox. Compete with native insect pollinators.
Diminished population	Remaining population sizes may not be adequate to insure sustainability. It is estimated that in order to sustain a population, there should be a minimum "effective population" size of no less than 500 pairs. By "effective population" it is meant excluding juveniles, aged, or unpaired birds. There also needs to be adequate habitat extent to support such population. In 1980 it was estimated that there were: 540 ± 213 apapane in a transect area of 20 sq. kilometers on Lana`i 15,825 ± 1,129 in a transect area of 44 sq. kilometers on West Maui 94,000 ± in a transect area of 404 sq. kilometers on East Maui

FIGURE 6-19 Problem Birds on Lana'i

Common Name	Latin Name	Comments
Japanese White Eye	Zosterops japonicus	Competes for food and nesting sites. Present on all main islands. Common.
Japanese Bush Warbler	Cerria diphone	Competes for food and nesting sites. First recorded on Lana'i in 1980.
Northern Cardinal	Cardinalis cardinalis	Feeds on sandalwood fruits. Present on all main islands. Common.
Java Sparrow		
Erckel's Francolin	Frncolinus erkelii	Common.
Gray Francolin	Francolinus pondicerianus	Very Common.
Spotted Dove	Streptopelia chinensis	May feed in native forest. Common.
Warbiling Silverbill	Lonchurra malabarica	Common. First recorded on Lana'i in 1979.
Chukar	Alectoris chukar	Very common. Introduced in 1923.

Native Insects in Lana`ihale

The Bishop Museum arthropod list contains records of 472 endemic and indigenous arthropods from Lana`i. Even this number is thought not to be complete. Bishop Museum's checklist lists 11 extinct species, 2 Candidate 1 level species, and 25 Candidate 2 level species. No species are listed as endangered or threatened. Hobdy ('93) estimated that 30% of insect species on Lana`i were believed to be endemic, and that roughly 10% of the native insect species in Hawai'i were on Lana`i. Even with so many species recorded, it is believed that records for insects are lacking. A partial list of arthropod species native to Lana`i follows in Figure 6-20. Rather than attempt to provide descriptions for all of over 400 species, only those listed as candidate species or species of concern are covered.

Insect endemism is not as high as plant endemism, in part because insects can fly and are able to move between the Maui Nui islands. However, in terms of numbers of species, the majority of native species were insects. There are or were native species of spiders, wasps, flies, fungus gnats, beetles, leaf hoppers and true bugs, among others. Endemic Lana`i insects include species of beetles *(Coleoptera)*, flies (*Diptera)*, bugs *(Hemiptera)*, true bugs (*Homoptera)*, bees & wasps (*Hymenoptera)*, moths and butterflies (*Lepidoptera*), and others.

Most Lana`i insect species are very host-specific in feeding & breeding requirements, and are closely interrelated to vegetation communities (Hobdy, 1993). This means they were likely to have fulfilled many key roles in ecosystem integrity, including pollination, etc. Insects also contributed to nutrient cycle, biomass, organic material, and litter component. Native insects were often important as pollinators of specific plants, or because they provided food for birds that were pollinators of specific plants. Insects were also predators, detritivores, soil processors and wood borers, contributing to the food cycle, the breakdown of dead trees and leaves, to soil nutrients, etc.

Examples of some interesting native Lana`i insects include the Nesoprosopis bees and Pomace flies. Over 50 species of Nesoprosopis bees have been found in the islands. Dr. Sam Gon III, of The Nature Conservancy, estimates that there were about 17 on Lana`i, several of which were only found on Lana`i. Nesoprosopis bees, also known as yellow-face bees are smaller and thinner than honeybees, and more solitary. They feed on tiny flowers.

Pomace flies are one of the best examples of adaptive radiation. Over 800 species of native Hawai‘ian pomace flies have been described, and almost all are host-specific. Pomace flies are often called fruit flies, but they are actually part of a different family of insects.

Threats to Lana‘i Hale Insects

Primary threats to remaining native insect populations in Lana`i include:

- Loss of habitat such as nesting sites or food sources necessary to maintain populations.
- Introduced insects may prey on or compete with other insects, damage plants, or carry disease A few of these problem insects are desribed in the Figure 6-21.
- Many insects were brought in with cane or pineapple crops to manage insect pests, but instead turned out to be generalist and fed on native insects and plants.
- Loss of native insects in turn can equate to loss of critical habitat elements, such as pollinators or food source, for other species.
- Introduced Pathogens.

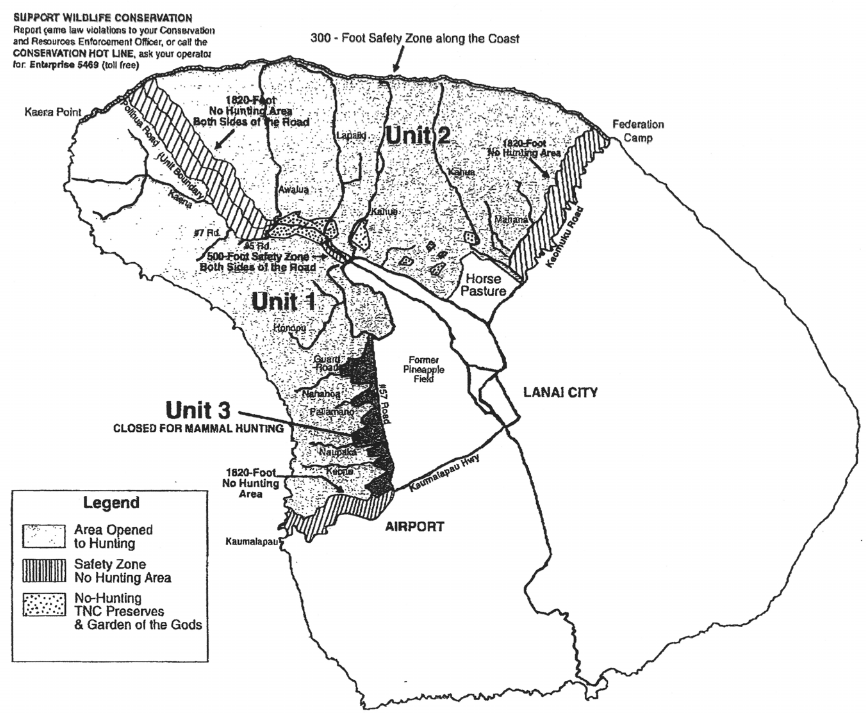
FIGURE 6-20 Lana`i Arthropods - Endangered, Proposed, Threatened, Candidate and Species of Concern

US FWS Status	Bishop L Status	Order	Family	Genus	# Spp in Genus	# Spp on Lana`i	# Lana`i Spp Listed	Species	Description
E		Heteroptera	Scutelleridae	Manduca				blackburniae	Blackburn's sphinx moth
C2	C1	Odonata	Coenagrionidae	Megalagrion	22	8	3	pacificum	damselfly - Pacific megalagrion
C8	C1	Odonata	Coenagrionidae	Megalagrion				xanthomelas	damselfly - orange-black megalagrion
SOC	C2	Archaeognatha	Machilidae	Neomachilis				heteropus	Hawai'ian long-palp bristletail
SOC		Coleoptera		Rhyncogonus				freycinetiae	Weevil, `Ie'ie rhyncogonus
SOC	C2	Coleoptera	Curculionidae	Rhyncogonus	34	3	2	lanaiensis	Lana`i rhyncogonus weevil
	C2	Coleoptera	Elateridae	Hyaleus				plebius	
SOC	C2	Coleoptera	Cerambycidae	Plagithmysus	139	4	2	lanaiensis	Long-horned beetle, Lana`i `Ohi`a beetle
SOC		Coleoptera		Plagithmysus				platydesmae	Long-horned beetle, Pilo Kea
SOC	C2	Coleoptera	Elateridae	Eopenthes	33	4	2	arduus	Click beetle , arduus eopenthes
SOC		Coleoptera		Eopenthes				plebius	Click beetle, common eopenthes
SOC		Coleoptera		Proterhinus	72				Hawai'ian Proterhinid beetles
SOC	C2	Diptera	Drosophilidae	Drosophila				lanaiensis	Lana`i pomace fly
SOC	C2	Heteroptera	Scutelleridae	Coleotichus	1	1	1	blackburniae	Koa bug
	C2	Heteroptera	Miridae	Kalania	1	1	1	hawaiiensis	
	C2	Heteroptera	Pentatomidae	Oechalia	14	2	1	grisea	
SOC	C2	Heteroptera	Rhopalidae	Ithamar	2	2	1	hawaiiensis	Hawai'ian rhopalid bug
SOC	C2	Homoptera	Psudococcidae	Phyllococcus	1	1	1	oahuensis	mealy bug - opuhe gall
SOC	C2	Hymenoptera	Colletidae	Hyaleus	60	15	11	anthracina	anthracinian yellow-faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				assimulans assimulans	assimulans yellow-faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				caeruleipennis	blue-wing yellow-faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				difficilus	difficult yellow faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				facilis	easy yellow faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				filicum	fern yellow faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				laeta	laetan yellow faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				longiceps	longhead yellow faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				obscurata	obscuratan yellow faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				satelles	satellus yellow faced bee
SOC	C2	Hymenoptera	Colletidae	Hyaleus				volatilis	volatile yellow faced bee
SOC	C2	Hymenoptera	Vespidae	Odynerus	100	11	1	nigripennis	black-winged odynerus vespid wasp
SOC	C2	Lepidoptera	Crambidae	Omiodes	23	4	1	monogona	Hawai'ian bean leaf roller
SOC		Lepidoptera		Helicoverpa				confusa	Moth, confused helicoverpan noctuid
SOC		Neuroptera	Distolean	Eidolean				perjurus	Molokai Antlion
SOC	C2	Odonata	Coenagrionidae	Megalagrion				nigrohamatum nigrohamatum	damselfly - nigrohamatum megalagrion

FIGURE 6-21 Insect Pests in Lana`i

Genus	Species	Common Name	Description
Sophonia	rufofascia	Chinese leaf hopper, two-spotted leaf hopper	Destroys uluhe stands, `ohi`a lehua trees. Worse when plants are under stress from drought or etc. Suck the juices out of leaves, leaving yellow spots. Can stress trees to death. Typical scenario: deer move in, eat ferns and other understory, then plant is exposed and ground becomes dry. When drought hits, plants are more stressed and leaf hopper creates more damage.
Adoretus	sinicus	Chinese rose beetle	Feeds on leaves of native plants, incl. Abutilon menziesii. Affects mostly dryland and some mesic plants. Less of a problem than the leaf hopper.
		Hibiscus snow scale	Affects mostly dryland areas, and mostly Hibiscus, (including Abutilon and ilima).
		Mosquitoes	Introduce and carry avian malaria, avian pox and other diseases that destroy bird populations, some of which may have been pollinators.
		Ants	There are no native ants in Hawai`i. Ants prey on and compete with native insects for food, nest sites, etc. There have been many extinctions of native insect species due to ants.
		Yellow jackets, vespula wasps	Very predatory, and very disruptive to native ecosystems. Yellow jacket entry would be difficult to prevent, as a queen could make it from another island across to Lana`i, so measures need to include monitoring and removal.
		Small parasatoid wasps	Several types of small parasatoid wasps have been introduced. These lay their eggs in the eggs of spiders and other native insects, killing the young of native insects before they hatch.
		Black twig borer	Pest brought in with coffee. Attacks native plants. Affects dry areas and mesic areas surrounding Lana‘ihale.

FIGURE 6-22 Game Management Units on Lana‘i



Existing Conservation Efforts

Existing conservation efforts include game management and monitoring efforts run by both Castle and Cooke Resorts, LLC and the State, volunteer planting efforts run mostly by the company, Rare plant exclosures supported by the Company and the US Fish & Wildlife Service, and ex situ collections of various species.

Game Management & Monitoring

The State DLNR runs hunting primarily on the north and western sides of the island, while CCR manages the south and east portions. Different hunting periods and areas are allotted for use of rifle, muzzle loader, and archery hunts. Success rates vary with animal populations, weather, hunter skill and etc. Company-run hunts include paid hunts by hotel guests, as well as resident damage control hunts on Lana‘ihale, night hunts, and license hunts on former agricultural lands. Damage control hunting is sometimes undertaken around the resorts, golf courses and other infrequently hunted areas when complaints are raised. However, animal management that close to hotel grounds is generally restricted to hotel employees.

At one time, the Nature Conservancy also managed animal populations in its Kanepu‘u preserve and nearby exclosures, in partnership with the State Department of Land & Natural Resources, Division of Forestry and Wildlife (DOFAW). The Nature Conservancy prepared and implemented six year management plans, funded by a TNC - State match. Management efforts included ungulate control (hunting and fencing), weed control, dry forest restoration, research and monitori ng, and fire control. Although most of these efforts did not take place on Lana‘i Hale, they did help to protect the Lana‘i Hale ecosystem.

The State Division of Forestry and Wildlife monitors animal head counts along established transects annually. These transects have been mapped using global positioning system(GPS) equipment .

State Game Management Area Units 1 & 2 are monitored together in 31 transects at half-mile intervals. CCR Management Units are monitored in 28 transects at half mile intervals. Transects taken at 40 mph along established transect routes at ½ mile intervals, flying at a relative altitude of 300 feet.

This flight path protocol provides coverage of over 1/3 of the area. Total estimated population numbers are extrapolated from these observations. Thirty percent coverage is quite good. Many U.S. mainland game management area monitoring operations are only able to fly about 1/10 of the area for their extrapolations.

Some uncertainty is inherent in any extrapolation method. However by repeating the census annually according to consistent methods and transects, this method yields fairly reliable population trend data, and may be considered a reliable indicator of whether deer and mouflon numbers are growing or decreasing.

Current Game Management Areas:

The areas outlined in green are managed by the State, and those in gold by the company. The purple and cyan areas indicate the Kanepu‘u preserve and more recent plant exclosures established by the company with funding assistance from the US Fish & Wildlife Service.

In providing information for the Tables 6-24through 6-30 on the following pages, DOFAW staff asked that the following caveat be given along with the data.. “The use of the term ‘estimated population’ is liberal. A more specific term utilized in wildlife management is “trend”, which reflects the upward or downward movement of the numbers of animals observed or projected to be observed over the given survey area. These trends, when used in conjunction with harvest data for the previous year, are invaluable in the setting of bag limits and seasons. Without prior harvest data to compare with the trends, no conclusion can be drawn as to future hunter success”.

FIGURE 6-23 Game Management Areas and Plant Exclosures on Lana'i

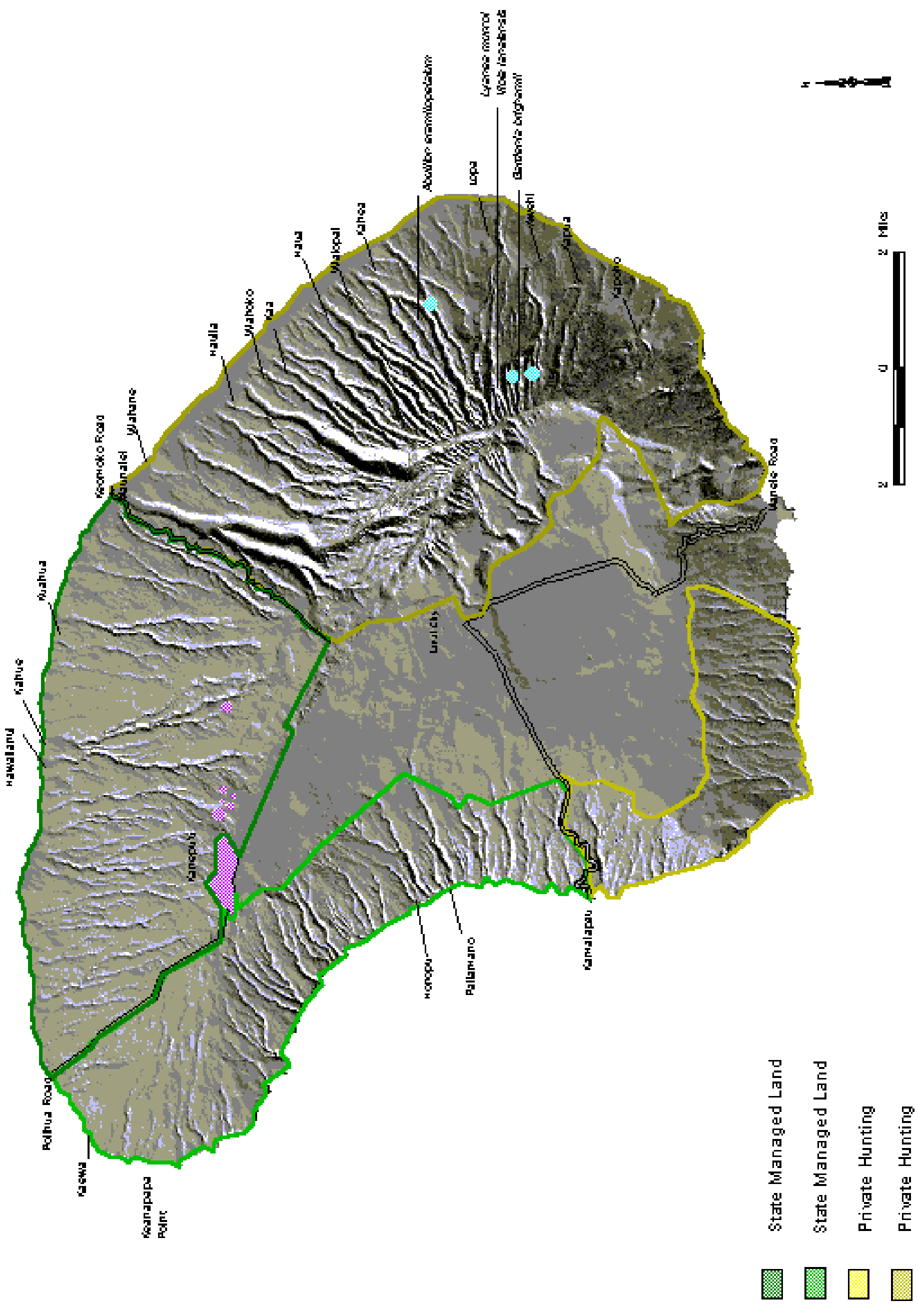


FIGURE 6-24 Lanaʻi Company Game Management Area - Deer Counts

	Buck	Doe	Fawn	Unclass	Total	Estimated Population*
1994	41	321	22	46	430	959
1995	34	323	19	60	436	972
1996	22	191	8	159	380	848
1997	39	260	9	91	399	890
1998	47	278	32	113	470	1048
1999	22	152	16	57	247	551
2000	14	134	9	71	228	508
2001	9	42	15	25	91	432
2002	9	93	7	11	120	268
2003	No Survey					
2004						
2005	38	164	13	28	243	654
2006	25	244	19	73	361	971
2007	61	351	23	136	571	1,536
2008						

(Projection Index = 2.23) Lanaʻi Company Area = 30,000 acres

FIGURE 6-25 Lana`i Game Management Area - Deer Counts in Lana`ihale

	Hale Count	General Habitat Conditions Over Entire Area
1994	55	66% increase over ʻ93 Habitat dry & stressed
1995	46	Habitat dry & stressed
1996	21	Bad weather / flew 50 mph Habitat indicated mild summer
1997	28	Looked like start of drying period
1998	52	Extreme drought stress
1999	26	Moderate to severe drought
2000	34	Continued severe drought
2001	10	Prolonged severe drought
2002	17	No improvement from spring rain.
2003	No Separate Survey Data Available After 2002	
2004		
2005		
2006		
2007		
2008		

FIGURE 6-26 Lana‘i Company Game Management Area - Mouflon Sheep Counts

Year	Mouflon Sheep Noted
1994	79
1995	16
1996	12
1997	51
1998	72
1999	10
2000	7
2001	11
2002	34
2003	No Survey
2004	
2005	69 Total / 186 Estimated
2006	120 Total / 323 Estimated
2007	186 Total / 500 Estimated
2008	N/A

FIGURE 6-27 Lana‘i Cooperative Game Management Area - State Managed Area Counts

	Buck	Doe	Fawn	Unclass	Total	*Estimated Population
1994	111	567	59	176	913	2,438
1995	103	607	30	75	815	2,176
1996	104	537	24	116	781	2,085
1997	119	405	8	181	713	1,903
1998	108	561	101	75	845	2,256
1999	123	503	55	105	786	2,098
2001	87	363	52	174	676	1,805
2002	59	297	39	89	484	1,293
2003	51	261	30	32	374	1,006
2004	39	151	35	169	394	1,060
2005	74	359	42	84	559	1,504
2006	113	476	25	175	789	2,125
2007	93	545	20	273	931	2,512
2008						

Projection Factor: 2.67

Assumptions: buck to doe ratio applies for unclassified... but fawns are assumed equal boy/girl

FIGURE 6-28 State Managed Area - Axis Deer Hunt Statistics

	Estimated Population*	Total Harvest	Total Hunters
1994-1995	2,438	767	2,118
1995-1996	2,176	678	2,632
1996-1997	2,085	462	1,919
1997-1998	1,903	288	1,497
1998-1999	2,256	655	1,687
1999-2000	2,098	698	1,795
2000-2001	1,805	500	1,717
2001-2002	1,293	377	1,709
2002-2003	1,006	338	1,508
2003-2004	1,060	307	1,472
2004-2005	1,504	294	1,357
2005-2006	2,125	384	1,433
2006-2007	2,512	633	1,679
2007-2008		563	1,798
2008-2009		613	1,702

FIGURE 6-29 State Managed Lands - Mouflon Census

	Ram	Ewe	Lamb	Unclass	Total	Estimated*
1994	82	565	0	191	838	2,237
1995	74	617	0	57	748	1,997
1996	110	487	1	70	668	1,784
1997	156	450	1	76	683	1,823
1998	116	518	6	56	696	1,858
1999	110	525	1	6	642	1,714
2000	68	438	11	133	650	1,735
2001	68	371	15	48	502	1,340
2002	23	269	4	55	351	944
2003	50	367	5	36	458	1,232
2004	40	243	6	84	373	1,003
2005	119	535	2	56	712	1,915
2006	98	501	5	168	772	2,077
2007	189	898	1	315	1,403	3,774
2008						

FIGURE 6-30 State Managed Area - Mouflon Sheep Statistics

	Estimated Population*	Total Harvest	Total Hunters
1994-1995	2,237	722	1,727
1995-1996	1,997	435	1,192
1996-1997	1,784	293	944
1997-1998	1,823	640	1,496
1998-1999	1,858	641	1,351
1999-2000	1,714	455	1,298
2000-2001	1,735	445	1,148
2001-2002	944	396	1,115
2002-2003	1,232	441	1,108
2003-2004			
2004-2005	1,003	359	1,015
2005-2006	1,915	408	939
2006-2007	2,077	614	1,226
2007-2008	3,774	694	1,316
2008-2009		225	661

FIGURE 6-31 Observations on Habitat Conditions

	Habitat Condition
1994	Dry Summer effects showing but off-season rains helped
1995	Dry , stressed
1996	Mild summer w/off-season rains
1997	Looked like beginning of dry period
1998	Severe drought Vegetation dessicated
1999	Conditions indicated extremely dry weather
2000	Prolonged dry weather
2001	Conditions very dry
2002	Conditions same - dry with spring rains
2003	Dry range conditions
2004	
2005	Dry range conditions.
2006	Moderate drying of vegetation.
2007	Moderate drying of vegetation.
2008	Dry range conditions.

Existing Planting & Plant Exclosure Efforts

CCR runs periodic volunteer planting programs with volunteer groups and organizations such as the Lion's Club and the Boy Scouts. These are supported by the company's nursery. In recent years, the CCR Conservation Division has been expanded to include staff for regular forest management. This enables CCR to increase its efforts toward watershed preservation: weed removal, plantings, funding development and other functions above and beyond those already performed by its animal management crews.

Four exclosures exist in the Lana'i Hale and surrounding areas. These are indicated in Figure 6-9 above. The exclosures protect small populations of Gardenia brighamii, Abutilon eremitopetalum, Cyanea munroii and Viola lanaiensis. Two additional exclosures are proposed. The Puhielelu exclosure is sited to protect a variety of native plants in the Lana`ihale area, and an additional un-named exclosure is planned to protect critical wet forest habitat for certain snail communities.

Ex-Situ Collections & Reintroduction

Ex-situ collections of plants, plant tissue and seeds exist at various locations, including the National Tropical Botanical Garden & Center for Plant Conservation; the Waimea Arboretum & Botanical Garden, the Amy Greenwell Ethnobotanical Garden, the Honolulu Botanical Garden and others. Collections include Abutilon eremitopetalum, Abutilon menziesii, Cyanea macrostgia ssp gibsonii, Cyrtandra munroii, Gahnia lanaiensis, Phyllostegiat glabra var. lanaiensis, Santalum freycinetianum var. lanaiensis, and others.

The University of Hawai'i at Manoa is raising certain native snail species with the hopes that these can be re-released at some point. *(Sources: Thomas et al, Lana`i Plant Cluster Recovery Plan, 1995; and personal communication, Dr. Mike Hadfield, UH Professor of Zoology & Director of Kewalo Marine Laboratory)*

Necessary Actions

Fencing

If the Lana`i watershed is to have a realistic hope of recovery, there should be no herbivores within the protected area. This is the most important and highest priority management strategy. This has been supported as a priority, both by the peer review panel of resource managers, who reviewed various proposals and unanimously concluded that this was the most fundamental measure that needed to be taken, and by the advisory groups consulted.

Given the relative importance of this measure, several options were considered both within the Lana'i Water Advisory Committee, the Biodiversity Committee and with the public. A copy of presentation made to the public is included as an appendix in this plan. In general, options considered included fencing off either a large area of the island's northeast quarter, a somewhat smaller area encompassing the upper elevations of Lana'ihale, limiting fencing to small exclosures, or a combination of the above.

The larger fence was considered the most protective, and had various advantages such as being easier to maintain, since it was aligned along pre-existing roads on accessible, moderate terrain. This terrain would also limit fence wash-out problems. The larger fence also protected a larger slice of both biodiversity and potential recharge, benefitting more rare taxa. However, the larger fence was deemed unrealistic and overly drastic for a number of reasons. First, the community relies extensively on hunting in Lana`i, and it was thought that this fence would have an adverse impact on local residents. Also, some of the very advantages of the fence, were also disadvantages. Its accessibility would make it prone to vandalism and breakage, and its large extent would make it more of a monitoring and repair task. Finally, it was felt that the area to be enclosed was too large to realistically manage right from the beginning, and that if such a fence were ever to be built it would have to be with community support, built after time and a track record of success with a smaller project.

Exclosures and smaller fence areas were considered, but this postage-stamp model was rejected. While exclosures for enhanced protection of the most rare species may still be necessary outside or even inside a larger fence, exclosures alone would do little to protect the watershed. However, exclosure fences were still considered appropriate for certain areas. Where utilized, it is recommended that these be a mininimum of 50 meters (about 165') away from nearest target plant.

The selected fence was the one enclosing Lanaʻihale. This was selected because it both protected the key recharge area of Lanaʻihale as well as many of the more critical plant species, had lower impact on hunters, and achieved community buy-in more readily. The following pages further describe the fence options considered by the advisory group and the public.

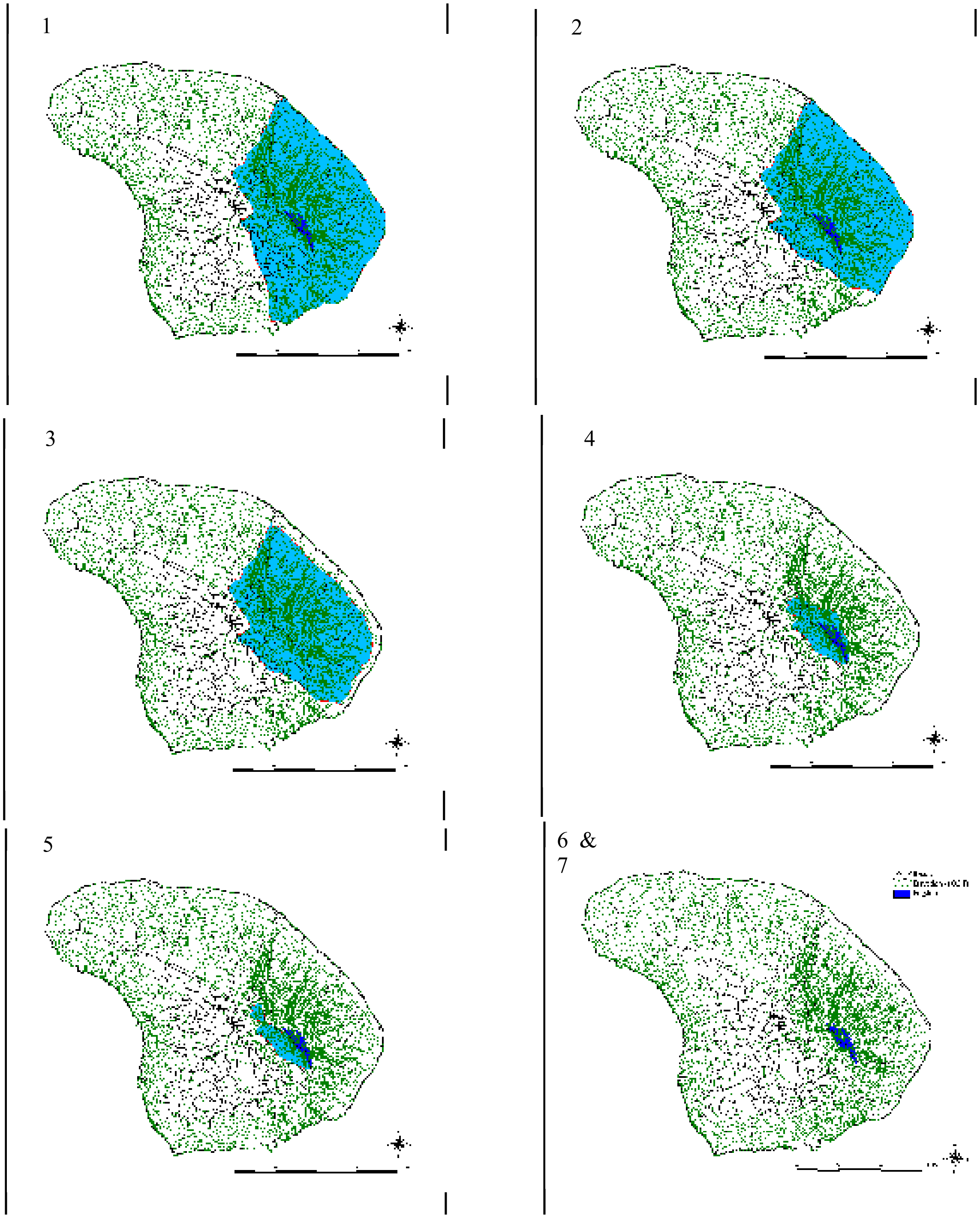
Consideration was also given to survey of proposed fence lines to insure that no rare or endangered communities of insects, snails, plants or other native flora or fauna would be harmed. This was done for Increments I and II, although there was some discussion as to whether such surveys were sufficiently thorough. The same should be done for Increment III.

The fencing option chosen was option # 4 in Figure 6-23 and Figure 6- 10. This was subsequently modified to allow for construction in phases. A map of the current alighment is presented in Figure -6-11.

FIGURE 6-32 Fenceline Options Discussed with Panel of Experts and With Community

Option	Enclosed Acreage	Miles of Fence	Cost to Insstall Est.	Advantages	Disadvantages
1 - Keomoku	32,055	13.9	410,000	Protects largest area fastest, Protects more plant communities , Cheapest per area protected Easier maintenance on roads	Large impact on hunters, Exposure to vandalism
2 - Keomoku2	26,555	14.7	450,000	Protects large area more plant communities Cheap per area protected easier maintenance on roads	Large impact on hunters Exposure to vandalism?
3 - "Old Pipeline"	22,807	23	1,100,000	Pprotects large area more plant communities Cheap per area protected	Large impact on hunters, Exposure to vandalism, Low side expensive to maintain Cost per area higher
4 - "Fish"	3,588	12.1	680,000	Protects critical recharge area, Less impact on hunters	Cost per area a bit higher, Protects less plant communities
5 - "½ Fish"	1,835	11.5	400,000	Least impact on hunters	Will not protect key area Protects few plant communities Cost per area a bit higher
6 - No Fence - Eradicate	N/A	0	N/A	Most protective option Less on-going maintenance	Largest impact on hunters
7 - No Action	N/A	0	N/A	Least short-term investment	Loss of recharge Loss of Lana`i biodiversity
8 - Phased 1 -Exclosure 2 -Keomoku 3 -Makaiwa	Step 1 - depends Step 2 - Step 3 -			On second page of Figure 6-10. Protects largest area long term More plant communities protected.	Large impact on hunters Delays to step 2 could result in loss of everything beforefence is built Most expensive program
9- Modified Phased	1- "Fish" 2 - add selected gulch(es) / a'apuaa			Protects larger area than fish Protects down to sea along at least one or two gulches Less impact on hunting than larger options	Higher cost than most options Larger impact on hunters than fish or ½ fish
10 - "Big Fish"				Following road below bench field on SW for top of fish Would make that end less $ / / ft enlarging bottom somewhat wld include major snail and seabird colonies, still less impact on hunters than larger options.	High cost and difficult terrain on lower half. less protective than larger options. Still does not protect all ecosystems.

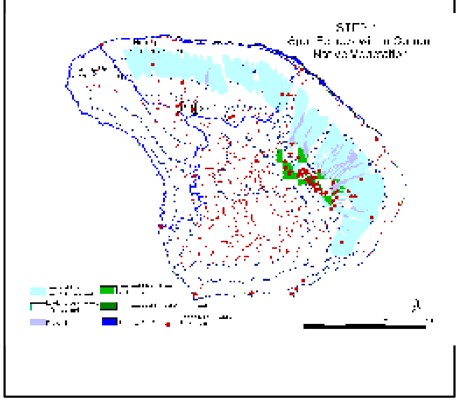
FIGURE 6-33 Fencing Options Considered - Presented Left to Right In Order of Figure Above



Watershed Protection

FIGURE 6-34 Fencing Options Considered - Continued

8 a



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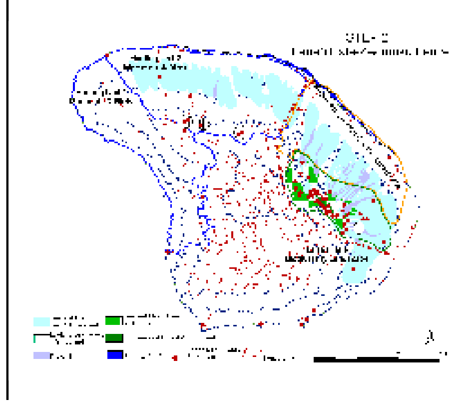

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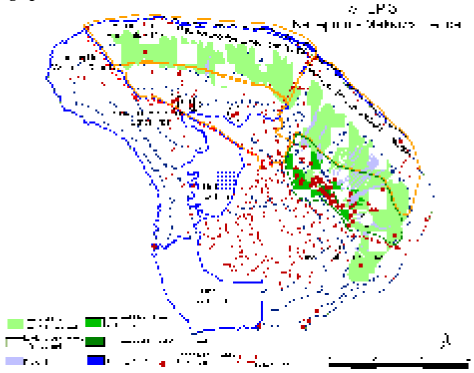

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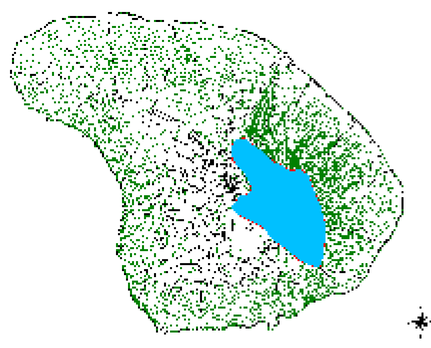

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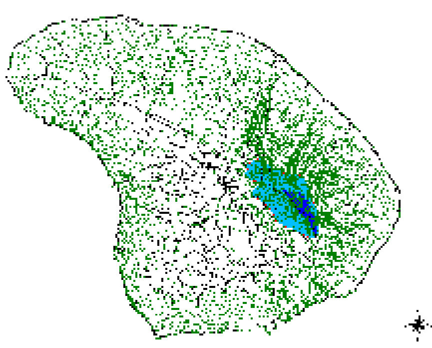


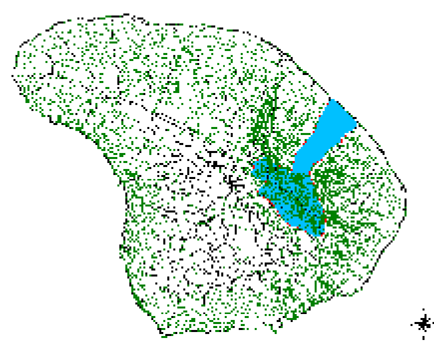
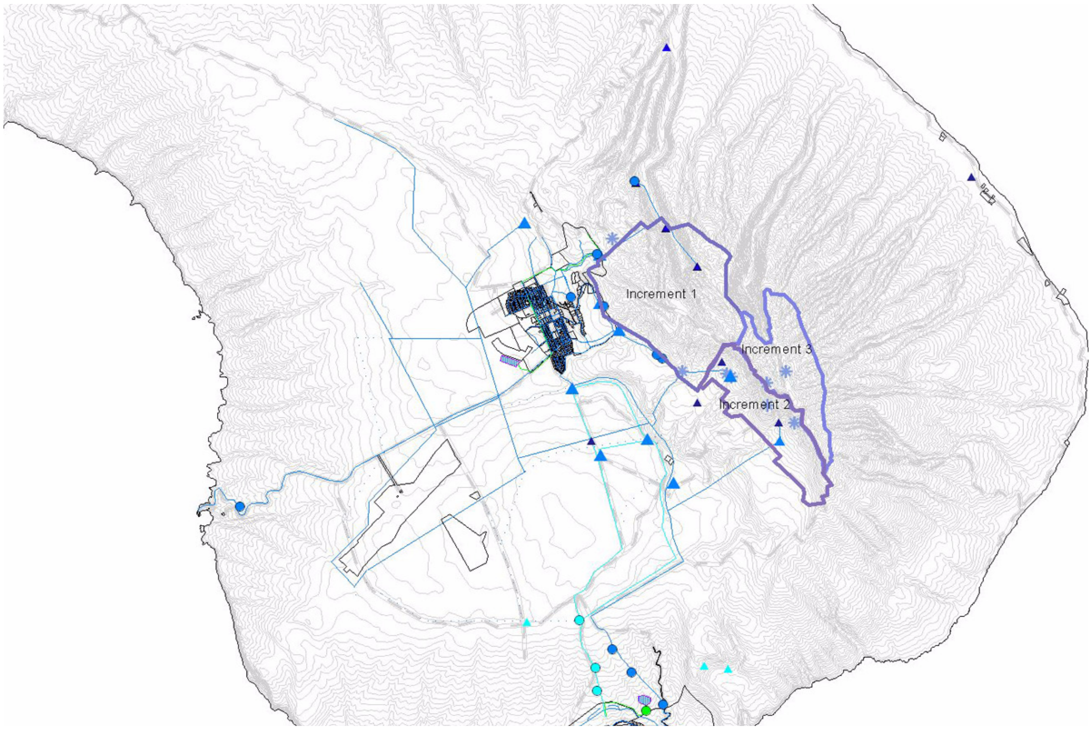


FIGURE 6-35 Current Alignment and Increments of Fence



Watershed Skybridge

Committee members received written testimony on watershed management considerations, and in response to certain unknowns and potential controversy, the committee also took the unusual step of convening a “skybridge” multi-island conference call between forest experts on Oahu, Maui, & Lana`i to receive further testimony and allow experts to discuss issues (One Big-Island expert was kind enough to be present in Oahu also) .

The results of this conference were unequivocal. Fencing was the measure of primary importance, without which all other measures were likely to fail. In further discussions, the Lana‘i Water Working Group / Lana‘i Water Advisory Committee determined that the issue was important enough and had enough potential to effect subsistence hunters and others, that a series of public informational meetings and discussions should be held.

The results of the public meetings were broad acceptance of the fence as a necessity. The community collectively has great concern for the health of its water systems.

Additional Measures

The Lana‘i Water Advisory Committee had many long discussions about how best to protect the watershed. Fencing was clearly considered the most important management measure, but it was not the only one deemed important. Additional measures are described below.

Fencing and other management must be performed in concert - i.e. fencing must be backed up with management of animal populations, appropriate weeding activity and so forth. The LWAC spent some time going over probable cost items, such as survey, herding hunting, ammunition, campsites, shelters, training, liability, and most importantly construction of the fence.

Removal of feral ungulates from inside fenced areas

LWAC agreed on the protocol of hunting to elimination within fence for protection of watershed, but maintaining managed populations outside of the fence for food and sport. Residents were to be the first allowed to hunt within the fence - followed by ongoing staffed hunts if needed. The possibliity of a non-kill herding effort, using men on foot, helicopters, spotlighting and so on to move deer out of the fenced area before it was sealed was also discussed. Once completed, if hunting proved unsuccesful in a given area within the fence, snares, traps or any other means necessary would be used to complete elimination, especially in remote areas. Other means discussed included repellants, non-forage distasteful plants, along buffer strips and other possible means to discourage deer or sterilization, capture and transport, or other non-lethal means of controlling them. At the time it was deemed that none of the alternate methods in literature had been sufficiently developed to be both practical and safe for consumers of hunted meat, nor would they have the necessary impact on populations in time to save the watershed.

Management of Feral Ungulates Outside Fenced Areas

Lana'i has an unusually active contingent of subsistence and food hunters. In respect for these community values, consideration was given to possible enhancement of hunting outside of the fence to make up for opportunities that could be lost by elimination of deer within the fenced area. Provision of water or salt licks was discussed, but ultimately rejected as having the reverse effect on populations than was desired.

Fire Protection

Lana'i Hale plants are not well adapted to fire. Some of the more prevalent and invasive weed species found on the hale are fire inducting. The Lana'i Hale watershed is susceptible to fire, and fire could damage recharge on the island. For this reason, once the fence is in and animal management is showing results, it was deemed important to take certain precautionary measures:

- Survey susceptible areas, including lands taken out of pineapple to identify ways of minimizing fire risk
- Create firebreaks in key areas to prevent spread of fires.
- Create buffer zones to prevent spread of fires to important areas.
- Designate fire-free zones for human use to prevent indadvertent start of a fire.
- Remove, control and /or eradicate fire-inducing weed species as much as possible. At the very least, remove them from the most sensitive areas.
- Prioritize measures to protect areas where small populations mean that a single catastrophic fire could eliminate all remaining population of a species. (Ex. Tetramolopium remyi)
- Heighten public awareness of the dangers and implications of fire. Not just immediate destruction, but potential for longer term loss of recharge.
- Develop a prioritized species response plan, to mitigate damage in the event of a fire (protecting rarest species first).

- Inventory equipment necessary to protect the Lana'ihale from fire and to protect it during a fire. Obtain necessary emergency equipment and /or seek funds to make this acquisition possible (helicopters/strategically placed reservoirs, water trucks, etc.).
- Provide training for Conservation staff and fire fighting staff on special needs within the Lana'ihale area, and on response plan priorities.

Removal of Non-desirable Species

- Certain weeds diminish the forest's ability to recover after disturbance. Identify and remove such weeds.
- Certain rodents and other small animals also impair the forest's ability to recover from disturbance. This can be especially so during the fruiting or seeding time of threatened or endangered native plants. Remove rodent species likely to feed on native plants.

Protection of Sensitive Desirable Species

- Ferns, mosses, lichens, native birds, snails, and certain plants are very sensitive to disturbance. Communities and individuals of sensitive species should be identified and protected.
- Prevent trampling by spreading populations of feeding ungulates
- Prevent invasive weeds or remove them before they become established
- Take measures to reduce erosion.
- Develop a fire, prevention response and prioritization plan.
- Construct exclosures to protect sensitive species where approrpriate.

Monitoring, Mapping and Documentation

- Establish regular transects, using standard methods (point-line intercept or etc.) to monitor the status of target communities, and effectiveness of control measures.
- Perform scheduled field checks and document results.
- Perform additional checks after unusual events, catastrophes, etc. to see what changes have occured in target communities and identify mitigative measures necessary.
- Map monitoring plots, size and class of plants inside each plot (desirable and non-desirable).
- Maintain photographic documentation of plots - especially plant communities - to monitor recovery or loss.
- Establish water and soil moisture gauges to evaluate and track habitat characteristics and quality.

Control Incoming Species

- Establish adequate screening and quarantine for incoming agricultural goods and plants.
- Educate public, landowners, hunters and hotel guests about the dangers of exotic species, potential contaminants, etc.
- Set up procedures to avoid introduction of non-desirable plants and plant pathogens

- set up procedures to avoid introduction of non-desirable insects or insect pathogens

Eliminate or Mitigate Insect Pests

- Identify species to target for elimination, such as chinese rose beetle, chinese leaf hopper, and others.
- Determine protocols, spraying or other schedules, necessary equipment, etc.

Restore Native Populations of Insects, Forest Birds, Sea Birds, Snails, etc.

- Restoration of native species has several benefits for general forest health. Among these are the restoration and improvement of the natural nutrient cycle of the areas soils, establishment of a healthy litter layer, etc.
    - Native snails and insects evolved to be suitable with native plant communities. They also provided important quantities of biomass, nutrients to soils.
    - Sea-birds provided nutrients such as nitrogen, phosphorous, etc. in the form of guano.
    - Some native insects aid in decomposition and soil amendment.
- Restoration of native insects and birds helps to restore and improve pollination opportunities. Forest birds and insects provided important pollinators, the loss of which can exacerbate loss of forest plants.

Control Erosion

- Select realistic / effective areas for management
- Eliminate animal stresses that perpetuate the erosion cycle
- Establish strategic plantings to prevent soil loss
- Construct wattles or other soil trapping devices
- Establish native plants on newly trapped soil
    - Mycorrhizal inoculants can aid the establishment of outplanted seeds
    - Can outplant species grown ex situ.
    - Can broadcast seeds

Protect Species Prone to Gathering By Humans

- For example, sandalwood, due to its high economic value, was subject to removal by individuals seeking the heart wood. Identify species which are likely to be tampered with, and take effective measures to protect them.

Identify Plant Pathogens or Diseases of Concern and Take Measures To Protect Native Plants:

- Using the example of sandalwood
    - "Spike disease" - harmful to sandalwoods in India, believed to be in HI
    - Santalum seed fungus - destructive to viability of seeds (sandalwood)
    - Santalum heart rot

    - Possibly others
- Inventory disease problems affecting key species, as well as known management strategies.
- Enhance quarantine & inspection of carrier plants to prevent further introduction of problems.

Internal and Peer Review of Management Plans to Prevent Problems

- Even forest management experts can overlook protective measures or even adverse impacts of protective measures. Once a management plan is drafted, review it internally and invite outside experts to peer review, to eliminate possible ommissions or errors or identify necessary precautions.
- Examples of such errors can include:
    - fencing without adequate monitoring,
    - fencing without weed removal
    - over collection of seeds
    - damage or spread of pathogens by incorrect collection of tissue cultures,
    - careless management on part of humans (human trampling, unmonitored actions, etc.)
- Include proper forest entry practices in all management work.

Collection and Maintenance of Genetic Material

- Seeds, live plants, and plant tissue from threatened areas can be preserved and /or propagated in ex-situ populations. Curators of such collections should take care to avoid in-breeding or cross contamination of genetic material with other variations of a given species. Collectors of seeds or plant tissues should avoid the collection of genetically weakened specimens.
- Ex-Situ Collections - certain plant seeds and individuals exist in collections by
    - National Tropical Botanical Garden,
    - Waimea Arboretum & Botanical Garden
    - Amy Greenwell Ethnobotanical Garden
    - Hawai‘i Plant Conservation Center

Selective Augmentation and Re-introduction of Species from Existing Populations or Ex-situ Collections

- Avoid cross breeding or cross contamination of genetic material.
- Be sure plants have been properly collected, and seed sources appropriately identified.
- Be careful to avoid cross contamination in nurseries or germination media, and exposure to some plant materials.
- In preparation for outplanting, care must be given to proper handling, equpment and training.
- Once out-planted, care must be given to plant care and maintenance until established.

- Survey out-planting sites in advance.
- Prepare necessary protection, possible exclosures, monitoring & maintenance schedules and plans for out-planting sites.
- If necessary, construct camp sites or shelters in advance.

Additional Research on Targeted Plant Communities

The following additional research has been identified as desireable for target plant communities.

- Associated ecosystem components
- Relations between native plant communities / birds / insects (pollination, feeding, etc.)
- Critical habitat size / population size for species viability
- Growth and mortality at various stages of plant life, seasonal changes
- Optimum conditions for reproductive vitality, flowering/seeding conditions
- Light requirements at various stages of life
- Water, soil & nutrient requirements at various stages
- Pollination vectors, seed dispersal
- Means to compensate for missing pollination vectors or other keystone habitat concerns
- Minimum numbers needed for populations to be stable
- Susceptibility to inbreeding

Management Recommendations to Preserve Native Birds

- Protect habitat - including steps to preserve plant communities, snails, insects, etc.
- Prevent predator entry - adequate quarantine, fencing, baiting predators, etc.
- Remove rats and cats from native bird habitats - catch, bait, etc.
- Prevent entry of non-native birds - (avoid disease, competition)
- Prevent entry of mosquitoes and other problem insects
- Control mosquitoes at breeding sites - insecticides, sterilizers, introduction of sterile or non-carrier mosquitoes
- Specific strategic management of existing seabird colonies for enhanced protection.
- Construct feral ungulate fencing in such a way as to avoid harming native bird populations.
    - fence must be visible to prevent birds from crashing during night landing
    - white flagging or tape on top can help
- Establish rat, cat and other small mammal control within the watershed.
- Consider carefully managed re-introduction programs for amakihi, i`iwi, maui creeper, others
- Preserve Lana`i specific genetic material
- Consider minimum habitat size for sustainability of bird populations in deciding fence or othe rman-agement options

Benefits of Protecting Remaining Bird Species and/or Restoring Bird Populations:

- Birds serve(d) specific functions in the watershed on Lana`i
  - direct pollination of native plant species
  - seed dispersal (ex: amakihi ate fruit and insects, spread seeds in feces)
  - source of nutrients (esp from sea-bird feces)
  - possible additional non-identified roles, as birds were integral part of ecosystem
- Rare native plants would benefit from having native pollinators and spreaders of seeds restored.
- Nutrient cycles, especially as affected by seabirds, are now being understood to affect soil and plant health more than previously recognized (*Source: Personal communication with Dr. Fern Duvall descrbing paper by Storrs Olson of Smithsonian, indicating that one of the changes in the forest could have come about by loss of sea birds returning nutrients to soil.)*
- Encourage sea birds to return by establishing safe, predator-free sites for them
- In order to successfully maintain existing apapane and seabird populations, and /or to restore previously existing species with close approximations (Maui equivalents) - adequate disease free habitat extent will be required.

Management Recommendations to Preserve Native Snails

- Preserve native snail habitat, especially the upper elevation Lana‘i Hale forest.
- Encourage reforestation with native species, as many non-natives, including Cook pine and Eucalyptus, are not good hosts for native snails (although snails have been found on some non-native plants where they are intermixed with natives). (*Source: Personal communication, Mike Severns*)
- Establish and enforce a ban on collecting.
- Educate the public on damage caused by collecting.
- Eliminate predation by rats and other animals..
  - Construct exclosures to protect snails from predation.
  - Exclosures for snails are roughly waist high. They are constructed of painted, corrugated aluminum roofing. A trench is dug, and in that trench the fence is installed with its foot buried about 6" into the ground, at the top of the fence is a shed-like “roof” that protrudes to either side. Under that “roof” are two additional barriers, a trough of large crystal salt, and a 2-wire electric fence, constructed of two thin wires spaced 8mm apart. The electric wires are powered by solar panels mounted on the inside of the exclosure.
  - The largest such exclosure currently existing is about 40x25 meters.
  - Rat bait boxes may be placed on the outside of the exclosures for further protection
  - Tree limbs and other branches should be prevented from touching the fence exclosure structure , as they may provide a path for predators

- Prevent or eliminate predatory snails, as applicable
- Prevent entry of non-native snails & slugs to avoid possible introduction of diseases
- Snails may be subject to captive rearing and reintroduction as appropriate.
- CARE must be exercised in designing control of slugs.
    - Slugs don't generally hurt snails, but there are no native slugs in Hawai‘i, and there is some chance that they could be a source of introduced disease. (Source, Personal Communication, Dr. Hadfield)
    - Any poisons designed to eliminate slugs would also be likely to affect snails.
    - If any poison or bait were used to control snails, it should be limited to extremely LOCAL applications in areas where it was fairly certain no native snails were present.
- Consider careful removal of non-native plant species where appropriate, and replacement with native species. (This measure requires exercise of care to insure that no snails are sitting on the plants to be removed).
- Some species of native snails seem to be adapting to certain introduced plants. In cases where this has occurred, consider selective use of non-native plants that the snails are adapting to.
    - Partulina variabilis
    - Partulina semicarinata

Management Recommendations to Preserve Native Insects

- Protect native habitat on which native insects rely, especially host plants.
- Eliminate non-native predator insects, especially yellow-jackets and ants.
    - Establish pheremone traps for predators.
    - Find and destroy nests with freezing or insecticides
    - Bait ?
- Develop improved quarantine measures and other controls to prevent entry of non-native insects
- Monitor native insect populations to determine species requirements, critical habitat, population size, etc.

Other Prevention Protocols

Through wind dispersion and other means, plants introduced in only a few sites well outside the watershed can and do spread to the watershed.

- A database of cultivated and naturalized non-native species on the island of Lana`i should be developed through survey of nurseries, botanical gardens, parks, hotel and other public landscape and other likely introduction sites.

- The best predictor of invasiveness for most taxonomic groups is a record of invasiveness in similar climates elsewhere in the world. The databases of historically invasive plants and non-native plants present in Lana`i should be cross-checked to identify species of concern.

- A series of species reports should be developed for targeted species, summarizing both literature and field research, and include results fromGPS data collection and distributional mapping, as well as information on attributes of other invaded ecosystems, control data, and so forth. A protocol for obtaining and structuring such information has been developed and implemented in Maui.
- Many of the key corridors by which invasive alien species are introduced are not the same areas where active management transects are located. Efforts need to be directed toward monitoring likely introductory routes such as roadsides, parks refuse sites, vacant lots, harbors, airports and residential areas.
- Through active identification efforts, plants may be detected at earlier stages of naturalization, or even prior to naturalization, avoiding widespread damage.

Education of Land Owners, Residents, Guests, Hunters

- Rare plants and their value
- Importance of watershed / importance of biodiversity
- Non-desirable plants and the threats posed by them
- How to enter the forest and other sensitive areas while causing minimal risk of doing harm
- Dangers of open flames, especially. in certain areas
- Plant walks outside critical areas

Legal & Regulatory Protections

- "It is illegal to remove, cut dig up, damage or destroy an endangered plant in an areas not under Federal jurisdiction in knowing violation of any State law or regulation or in the course of any violation of a State criminal trespass law (ESA §9(a)(2))
- Hawai`i State law prohibits taking of endangered flora aand encourages conservation by State governement agencies. "Take" means to harass, harm, collect, uproot, destroy, injure or possess endangered species of land plants, or to attempt to engage in any such conduct (HRS 195D-5(d))

Enforcement of Protective Measures

- Make effort to discourage and enforce prohibitions on collection of special species.
- Limit and or manage access to critical areas, as well as activities within those areas.
- Enforce proper forest entry practices for those who do enter.
- Ensure that any uses in sensitive areas are compatible with protecton goals .
- Maintain a regulatory presence in the watershed, manage public activities and education.
- Obtain assistance from agencies or other partnerships if needed.
- Develop a recreational use plan for guiding human activities in the watershed without damage to sensitive areas.

Community Outreach

- Educate the public regarding
    - Importance of watershed
    - Importance of Biodiversity
    - Plants of concern
    - Appropriate forest entry practices
    - Field volunteer training
- Establish a workshop and lecture series
    - Uses of plants in native culture
    - Value of native resources
    - Importance of watershed and connection with native vegetation
    - Plant, animal and bird identification
    - Threats and long term effects of unabated threats (Rapa Nui lesson)
- Solicit community input and partnering
    - Link w/ other environmental agencies and groups. Develop partnerships.
    - Create a pool of docents
    - Develop a guided hike program
    - Offer field trips to biological and cultural sites.
    - Utilize trained docents from partners as leaders.
    - Provide them with / partner to develop prepared informational materials
    - Partner to ensure adequate vehicles and logistical support
- Prepare interpretive materials for use in both community and by visitors
    - booklets, pamphlets
    - web sites
    - public access programs
    - develop native resources curriculum for the schools
- Identify and implement volunteer projects
    - Weed control
    - Restoration activities - outplanting, nursery, maintenance, erosion control
    - Fence building and repair
    - Hunting
    - Construction of wattles to retain soil
- Communicate progress
    - establish media contacts for coverage of projects both local and statewide dissemination

- regular means of communicating relevant information to the community
- utilize existing community special events as venue for promoting education and increasing viability of projects:
  - Aloha Festival
  - Health Fairs
  - Pineapple Festival
  - Other Cultural Events
- Develop and implement long-term alien species awareness and prevention program
- Seek grant funding to develop a video
- Develop a tie-in with the local business community

Coordination with Existing Conservation Efforts

- CCR
  - Some managed hunting and effort to reduce deer on the hale
  - committing funds and developing activities to manage invasive species on Hale
- USFWS
  - ecosystem conservation planning efforts / ongoing work projects
- DOFAW
  - game management areas
  - monitoring census
  - fencing projects on hale and elsewhere
  - endangered petrel project
  - helps to fund Kanepu‘u through NAPP
  - Considering re-intro of nene in conjunction with Hui Malama Pono O Lana`i?
- Kanepu‘u Volunteers
  - Community workdays and volunteer projects in Kanepu‘u
- Maui County BWS
  - WUDP, Lana‘i Water Advisory Committee process
- Certain plant seeds and individuals in collections by
  - National Tropical Botanical Garden,
  - Waimea Arboretum & Botanical Garden
  - Amy Greenwell Ethnobotanical Garden
  - Hawai‘i Plant Conservation Center

FIGURE 6-36 Partial Implementation Matrix - Watershed

Feral Animal Control - Fence

Action	Why	By When	By Whom	Cost Estimate
Obtain funding for fence Increment III, or establish rate structure to cover it.	Up-front capital expenditure too great for one entity	within next two years	CCR	$900,000
co-fund grant sources	up-front capital too great for one entity alone - but company will bear partial cost with help from public sector	within next two years	CCR	
Interim - determine whether / where exclosures need to be built while awaiting funds for fence	for some species, the time it takes to obtain public funding for large-scale fence may prove too long...this question needs to be examined and considered	begin immediately determination within 6 months - begin construction for key areas as soon as identified	CCR, DOFAW, LF&WP	Depends upon need.
Survey fence-line	identify best route, potentially affected communities, etc.	within 6 months of funding approvals	CCR in conjunction with DOFAW, US F&WS	Should be included in estimate above
Construct fence	major threat to remaining watershed and other ecosystems is deer	by schedule to be developed but w/in 2 yrs of funding	CCR with help from partners and agencies as needed.	Should be included in estimate above
Maintain Fence and surrounding buffers	without proper maintenance, fence will not work	entire fence perimeter should be checked ... (semi-annually?) to insure integrity	CCR crew	$100,000 per year crew to maintain materials for repairs vehicles, equipment, etc. should also cover some of related expenses
Small exclosures w/in fencelines for snails, seabirds, etc.	target specific areas: nesting sites, known communities, etc.	Can begin inventory of desired sites now, build as indicated	CCR with help from DOFAW, biodiversity committee, etc.	same public / private mix?
Feral Animal Control -	Animal Removal			
Manage Hunting inside and outside of fenced area	hunt to elimination inside fence. This may have to include judas-deer, night hunts, use of lights, use of snares or traps, etc. Manage hunting and access outside of fence	on-going elimination of deer inside fence to begin immediately upon completion of each fence increment.	CCR w/ help from DOFAW, public hunting groups, etc.	part of CCR budget (100,000 per year).
Determine whether deer repellant, non-invasive plant species that taste bad to deer, or other additional measures are desirable to add insurance to buffer zone along outside of fence	additional means of controlling deer may not be adequate by themselves, but may help to enhance the effectiveness of fencing	periodic update of recent research.	DOFAW, Lana`i Co., LWAC, Hui Malama Pono O Lana`i, etc.	Part of other proposed budgets? If desired, planting can be part of volunteer program ?

Determine & implement appropriate predator removal strategies, and implement on-going (rats, cats, etc. - prey on birds & seeds) baits, traps, buffer zones around exclosures, (for ex. see snail exclosure fence design in text)	rats and cats prey on native birds, rats also eat seeds of native plants this may involve controversial issues such as baiting, trapping, etc. Look for repellants too?	within 5 years	DOFAW, CCR. and LWAC	CCR. forest management budget..)
Feral Animal Control -	Monitoring			
Monitor deer & sheep populations maintain regular transects, scheduled field checks, additional checks after unusual events, etc.	determine effectiveness of measures	annually	DOFAW & CCR with enhanced communication with company.	DOFAW & CCR
Fire Protection				
establish fire protective measures:	fire is major threat to watershed and to habitat of all remaining species.	can be started immediately, regardless of fence status	DOFAW, Fire Dept., Company, LWAC, Kanepu'u group, Boy Scouts, others?	CCR. forest mangement budget...
Inventory worst risk areas				
Fire breaks & Buffer zones				
Remove fire-inducing weed species				
Inventory & obtain emergency equipment as needed				
Develop prioritized response plan				
Develop and implement education program			Volunteer Assistance?	
Weed Removal				
Selective removal of non-desirable plant species - prioritize & implement fire hazard weeds invasive weeds listed elsewhere in report	reduce threats of fire, habitat loss, erosion, etc.	immediately and on-going	CCR DOFAW Volunteers Assistance from LWAC? Assistance from Hui Malama Pono O Lana`i?	On-going CCR. annual budget? (part of $100,000 K annual?) Additional assistance to be sought from Fed, State agencies?
Insect Mitigation				
Mosquitoes identify promising methods (eg: enhanced quarantine measures, selective spraying at breeding sites, or selective intro of sterile or genetically non-avian-disease carrying mosquitoes to reduce threat of avian malaria, pox, etc.) -	reduce threats to pollinators, plant species	efforts can begin immediately & continue indefinitely	CCR. with assistance from DOFAW, Dep't of Ag, others?	ongoing budgets of listed agencies? additional assistance to be sought in over-all grant request?

Yellow jackets locate nests eliminate with freezing or insecticides	powerful predators on native insects	efforts can begin immediately and continue indefinitely	CCR. with assistance from DOFAW, others	ongoing budgets of CCR and DOFAW?
Mitigate Human Impact				

Enforce bans on collecting native species, snails, seeds, etc.	reduce loss of threatened species	immediately and on-going	CCR, DOFAW, others?	ongoing budgets of listed agencies?
Education on proper forest entry				
Education on Watershed values				
Improved Quarantine & Inspection Protocols	Prevent entry of birds, insects, pathogens, plants	Review can begin immediately Implementation depends upon review	Dep't of Ag, DOFAW, USGS-BRD can review	?
Erosion Control				
Strategic Planting				
Wattles, Other Soil Trapping				
Animal Mgmt				
Reintroduce/Augment	Selected Species			
Bird Pollinators				
Native Plants				
Others?