

Biological Inventory and Assessment of Lehua Islet Kaua‘i County, Hawai‘i

Final Report
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K. R. Wood¹
Eric A. VanderWerf²
Chris Swenson²
Maya LeGrande³
Heather Eijzenga⁴
Ronald L. Walker²

Abstract. The U.S. Fish and Wildlife Service funded field surveys between 2001—2004 in order to research and evaluate the biological diversity of Lehua, a small off-shore islet to the north of Ni‘ihau and west of Kaua‘i, Hawai‘i. These surveys focused on the conservation status of Lehua’s biota with a special focus on botany, ornithology, entomology, and alien species management. In this report, we present the results of that research and make management recommendations for the long-term protection and enhancement of Lehua’s indigenous and endemic biotic diversity. Significant discoveries include previously undocumented breeding colonies of Black-footed Albatross (*Phoebastria nigripes*) and Laysan Albatross (*P. immutabilis*); the largest breeding colony of Brown Boobies (*Sula leucogaster*) in the Hawaiian Islands (521 pairs); the presence of Newell’s Shearwater (*Puffinus auricularis newelli*), a threatened species, and Band-rumped Storm-petrel (*Oceanodroma castro*), a candidate for listing; the presence of endemic and indigenous insects as well as alien ants; the presence of 22 species of native plants persisting despite the effects of rabbits; confirmation of the continued presence of alien rabbits (*Oryctolagus cuniculus*); documentation on the presence of Polynesian rats (*Rattus exulans*); general observations on geology and ecology, in addition to biotic checklists which includes discussions and historical accounts of all 31 bird and 55 plant species that have been observed on the island; a comparative checklist of vascular plants for all three of Kaua‘i’s offshore islets including Lehua, Ka‘ula, and Moku‘ae‘ae; a preliminary checklist of macro-algae; a preliminary checklist of arthropods; and a discussion on future biological restorations. The most urgent management needs on Lehua are eradication of alien rats and rabbits, control of alien Barn Owls and Cattle Egrets, and establishment of a trail system and standard survey protocols to minimize the extent of human disturbance to nesting birds.

Key Words. Offshore islets; biodiversity; alien species; active conservation.

¹ *Pelea Polynesia* P. O. Box 745, ‘Ele‘ele, Kaua‘i, HI 96705, kenwood@pelea.org

² U.S. Fish and Wildlife Service, Pacific Islands Office, 300 Ala Moana Boulevard, Room 3-122, Box 50088, Honolulu, HI 96822.

³ Bernice P. Bishop Museum, 1525 Bernice Street, Honolulu, HI 96817

⁴ University of Hawai‘i, Department of Botany, St John Hall, Honolulu, HI 96822.

DESCRIPTION OF LEHUA

Lehua islet, renowned for its diversity of nesting seabirds, is a tuff crater that lies 1.2 kilometers north of Ni‘ihau and roughly 31 kilometers to the west of Kaua‘i’s Mana Point (ArcView GIS 3.2a). Ni‘ihau was formed around 4.89 million years ago (Carson & Clague 1995) and Lehua is thought to be the result of a secondary volcanic event whereby pyroclastic material erupted with explosive force due to the very high proportion of gaseous to liquid matter to form a tuff cone. Palmer (1937) in his paper on the geology of Lehua and Ka‘ula Islands states that “Lehua lies some 9 miles (14.5 kilometers) north-northwest of the supposed position of the original summit crater of Ni‘ihau and bears the structural relationship of a secondary tuff crater”. Palmer further describes the formation of the tuff crater whereby “excessive amounts of gas in their swift up-rush break the lava into small particles, which are carried high into the air and which solidify before finishing their descent. Thus such an eruption is a sort of rain of ash or lava particles”. This process created the relatively soft porous material of tuff that has built on itself to form the cone of Lehua and which appears in various shades of gray or has weathered into darker shades of browns by the formation of hydrous oxides of iron. Lehua and a nearby tuff crater called Ka‘ula Islet, which lies 37 kilometers to the west-southwest of Ni‘ihau, have similar origins and structures (Palmer 1937). Both islets represent crucial locations for the breeding of seabirds, and were chosen by the Offshore Islet Restoration Committee (OIRC) as priority islets for future preservation and enhancement.

Lehua has an area of 1.1 square kilometers and its highest elevation is 213 meters (see Figure 1). On Lehua’s windward northern end its cone had been breached from millennia of weathering by wind, waves, and rain, leaving a 918 m wide opening where the sea has entered to form an inner crescent bay. The entire coastal perimeter of Lehua is 6,196 m and there is a distance of 2,737 meters from the tip of the west horn (i.e., Kaahuna) and along the arcuated crest to the tip of the eastern horn (i.e., Naupaka, [ArcView GIS 3.2a]).

Several notable geological features occur on Lehua including a natural arch that allows the ocean to pass between the inner and outer crescent, yet is solid enough at the ridge-crest to allow pedestrian passage over the remnant blocks of tuff that join the summit ridge above the arch opening. This natural arch occurs approximately 350 m south of the Kaahuna west horn where

the ridge is very narrow and appears to have a fault line. Also in the Kaahuna region, on the inner crescent side, are weathered dark gray stratified divisions of exposed and hollowed tuff where thousands of small burrows and cavities have formed, ranging in size from 25—100 cm deep. Many of these natural cavities are used for nesting by Wedge-tailed Shearwaters (*Puffinus pacificus*), Bulwer's Petrels (*Bulweria bulweri*), and perhaps Band-rumped storm-petrels (*Oceanodroma castro*).

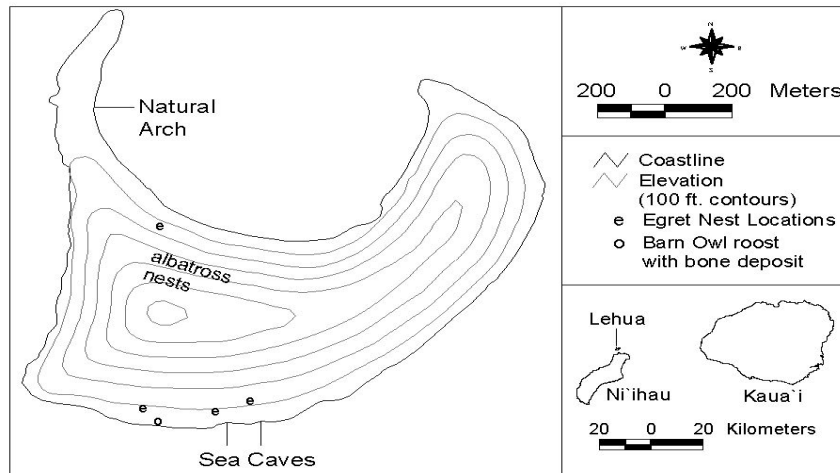


Figure 1. Map of Lehua Islet, showing locations of sea caves used for nesting by Black Noddies, natural arch that may be a partial barrier to rabbits and rats, Cattle Egret nest locations, and Barn Owl roost.

Along the shoreline of the eastern inner crescent lies a remarkable marine bench about 50 m wide and 150 m long. This bench holds a large pool that lies just above the bay and always seems to be filled with seawater. The lower inner crescent is extremely eroded with steep, deeply carved fissures that Palmer (1937) described as “sharply incised, miniature canyons”. Seacliffs of vertical weathered rock occur throughout Lehua and range between 3—55 m in height. Although the lead author has climbed down to the inner crescent coastline below Kaahuna west horn, the extremely steep topography above the marine bench and below Naupaka east horn make it unsafe to descend to the central and eastern inner crescent coastline. Along the upper inner crescent, parallel beds of strata are revealed in a series of weathered shelves forming an amphitheatre-like formation of level pathways and represent another of the natural wonders of Lehua. These shelves descend around one third of the way down from the crest toward the inner crescent bay. The shelves average approximately two meters in width and drop 1.5—2 m down to the next lower shelf, very much like a series of large steps. Other notable features on Lehua include two sea caves near the central southern outer crescent where over 300 Hawaiian Black Noddies (*Anous minutus melanogenys*) nest. These caves are approximately 10 m deep and have small black sand beaches in the rear, in addition to stalactites on their ceilings above, which have formed as small nipples or as large as 10 cm long. Around 200 m to the west of the sea caves and on a shelf above the sea there is a 4 m deep concave overhang that has a 2—4 m deep bed of fine sandy sediment deposited by erosion of the overhanging tuff cliff. On close examination the bones of birds and rodents were found in great numbers, indicating that the overhang most likely represents the roost of a predatory owl. This deposit of bones offers a valuable opportunity to study the recent historical diversity of vertebrate species preyed upon by owls.

On a cultural level, the remains of at least two stone platforms are present along the southern coast overlooking the sea toward Ni‘ihau. One, 200 m to the west of base camp, was noted by Palmer (1937) who states that Kenneth P. Emory believed the platform may represent a site built by bird hunters or possibly fisherman. This platform sits at 20 m elevation on the edge of a coastal tuff cliff and is a 6 m x 4 m rectangle, approximately 1.25 m tall along the southern end and 50—70 cm tall on the northern end. The second platform occurs to the east on a similar level headland along the edge of a coastal cliff. This site is a 3.5 m x 1.75 m rectangle,

approximately 30—50 cm tall. In addition, the remains of dozens of ahu, or rock cairns, were identified in September 2003 along the summit ridge of the island (Hawai'i Department of Land and Natural Resources 2004).

On first arrival to Lehua, one is impressed by the abundance of seabirds nesting on the ground, in shrubs, and filling the sky above. Access to the islet can be made on the leeward side of Lehua around the central southern outer crescent during typical trade-wind weather when the surf is not too rough. The southern slopes climb steeply up to the summit crest. These southern slopes still have sections of smooth tuff built by constructive volcanic action and a strong climber can move along and access different sections of the outer crescent with caution. Many small gullies have been carved into the outer southern crescent by ephemeral streams, wind, and rain. Most of these incised radial drainages run north to south and are trenched from the upper slopes down to the southern lower coast, yet just above and west of the sea-caves there are several exceptions where the drainages run east to west and parallel to the coast. It is in these drainages, where fine silty soils have accumulated and moisture percolates after rains in lower gully seeps, that rabbits have been observed in their greatest densities.

From the landing site, the easiest way to access the summit of Lehua is to head past the western Hawaiian stone platform and contour just above the smoothly sculptured and weathered tuff sea-walls toward the southwestern ridge. According to Palmer (1937) this southwestern ridge is a subsidiary crest line that “is not part of the crater rim but is a break or topographic unconformity separating two surfaces of quite different origin”. Along this subsidiary crest one can easily climb up to the 213 m summit where the U.S. Coast Guard maintains a small solar powered light for navigators. At that point one can view all points of Lehua except for the eastern slopes just to the south of the Naupaka point (i.e., east horn). From this ridge-line view one can see the entire western side of Kaua'i from the Na Pali cliffs south to Waimea and beyond to Kaua'i's rising summit peak of Kawaikini. Looking to the south, the sandy beaches of Ni'ihau's Kaaukuu Bay appear within swimming distance and further to the south a kiawe (*Prosopis pallida*) coastal dry forest extends for around five kilometers across a coastal flat zone to Ni'ihau's Kaali cliffs. Kaua'i affords some protection to Lehua from east-northeasterly storms and Ni'ihau partially protects Lehua from storms out of the south. On a clear day the outline of Ka'ula Islet, Lehua's

sister crescentic tuff cone, which is even richer in its diversity of nesting seabirds, can be seen approximately 40 kilometers to the south-southwest.

Depending on the time of year, a multitude of species can be observed in the surrounding waters of Lehua, including dolphins, humpback and melon-head whales, green sea turtles, sharks, manta rays, and monk seals. Lehua's waters harbor a rich, coastal marine biota of reef fish, macroalgae's and corals. Thousands of Red-footed and Brown Boobies, shearwaters, along with many other species of seabirds can be seen circling and filling the sky above or nesting in all possible niches of the islet. Of great interest are the breeding populations of Black-footed and Laysan Albatross that dominate the inner crescent amphitheatre just below the summit. Both species raise their young together on these weathered shelves of tuff, where the trade winds strongly blow up the inner crescent to afford an easy lift for flight and a cooling breeze for the young that are grounded in the dry heat and scorching sun. Native yellow-faced bees (*Hylaeus flavifrons*) can be seen working in the ilima (*Sida fallax*) flowers, along with other native insects such as the seed bugs (*Nysius kinbergi*) that are associated with *Portulaca*, in addition to shore flies of the genus *Canaceoides*, to name a few.

FLORA

Since rabbits were already present when Caum surveyed Lehua in 1931-1932, we will never know the abundance of biological diversity that may have occurred there. Caum (1936) documented seven endemic, 10 indigenous, and nine non-native naturalized species of vascular plants. At the time of this report, the authors are aware of nine endemic, 13 indigenous, and 27 naturalized species currently growing on Lehua. We have been unable to re-locate five species which Caum reported, including two of the seven endemic species (i.e., hinahina [*Heliotropium anomalum* var. *argenteum*] and 'ihi [*Portulaca villosa*]), two of his observed indigenous flora (i.e., pohuehue [*Ipomoea pes-caprae* subsp. *brasiliensis*], and the sedge *Cyperus polystachyos*), in addition to two naturalized species. We were able to add four additional endemics and five additional indigenous species to Lehua's native species list making a total of 26 recorded native plant species, with four of the previously mentioned taxa no longer extant (see checklist).

A total of 55 species of plants have been documented on Lehua since 1931, with 49 currently

known to occur on the islet. The number of non-native naturalized species increased from the nine observed by Caum to 27 species now reported during this inventory. It is these non-native species that dominate the vegetation of Lehua at this time with the exception of the native endemic morning glory pa‘uohi‘iaka (*Jacquemontia ovalifolia* subsp. *sandwicensis*), which the rabbits seem to avoid and can be found dominating both the inner and outer crescent regions, in addition to the endemic grass häkonakona (*Panicum torridum*) which dominates the upper third of the inner crescent amphitheatre after heavy rains. It is interesting to note that the invasive Panini cactus (*Opuntia ficus-indica*) that was common on Lehua in 1931 is no longer extant and may have died off as the result of a bio-control that was released in Hawai‘i several decades ago. The other non-native species which Caum observed and no longer occurs at this time is *Lantana camara*. Caum makes mention that Mr. Aubrey Robinson, the owner of the island of Ni‘ihau, has for a number of years conducted a systematic campaign of extermination against lantana on Lehua, to prevent the spread of the plant to Ni‘ihau.

Several non-native invasive species that were not present during Caum’s survey have now become well established throughout Lehua including the sourbush (*Pluchea carolinensis*), the Indian fleabane (*Pluchea indica*), and the dominating buffelgrass (*Cenchrus ciliaris*). The *Pluchea* shrubs, in addition to another weedy shrub in the mallow family, *Abutilon grandifolium*, appear to have replaced the native naupaka shrub *Scaevola taccada*, which was most likely a common species and nesting site for the red-footed booby (*Sula sula*) population on Lehua. Although there is no documented proof that naupaka occurred on Lehua, the Hawaiians gave the name Naupaka to the east horn of Lehua, most likely signifying the plants presence, as there is no other meaning for ‘naupaka’ in the Hawaiian language.

Because of the adverse effects caused by the long term presence of rabbits and rats on Lehua, there appears to be no plant associations left that represent what Lehua may have been like in its natural state. In addition, as the result of its harsh environment (i.e., strong winds and arid conditions), the steeper regions of Lehua are rather depauperate in vegetation with only occasional plants clinging to small soil pockets in the cracks of barren tuff. It is presumed that extreme weather in combination with introduced rodents and rabbits have worked to keep

Lehua's vegetation to a minimum and caused the extirpation of an unknown number of native life forms.

The most widespread vegetation type at this time is the *Cenchrus ciliaris-Setaria verticillata-Portulaca oleracea-Jacquemontia ovalifolia* association, which dominates the southern outer crescent wherever sediments have accumulated in gulch bottoms and throughout the lower flat regions above the coastline. This plant community is interspersed with other common associates including the dominant shrub *Pluchea indica*, along with *Pluchea carolinensis*, and their occasional hybrid *Pluchea xfosbergii*, in addition to other herbaceous species such as *Ageratum conyzoides*, *Chenopodium murale*, *Waltheria indica*, *Cenchrus echinatus*, and *Chloris virgata*.

Regions that appear barren within the inner crescent and have no evident set of dominant species during dry periods can be transformed after rains into varying grassland-herblands due to a dormant soil seed bank. Sections of the inner crescent after rains can re-vegetate themselves into a *Panicum torridum-Chenopodium murale-Ageratum conyzoides* association or form *Portulaca oleracea-Jacquemontia ovalifolia* associations within meters of each other. *Panicum torridum-Sicyos maximowiczii*, which is a grass and vine association, can also be observed commonly within the inner crescent. The most prolific growth on this north side occurs around the upper inner crescent shelves that are flatter and have less loss of soil due to wind and rain runoff.

The southwestern slopes of Lehua are dominated by a *Pluchea indica-Chloris virgata* association interspersed with *Jacquemontia ovalifolia* subsp. *sandwicensis* and *Portulaca oleracea*. This region also has the greatest concentration of *Argemone glauca* and the last remaining individuals of *Fimbristylis cymosa* subsp. *umbellato-capitata*.

Comparative Checklist of Vascular Plants. The authors have compiled the following checklist of vascular plant species that occur on all three of Kaua'i's offshore islets including Lehua, Ka'ula, and Moku'ae'ae. This checklist makes an easy reference for presence/absence of plants on each islet and shows the current status of each species, in addition to whether they were historically observed. The Lehua checklist represents this current research by Wood *et al.* 2001—2004 and includes the historical references from Caum's visit in 1931 and 1932. The

<i>Ipomoea cairica</i> (L.) Sweet	pol		▲	
<i>Ipomoea indica</i> (Burm.) Merr.	ind		▲ [1932]	
<i>Ipomoea pes-caprae</i> (L.) R. Br. subsp. <i>brasiliensis</i> (L.) Ooststr.	ind	H [1932]		
<i>Jacquemontia ovalifolia</i> (Choisy) H. Hallier subsp. <i>sandwicensis</i> (A. Gray) K. Robertson	end	▲ [1932]		
Cucurbitaceae				
<i>Sicyos maximowiczii</i> Cogn.	end	▲ S [1932]		
Euphorbiaceae				
<i>Chamaesyce hirta</i> (L.) Millsp.	nat	▲ [1932]		
<i>Chamaesyce celastroides</i> (Boiss.) Croizat & Degener	end		▲ [1932]	
<i>Chamaesyce celastroides</i> (Boiss.) Croizat & Degener var. <i>stokesii</i> (C. N. Forbes) Degener & I. Degener	end			▲
Fabaceae				
<i>Leucaena leucocephala</i> (Lam.) de Wit	nat		▲	
<i>Prosopis pallida</i> (Humb. & Bonpl. ex Willd.) Kunth	nat	▲		
Malvaceae				
<i>Abutilon grandifolium</i> (Willd.) Sweet	nat	▲		
<i>Sida fallax</i> Walp.	ind	▲ [1932]	▲ [1932]	▲
<i>Thespesia populnea</i> (L.) Sol. ex Correa	ind		▲	
Nyctaginaceae				
<i>Boerhavia repens</i> L.	ind	▲ [1932]	▲ [1932]	
Oxalidaceae				
<i>Oxalis corniculata</i> L.	ind	▲		
Papaveraceae				
<i>Argemone glauca</i> (Nutt. ex Prain) Pope var. <i>glauca</i>	end	▲ [1932]		
Plumbaginaceae				
<i>Plumbago zeylanica</i> L.	ind		▲	
Portulacaceae				
<i>Portulaca lutea</i> Sol. ex G. Forster	ind		▲ [1932]	▲ S
<i>Portulaca oleracea</i> L.	nat	▲ [1932]	▲ [1932]	▲
<i>Portulaca pilosa</i> L.	nat	▲		
<i>Portulaca villosa</i> Cham.	end V	H [1932]	▲ [1932]	
Primulaceae				
<i>Anagallis arvensis</i> L.	nat	▲		
Solanaceae				
<i>Lycium sandwicense</i> A. Gray	ind		▲	▲ S
<i>Solanum americanum</i> Mill.	ind	▲	▲ [1932]	
Sterculiaceae				
<i>Waltheria indica</i> L.	ind	▲ [1932]		
Urticaceae				
<i>Pilea peploides</i> (Gaud.) Hook. & Arnott	ind	▲		

Verbenaceae				
<i>Lantana camara</i> L.	nat	H [1932]		
Zygophyllaceae				
<i>Tribulus cistoides</i> L.	ind	▲	▲ [1932]	
Angiosperms--Monocots				
Cyperaceae				
<i>Cyperus javanicus</i> Houtt.	ind	▲ S [1932]		
<i>Cyperus polystachyos</i> Rottb.	ind	H [1932]		
<i>Fimbristylis cymosa</i> R. Br.	ind	▲ [1932]		
subsp. <i>umbellato-capitata</i> (Hillebr.) T. Koyama				
Poaceae				
<i>Cenchrus ciliaris</i> L.	nat	▲		
<i>Cenchrus echinatus</i> L.	nat	▲	▲	
<i>Chloris barbata</i> (L.) Sw.	nat		▲	
<i>Chloris radiata</i> (L.) Sw.	nat	▲		
<i>Chloris virgata</i> Sw.	nat	▲		
<i>Cynodon dactylon</i> (L.) Pers.	nat			▲
<i>Digitaria ciliaris</i> (Retz.) Koeler	nat	▲ [1932]		
<i>Digitaria insularis</i> (L.) Mez ex Ekman	nat	▲		▲
<i>Digitaria setigera</i> Roth	ind		▲	
<i>Echinochloa colona</i> (L.) Link	nat		▲	
<i>Eleusine indica</i> (L.) Gaertn.	nat			▲
<i>Eragrostis amabilis</i> (L.) Wight & Arnott	nat	▲		
<i>Eragrostis variabilis</i> (Gaud.) Steud.	end	▲		
<i>Heteropogon contortus</i> (L.) P. Beauv.	ind	▲ [1932]		
ex Roem. & Schult.				
<i>Lepturus repens</i> (G. Forster) R. Br.	ind	▲		
<i>Panicum fauriei</i> Hitchc.	end	▲		
var. <i>latius</i> (St. John) Davidse				
<i>Panicum pellitum</i> Trin.	end	▲ [1932]	▲ [1932]	
<i>Panicum torridum</i> Gaud.	end	▲	▲	
<i>Setaria verticillata</i> (L.) P. Beauv.	nat	▲ [1932]	▲	
Pteridophytes				
Dryopteridaceae				
<i>Nephrolepis multiflora</i> (Roxb.) F.M. Jarrett	nat	▲		
ex C.V. Morton				
Pteridaceae				
<i>Doryopteris decipiens</i> (J. Sm.) Hook.	end	▲ [1932]		

Table 2. Number of Vascular Plant Species Documented on Lehua, Ka‘ūla, and Moku‘ae‘ae.

Islet	# of Endemic	# of Indigenous	# of Naturalized	# of Polynesian	Total
Lehua	11	15	29	0	55
Ka‘ūla	5	10	10	1	26
Moku‘ae‘ae	2	4	5	0	11

Species Accounts. Species of both native and non-native vascular plants occurring on Lehua are listed below with data concerning their distribution and abundance. References are made to their abundance during both Caum’s research in 1931—1932 and the present research conducted by Wood *et al.* from 2001—2004. Hawaiian names are included for cultural significance and when given the option we used the preferred Ni‘ihau name.

Angiosperms--Dicots

Aizoaceae

Sesuvium portulacastrum (L.) L. (‘ākulikuli) is an indigenous mat forming perennial herb with long creeping stems and succulent leaves. It was observed to be locally common by both Caum and Wood *et al.* around the weathered shelves above the sea near the southwestern leeward side, in addition to a few patches on the crest of the west horn.

Asclepiadaceae

Asclepias curassavica L. (laulele) is a non-native, naturalized, erect perennial herb. It is reported by both Caum and Wood *et al.* as being rare along the southern slopes just east of the sea-caves.

Asteraceae

Ageratum conyzoides L. (maile hohono) is a non-native, naturalized, malodorous annual herb that was considered uncommon by Caum. Currently Wood *et al.* report it as being a dominant species after rains in the flatter zones throughout Lehua.

Artemisia australis Less. (‘āhinahina) is an endemic shrub with aromatic leaves that shimmer with silvery hairs. Although it was not observed by Caum, Wood *et al.* report a small localized population centrally located along the upper inner crescent.

Cirsium vulgare (Savi) Ten. (pua kala) is a non-native, naturalized bull thistle with a purple corolla and bristles on its stems and leaves. Caum made no report of this species and Wood *et al.* report a single plant observed on the central inner crescent.

Conyza bonariensis (L.) Cronq. (lani wela) is a non-native, naturalized, densely pubescent herbaceous species that was not observed by Caum but can be seen after rains in small numbers throughout the islet.

Gamochaeta purpurea (L.) Cabr (purple cudweed) is a non-native, naturalized herbaceous species of around 25 cm, erect with moderately wooly leaves. It was not observed by Caum but can be seen after rains in small numbers throughout the islet.

Pluchea carolinensis (Mill.) Gillis (sourbush) is a non-native, naturalized shrub of 1—1.5 m height with aromatic leaves. It was not observed by Caum but is currently a dominant species throughout Lehua's inner and outer crescent and has become the preferred nesting site of the Red-footed Booby, along with *P. indica* and *P. xfosbergii*.

Pluchea indica (L.) Less. (Indian fleabane) is a non-native, naturalized shrub of 1—1.5 m height and with coarsely dentate leaves. It was not observed by Caum but is currently a dominant species throughout Lehua's inner and outer crescent and has become the preferred nesting site of the Red-footed Booby along with *P. carolinensis* and *P. xfosbergii*.

Pluchea xfosbergii Cooperr. & Galang (marsh fleabane) is a non-native hybrid between *P. indica* & *P. carolinensis*. It was not observed by Caum but is occasional around the southern slopes of Lehua's outer crescent and has become the preferred nesting site of the Red-footed Booby along with *P. carolinensis* and *P. indica*.

Sonchus oleraceus L. (pualele) is a non-native, naturalized annual herb that was observed by both Caum and Wood *et al.* and can be seen occasionally throughout the islet.

Verbesina encelioides (Cav.) Benth. & Hook. (golden crown-beard) is a non-native, naturalized herb that was not observed by Caum. A few plants were seen by Wood *et al.* on the eastern face below the east horn.

Xanthium strumarium L. (kikānia) is a non-native, naturalized, erect annual herb with ovoid burs that are armed with hooked prickles. This species was not recorded by Caum and only a few plants were observed by Wood *et al.* around the western outer crescent where radial drainages are known to have seeps during winter rains.

Boraginaceae

Heliotropium anomalum Hook. & Arnott var. *argenteum* A. Gray (pōhinahina) is an endemic, prostrate subshrub that sometimes forms mats with whirled succulent leaves that are covered in soft, silky gray hairs. Only Caum observed these plants and he reported them to be restricted to the inner side of the crest ranging between the base of the east horn westward to about the median line on the rocks of the pre-summit series where it forms an almost pure stand. He states that further west toward the base of west horn it grows sparingly.

Heliotropium curassavicum L. (lau po‘opo‘ohina) is an indigenous, perennial herb with prostrate stems that was reported uncommon by Caum and growing in a few places on the southern cliffs, in the neighborhood of the landing, just above the water. This species was seen by Wood *et al.* in the area of the landing in addition to several larger populations in association with *Sesuvium portulacastrum* (akulikuli) that grows around the shelves of tuff above the sea on the southwestern leeward side.

Cactaceae

Opuntia ficus-indica (L.) Mill. (pānini) is a non-native cactus that was considered common by Caum and occurred on the southern and eastern faces of the islet with a few scattered clumps on the inner side of the crescent near the base of the west horn. Wood *et al.* made no observations of this species.

Chenopodiaceae

Chenopodium murale L. (‘āheahea) is a non-native, naturalized annual herb with erect stems of around 10—20 cm. It was not observed by Caum, yet is presently densely distributed throughout the islet after rains.

Convolvulaceae

Ipomoea pes-caprae (L.) R. Br. subsp. *brasiliensis* (L.) Ooststr. (pöhuehue) is an indigenous vine with long trailing stems that occasionally root at the node. Caum considered it rare on Lehua with only one small patch having been found on the inner side of the base of west horn, about 200 feet below the summit. No plants of this species were observed by Wood *et al.*

Jacquemontia ovalifolia (Choisy) H. Hallier subsp. *sandwicensis* (A. Gray) K. Robertson (pä‘ü-o-Hi‘iaka) is an endemic subspecies of vine with long, prostrate stems trailing up to 3 m. Caum called it the prevalent plant, common in all parts of the island except the tip of the west horn. Wood *et al.* also considers it to be the most abundant species. It appears that rabbits will avoid eating this plant.

Cucurbitaceae

Sicyos maximowiczii Cogn. (puaokama) is an endemic annual vine with trailing stems of up to 10 m long. Caum considered it rare and found it only in one location at the foot of a radial valley just to the west of the sea-caves “tank houses”. Caum remarked that rabbits had eaten the base of the singular plant and killed it. Wood *et al.* also observed large 10 m sq patches in the same general region as Caum, but also observed it in several dozen 3—10 m sq. patches along the inner crescent region. Seeds were collected for restoration.

Euphorbiaceae

Chamaesyce hirta (L.) Millsp. (koko kahiki) is a non-native, naturalized herbaceous annual herb that was reported by Caum as not uncommon and scattered along the crest of the island and very sparingly elsewhere. Wood *et al.* observed it throughout the islet after rains and considers it moderately common.

Fabaceae

Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth (kiawe) is a non-native, naturalized hardwood tree that was not observed by Caum. A single tree of this species is reported by Wood *et al.* as occurring at the lower end of a deep narrow radial drainage on the east central leeward side of the outer crescent. This single tree is a preferred site for red-footed booby nesting. It is interesting to note that around five dead red-footed boobies were observed in this tree. Some had apparently died sometime ago as the only evidence of their presence is their feet still left clinging to their roosting branch. Dozens of invasive cattle egrets (*Bubulcus ibis*) have been observed nesting in this tree and pose a serious threat to seabirds like the red-footed boobies that need shrubs or trees to raise their young.

Malvaceae

Abutilon grandifolium (Willd.) Sweet (ma'o) is a non-native, naturalized shrub of two meters that was not observed by Caum but is currently common in crevices on the less steep lower slopes of the outer crescent and is used by Red-footed Boobies for nesting and perching.

Sida fallax Walp. ('ilima) is an indigenous, prostrate or sub-erect shrub of around 25 cm in height. Caum recorded this species as rare with only two plants seen near the tip of the east horn on the inner crescent side and a few seedlings on the crest of the west horn. Wood *et al.* report this plant as being rare on the leeward side along the flatter sections above and west of the sea-caves, and locally common along the crest and inner crescent side of the west horn.

Nyctaginaceae

Boerhavia repens L. (alena) is an indigenous perennial herb with prostrate stems. Caum reported this species as very rare with only three seedlings observed along the flats above the sea-caves. Wood *et al.* report this species as being occasional throughout the islet.

Oxalidaceae

Oxalis corniculata L. ('ihi 'ai) is an indigenous perennial herb of 5-10 cm. with trifoliate leaves. Caum made no observations of this species and Wood *et al.* report that this species is seen occasionally throughout the islet after rains.

Papaveraceae

Argemone glauca (Nutt. ex Prain) Pope var. *glauca* (pua kala) is an endemic perennial herb with glaucous blue-green stems and leaves, yellow latex, and white flowers. Caum reports this species as being rare in 1931 with two plants seen in a pocket just behind the cliffs on the south side, and two more in a deep gully on the northern side of the southwest ridge. Wood *et al.* note that this species is occasional on the western slopes of the southwest ridge and along the inner crescent slopes.

Portulacaceae

Portulaca oleracea L. ('ākulikuli kula) is a non-native, naturalized, annual herb with succulent decumbent or sub-erect stems and small yellow flowers. Caum reports this plant as being uncommon along the length of the crest from about the middle of the southwest ridge to near the tip or the east horn. Wood *et al.* report this species as being one of the most common throughout the islet. This species appears to be desirable to rodents as the authors have observed extensive herbivory on their leaves and stems.

Portulaca pilosa L. ('ākulikuli) is a non-native, naturalized, perennial herb with purple-red stems and magenta flowers. It was not observed by Caum but Wood *et al.* report it as being occasional throughout the islet and sometimes locally common along the inner crescent.

Portulaca villosa Cham. ('ihi) is an endemic perennial herb with decumbent stems and white or pink-white flowers. Caum reports this species as rare with only one small stand on the crest of the west horn, near the tip. The plants were all small and in poor condition. Wood *et al.* have made no observations of this species.

Primulaceae

Anagallis arvensis L. (scarlet pimpernel) is a non-native, naturalized, short-lived herb of around 10 cm with a salmon colored corolla. This species was not observed by Caum and is recorded by Wood *et al.* as being occasional along the flatter inner and outer crescent regions after rains.

Solanaceae

Solanum americanum Mill. (pöpolohua) is an indigenous, short-lived perennial herb of around 50 cm in height with white or purple tinged corolla and glossy black berries. This species was not observed by Caum and is recorded by Wood *et al.* as being rare on the flats above and west of the sea-caves and occasional along the flatter zones of the inner crescent especially after rains.

Sterculiaceae

Waltheria indica L. ('uhaloa) is an indigenous sub-shrub with prostrate to ascending branches, velvety gray-green leaves, and yellow flowers. Caum reports this species as being very common in all parts of the islet with the exception of the farther part of the west horn where it occurs very sparingly. He further states that with the exception of *Jacquemontia*, it is the most common plant species on the island. Wood *et al.* report 'uhaloa as being common throughout the islet but not as dominant as *Cenchrus ciliaris*, *Portulaca oleracea*, *Ageratum conyzoides*, and *Chenopodium murale*. 'Uhaloa is able to survive during drought periods and dry summer months when the afore-mentioned herbs sometimes die back.

Urticaceae

Pilea peploides (Gaud.) Hook. & Arnott is an indigenous low perennial herb in the nettle family. Caum made no observations of this species and Wood *et al.* report it as being rare along the flatter zones of the inner crescent.

Verbenaceae

Lantana camara L. (lanakana) is a non-native, naturalized shrub that is usually around 1-2 m tall and is thickly branched with stout recurved prickles. Caum reports only one plant seen in a soil pocket on the edge of the southern cliffs. He notes that the plant was destroyed after the specimen was taken and that Mr. Aubrey Robinson, the owner of the island of Ni'ihau, has for a number of years conducted a systematic campaign of extermination against lantana on Lehua, to prevent the spread of the plant to Ni'ihau. Wood *et al.* did not observe this species.

Zygophyllaceae

Tribulus cistoides L. (nohu) is an indigenous perennial herb with creeping decumbent stems and

compound leaves that are densely covered in silvery strigose hairs. Caum made no observations of this species and Wood *et al.* note that 15 plants were present along the ridge and inner crescent side of the west horn.

Angiosperms--Monocots

Cyperaceae

Cyperus javanicus Houtt. ('ahu'awa) is an indigenous, 1 m tall perennial sedge with glaucous blue-green leaves and flattened brown-gold spiklets that prefers sites with water seepage. Caum observed it in several locations which include the base of the east horn growing just below the crest; in the radial valleys of the southern slope near the cliffs; and just behind the bench to the west of the gas tank houses (i.e., west of the sea-caves). Wood *et al.* observed only one population in a natural seep on a shelf just above the southeastern cliffs (UTM 387386 – 2435789). Seeds were collected for restoration.

Cyperus polystachyos Rottb. is a small indigenous sedge with stiff culms. The form observed by Caum was described as tiny compared to the normal form which ranges between 20-30 cm. Caum observed this population near the base of the east horn, on the outer side just below the crest. Wood *et al.* made no observations of this species

Fimbristylis cymosa R. Br. subsp. *umbellato-capitata* (Hillebr.) T. Koyama (mau'u 'aki'aki) is an indigenous perennial sedge, usually around 10 cm tall, with short rhizomes and stiff erect leaves and culms. Caum notes that it was very rare in 1931, growing sparingly along the crest of the southwest ridge, where it forms mats in the tiny rock pockets. In addition, he notes that a single, very small although fully mature clump was found on the crest of the west horn, well out toward the tip. Wood *et al.* only observed a few small clumps just below and east of the lower southwest ridge (UTM 386003 – 2435260) on a steep 45° slope with scattered chunks of slate-like tuff. These plants looked close to being dead with only a few green leaves apparent.

Poaceae

Cenchrus ciliaris L. (buffelgrass) is a non-native, naturalized, perennial species of grass that forms mats or tussocks. Caum made no note of this species. Currently it is the most dominating

grass and is thickly covering the flatter regions around the inner and outer crescent and can die back during dry periods. We have observed Wedge-tailed Shearwaters nesting below the tussocks of this grass.

Cenchrus echinatus L. ('ume'alu) is a non-native, naturalized annual species of grass with decumbent culms and burs with sharp bristles. Caum made no note of this species. Currently it is occasional throughout the islet with a greater density around the western end of the outer crescent.

Chloris radiata (L.) Sw. (radiate fingergrass) is a non-native, naturalized annual species of grass. Caum made no note of this species. Currently it is occasional to locally common throughout the islet.

Chloris virgata Sw. (feather fingergrass) is a non-native, naturalized annual species of grass with digitate feathery spikes. Caum made no note of this species. Currently it is occasional to locally common throughout the islet.

Digitaria ciliaris (Retz.) Koeler (kūkaepua'a) is a non-native, naturalized annual species of grass with decumbent stems. Caum states that a number of dead plants were found in a small patch near the middle of the west horn, and a single dead plant was on the crest of the southwest ridge. Wood *et. al.* observed this species throughout the islet especially after rains.

Digitaria insularis (L.) Mex ex Ekman (sourgrass) is a non-native, naturalized and densely tufted perennial with erect culms of 1 m. Caum made no note of this species. Wood *et al.* noted a single plant along the eastern slopes of the islet.

Eragrostis amabilis (L.) Wight & Arnott (lovegrass) is a non-native, naturalized annual grass with erect slender culms of 10-20 cm. Caum made no note of this species. Wood *et al.* noted this species throughout the islet especially around the flatter regions during the wet season.

Eragrostis variabilis (Gaud.) Steud. (kāwelu) is a endemic perennial with tufted culms of around

50 cm that can be common on islets. Caum made no observations of this species and Wood *et al.* made only one observation of a dried up plant in one of the radial drainages along the outer crescent just to the east of the sea-caves.

Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult. (pili) is an indigenous perennial with erect tufted culms of around 50 cm and flowers that have twisted or contorted awns. Caum reports this species as common in 1931, on the outer side of east horn, and scattering over the eastern half of the southern slope. He also notes that it grows very sparingly, if at all, west of the median line. Wood *et al.* also report this species as occasional on the eastern slopes of the islet and note that it is locally common along the upper southern slopes of the outer crescent with its greatest density around the central region.

Lepturus repens (G. Forster) R. Br. is an indigenous perennial grass with erect or spreading branches of around 30 cm. Caum makes no reference to this species and Wood *et al.* report a small population along the central eastern slopes of the islet and along the west horn.

Panicum fauriei Hitchc. var. *latius* (St. John) Davidse (panic grass) is an endemic, decumbent annual grass spreading out 10—25 cm . Caum makes no reference to this species and Wood *et al.* report it to be common along the upper southwest ridge up to the summit where it is most abundant along the western inner crescent and is occasional along the inner crescent to the east horn.

Panicum pellitum Trin. (kai'oi'o) is an endemic, decumbent annual grass spreading out 10—25 cm. Caum states that it was common in 1931 along the crest of the southwest ridge and at the tip of west horn, and Wood *et al.* also report it to be common along the summit of the southwest ridge and occasional along the western inner crescent, in addition to a few plants at the tip of the west horn.

Panicum torridum Gaud. (hākonakona) is an endemic grass of around 10 to 50 cm tall with velvety puberulent leaves. Caum made no observations of this species and Wood *et al.* report it to be a dominant species along the summit ridge with its greatest density within the upper inner

crescent after rains.

Setaria verticillata (L.) P. Beauv. (mau'ū pilipili) is a non-native, naturalized tufted annual grass of approximately 25-50 cm tall. Caum reports this species as very rare in 1931 with one clump observed on a tiny ledge near the landing place. Wood *et al.* report this species as still present.

Pteridophytes

Dryopteridaceae

Nephrolepis multiflora (Roxb.) F.M. Jarrett ex C.V. Morton (sword fern) is a non-native, naturalized fern, 30—50 cm tall, with fronds clustered on short decumbent to sub-erect rhizomes. Caum does not record this species. Wood *et al.* report this species as being rare with just a few plants observed along the upper inner crescent.

Pteridaceae

Doryopteris decipiens (J. Sm.) Hook. (kumuniu) is an endemic fern with small triangular fronds of around 10 cm. Caum notes that there were only a few clumps found on the inner slope near the peak, just below the crest of the ridge. Wood *et al.* report this species as occasional in the same general region noted by Caum.

Original Flora of Lehua. Lehua has lost most of its natural plant composition as a result of the long-term presence of rabbits and rats, and displacement by invasive weeds. As there were already rabbits on Lehua when Caum did his floral survey in the early 1930's, it is unknown what the previous native plant associations were. With no known sites available on Lehua to extract pollen core samples for paleoenvironmental research, the authors can only make an educated guess as to the original composition and matrix of species by using ecological data that describes the composition of similar, yet less disturbed islets and coastal sites of Hawai'i.

We hypothesize that Lehua may have been dominated by a *Scaevola taccada-Chamaesyce celastroides* var. *stokesii* shrubland with common shrub associates such as *Chenopodium oahuense*, *Senna gaudichaudii*, *Sesbania tomentosa*, *Artemisia australis*, *Kanaloa* sp., *Santalum ellipticum*, *Myoporum sandwicense*, and *Dodonaea viscosa*. It is also very likely that *Pritchardia*

Boraginaceae	
<i>Heliotropium anomalum</i> Hook. & Arnott var. <i>argenteum</i> A. Gray	end
<i>Heliotropium curassavicum</i> L.	ind
Brassicaceae	
<i>Lepidium bidentatum</i> Montin var. <i>o-waihiense</i> (Cham. & Schlechtend.) Fosb.	end V
Campanulaceae	
<i>Brighamia insignis</i> A. Gray	end E
<i>Lobelia niihauensis</i> St. John	end E
Capparaceae	
<i>Capparis sandwichiana</i> DC	end V
Caryophyllaceae	
<i>Schiedea globosa</i> H. Mann	end V
<i>Schiedea verticillata</i> F. Brown	end E
Chenopodiaceae	
<i>Chenopodium oahuense</i> (Meyen) Aellen	end
Convolvulaceae	
<i>Cressa truxillensis</i> Kunth	ind
<i>Ipomoea indica</i> (Burm.) Merr.	ind
<i>Ipomoea pes-caprae</i> (L.) R. Br. subsp. <i>brasiliensis</i> (L.) Ooststr.	ind
<i>Ipomoea tuboides</i> Degener & Ooststr.	end
<i>Jacquemontia ovalifolia</i> (Choisy) H. Hallier	end
subsp. <i>sandwicensis</i> (A. Gray) K. Robertson	
Cucurbitaceae	
<i>Sicyos maximowiczii</i> Cogn.	end
Euphorbiaceae	
<i>Chamaesyce celastroides</i> (Boiss.) Croizat & Degener	end
var. <i>stokesii</i> (C. N. Forbes) Degener & I. Degener	
<i>Chamaesyce degeneri</i> (Sherff) Croizat & Degener	end
Fabaceae	
<i>Canavalia napaliensis</i> St. John	end V
<i>Erythrina sandwicensis</i> Degener	end
<i>Kanaloa kahoolawensis</i> Lorence & K. R. Wood	end E
<i>Senna gaudichaudii</i> (Hook. & Arnott) H. Irwin & Barneby	ind
<i>Sesbania tomentosa</i> Hook. & Arnott	end E
<i>Vigna marina</i> (Burm.) Merr.	ind
Goodeniaceae	
<i>Scaevola coriacea</i> Nutt.	end E
<i>Scaevola taccada</i> (Gaertn.) Roxb.	ind
Hydrophyllaceae	
<i>Nama sandwicensis</i> A. Gray	end V
Malvaceae	
<i>Gossypium tomentosum</i> Nutt. ex Seem.	end V

<i>Hibiscus kokio</i> Hillebr. Ex Wawra subsp. <i>saintjohnianus</i> (M. Roe) D. Bates	end R
<i>Sida fallax</i> Walp.	ind
Myoporaceae	
<i>Myoporum sandwicense</i> A. Gray	ind
Nyctaginaceae	
<i>Boerhavia repens</i> L.	ind
<i>Pisonia grandis</i> R. Br.	ind
Papaveraceae	
<i>Argemone glauca</i> (Nutt. Ex Prain) Pope var. <i>glauca</i>	end
Piperaceae	
<i>Peperomia blanda</i> (Jacq.) Kunth var. <i>floribunda</i> (Miq.) H. Huber	ind
<i>Peperomia tetraphylla</i> (G. Forster) Hook. & Arnott	ind
Pittosporaceae	
<i>Pittosporum halophilum</i> Rock	end R
Plumbaginaceae	
<i>Plumbago zeylanica</i> L.	ind
Portulacaceae	
<i>Portulaca lutea</i> Sol. ex G. Forster	ind
<i>Portulaca villosa</i> Cham.	end V
Primulaceae	
<i>Lysimachia mauritiana</i> Lam.	ind
Rhamnaceae	
<i>Colubrina asiatica</i> (L.) Brongn.	ind
Rosaceae	
<i>Osteomeles anthyllidifolia</i> (Sm.) Lindl.	ind
Rubiaceae	
<i>Hedyotis littoralis</i> (Hillebr.) Fosb.	end V
<i>Hedyotis st.-johnii</i> B. Stone & Lane	end E
Santalaceae	
<i>Santalum ellipticum</i> Gaud.	end
Sapindaceae	
<i>Dodonaea viscosa</i> Jacq.	ind
Solanaceae	
<i>Solanum nelsonii</i> Dunal	end V
Thymelaeaceae	
<i>Wikstroemia uva-ursi</i> A. Gray var. <i>kauaiensis</i> Skottsb.	end
Urticaceae	
<i>Pilea peplodes</i> (Gaud.) Hook. & Arnott	ind

Verbenaceae	
<i>Vitex rotundifolia</i> L. fil.	ind
Angiosperms—Monocots	
Arecaceae	
<i>Pritchardia aylmer-robinsonii</i> St. John	end E
Cyperaceae	
<i>Cyperus javanicus</i> Houtt.	ind
<i>Cyperus polystachyos</i> Rottb.	Ind
<i>Cyperus trachysanthos</i> Hook. & Arnott	end E
<i>Fimbristylis cymosa</i> R. Br. subsp. <i>umbellato-capitata</i> (Hillebr.) T. Koyama	ind
Poaceae	
<i>Cenchrus agrimonioides</i> Trin. var. <i>agrimonioides</i>	end E
<i>Chrysopogon aciculatus</i> (Retz.) Trin.	ind
<i>Eragrostis variabilis</i> (Gaud.) Steud.	end
<i>Heteropogon contortus</i> (L.) P. Beauv. ex Roem. & Schult. (ind)	
<i>Ischaemum byrone</i> (Trin.) Hitchc.	end E
<i>Lepturus repens</i> (G. Forster) R. Br.	ind
<i>Panicum fauriei</i> Hitchc. var. <i>latius</i> (St. John) Davidse	end
<i>Panicum pellitum</i> Trin.	end
<i>Panicum torridum</i> Gaud.	end
Pteridophytes	
Blechnaceae	
<i>Sadleria pallida</i> Hook. & Arnott	end
Dryopteridaceae	
<i>Nephrolepis exaltata</i> (L.) Schott subsp. <i>hawaiiensis</i> W.H. Wagner (ined.)	end
Ophioglossaceae	
<i>Ophioglossum nudicaule</i> L. f.	ind
Pteridaceae	
<i>Doryopteris decipiens</i> (J. Sm.) Hook.	end

Marine Algae of Lehua. Marine algae were collected from inter-tidal and shallow marine areas near the rock bench fronting the sea caves along Lehua's south shore. Algae collections were made in March and May 2003. In order to obtain a more complete representation, additional collections should be made in other inter-tidal areas, especially from the tide-pool benches in Lehua's inner crescent, as well as from deeper waters around the islet.

Table 3. Preliminary Checklist of Lehua's Marine Algae

Species

Cyanophyta

Oscillatoriaceae

Lyngbya majuscula (Dillwyn) Harv.

Lyngbya semiplena Gomont

Chlorophyta

Anadyomenaceae

Microdictyon setchellianum M. Howe

Caulerpaceae

Caulerpa racemosa var. *peltata* (J.V. Lamour.) Eubank

Cladophoraceae

Cladophora laetevirens (Dillwyn) Kutz.

Codiaceae

Codium edule P.C. Silva

Dasycladaceae

Neomeris vanbosseae M. Howe

Phaeophyta

Chordariaceae

Chnoospora minima (Hering) Papenf.

Hydroclathrus clathratus (C. Agardh) M. Howe

Dictyotaceae

Dictyota bartayresiana J.V. Lamour.

Dictyota sandvicensis Sond. ex Kutz.

Lobophora variegata (J.V. Lamour.) Womersley

Padina sanctae-crucis Borgesen

Padina sp.

Sargassaceae

Sargassum echinocarpim J. Agardh

Turbinaria ornata (Turner) J. Agardh

Scytosiphonaceae

Colpomenia sinuosa (Mertens ex Roth) Derbes & Solier

Scytothamnaceae

Asteronema breviarticulatum Ouriques & Bouzon

Sphacelariaceae

Sphacelaria tribuloides Menegh.

Rhodophyta

Bonnemaisoniaceae

Asparagopsis taxiformis (Delile) Trevisan

Falkenbergia hillebrandii (Ardiss.) Falkenb.

Ceramiaceae

Aglaothamnion boergesenii (Aponte & Ballantine) L'Hardy-Halos & Rueness

Antithamnion antillanum Borgesen

Ceramium fimbriatum Setch. & N. L. Gardner

Ceramium flaccidum (Kütz.) Ardissonne
Griffithsia subcylindrica Okamura
Gymnothamnion elegans (Schousboe ex C. Agardh) J. Agardh

Champiaceae

Champia parvula (C. Agardh.) Harv.

Corallinaceae

Amphiroa rigida J.V. Lamour.

Jania sp.

Dasyaceae

Dasya iridescens (Schlech) A. Millar & I.A. Abbott

Dasya murrayana I.A. Abbott & A. Millar

Faucheaceae

Halichrysis coalescens (Farl.) A. Millar & R.E. Norris

Gelidiellaceae

Gelidiella machrisiana E.Y. Dawson

Phylloporaceae

Ahnfeltiopsis concinna (J. Agardh) P.C. Silva & De Cew

Plocamiaceae

Plocamium sandvicense J. Agardh

Rhodomelaceae

Amansia glomerata C. Agardh

Herposiphonia variabilis Hollenb.

Laurencia sp.

Rhodymeniaceae

Botryocladia skottsbergii (Borgesen) Levring

Chrysomenia sp.

SEA TURTLES

Lehua's rocky and generally steep shoreline does not offer any areas where turtles can easily crawl out and we did not observe any turtles on shore. We did not specifically survey for sea turtle but did observe one green sea turtle (*Chelonia mydas*) in December 2001 swimming along the south shore.

MAMMALS

Hawaiian Monk Seals. The endangered Hawaiian monk seal (*Monachus schauinslandi*) is the only native mammal observed on Lehua. Due to the steep topography and the complete absence

of beaches on Lehua, seals are only able to haul out on one of the three low rock benches on the island (there are 2 benches on the south shore and one in the inner crescent). Previous researchers did not mention the presence of seals, although they may well have been present. While we did not conduct formal seal surveys, we observed seals swimming near or hauled out on the island during several trips, including December 2001 (2 seals); February 2002 (2 seals); July 2002 (1 seal); March 2003 (1 seal); May 2003 (1 seal); June 2003 (2 seals); August 2003 (1 seal); September 2003 (2 seals); March 2004 (1 seal); and April 2004 (5 seals).

Rabbits. During our surveys, rabbits have been seen on every visit. Almost all appear to have a black and white patterned pelage. While rabbit droppings are present on virtually every area of the island, rabbits are most commonly observed in the vegetated gulches on the south side of the island where food and water seeps are most plentiful. They are also sometimes seen drinking from the step pools that descend some of the south side gulches. They appear to shelter in a variety of burrows and rock crevices. They may compete with seabirds for burrows but this has not yet been documented on Lehua. We are unable to provide accurate population counts as they will hide as we approach and are widely distributed, yet we suggest that there are seasonal population variations with significant decreases in population after extended periods of drought that affect vegetation cover. During our survey's we observed many more rabbits, including young, during the wetter months of winter and spring. Given that they have only a 30-day gestation period and give birth to litters of 5-7 young (Tomich 1986), they are highly capable of taking advantage of favorable conditions to rapidly expand their population. At this point in time (i.e., May 2004) we estimate that there are approximately 350—500 rabbits on Lehua.

It is uncertain exactly when rabbits were introduced to Lehua or by who, yet the first eyewitness account of their presence was by Caum in 1931, who stated that Lehua was “overrun with rabbits” (Caum 1936). In 1960, Richardson (1963) observed that the Lehua rabbits were “moderately abundant.” Watson (1961) claimed that rabbits were introduced to Lehua and Molokini in the 1880s or 1890s but his source of information is unclear. According to Tomich (1986) rabbits with a black and white pelage, similar to those on Lehua, were observed on O‘ahu, on Ford Island, as far back as 1825 and represent the first documentation of rabbits in

Hawai‘i. It is likely that rabbits were introduced to Lehua some time in the 19th century as a food source for occasional visitors to the island.

In the main Hawaiian Islands, rabbits were also introduced to O‘ahu’s Molokini and Manana islets but were recently eradicated by the Hawai‘i Department of Land and Natural Resources on Manana and have apparently died out from natural causes on Molokini. In the Northwest Hawaiian Islands, rabbits were introduced in the early 1900’s to Laysan and Lisianski Islands and Pearl and Hermes Atoll. They were later extirpated from Laysan and Pearl and Hermes and died out on Lisianski from natural causes. Lehua is currently the only Hawaiian offshore islet where rabbits still persist, although they are present on some of the main islands.

Loss of vegetative cover as a result of grazing and burrowing by rabbits has rendered substantial areas of some islands vulnerable to erosion. For example, rabbits introduced to Phillip Island, Australia destroyed 80% of the vegetation, causing the loss of all soil except from a few flat areas (Watson 1961). Rabbits also exert selective control on vegetation, altering species composition and vegetation structure (North *et al.* 1994; Chapuis *et al.* 2000).

Rabbits may also affect seabird nesting success. This is done indirectly through altering soil and vegetation, as in the case of Gould’s Petrel (*Pterodroma leucoptera*) on Cabbage Tree Island, Australia. When rabbits destroyed the forest understory, the burrowing petrels became exposed to predators and vulnerable to entanglement in sticky fruits of the bird-lime tree (*Pisonia umbellifera*) (Priddel *et al.* 2000). Additionally rabbits compete directly by contending for nest sites, altering existing burrows, and causing physical damage to eggs and chicks (Gilham 1963).

The case of Laysan Island provides an excellent local example of the damage that rabbits can inflict on Hawai‘i’s island ecosystems. By 1923, when the last rabbits were killed on Laysan, only four species of plants could be found, compared to the 28 plant species documented in 1896 before the rabbits were introduced (Morin and Conant 1998). It is unknown how many native species of arthropods were lost on Laysan, but it is known that the rabbits caused the extinction of at least three endemic land birds as the rabbits over-populated the island, consumed the vegetation, and created desert like conditions (Tomich 1986). Following the eradication of the

Laysan rabbits, native plant species re-colonized or were re-introduced and thrived. Laysan is now one of the best examples in Hawai'i of a relatively intact coastal ecosystem. However, careful pre- and post-eradication monitoring should be conducted on Lehua since recent research has shown that removal of alien herbivores can also result in unexpected changes to other ecosystem components, such as the proliferation of weeds (North and Bullock 1994; Priddel *et al.* 2000).

Rats. When Caum visited Lehua in 1931, he did not see rats although he reported having heard from an unnamed source that they were present on the island (Caum 1936). Richardson reported finding a dead rat of unidentified species on Lehua in 1960 and at least eight dead Bulwer's Petrels of which he assumed to have been killed by rats (Richardson 1963). Our surveys resulted in the collection of two desiccated corpses of *R. exulans* and the discovery of large numbers of *Rattus* sp. jaw bones which have yet to be identified to the species level. Live rats were seen on several occasions but attempts to trap them were unsuccessful. In September 2003, we found two freshly killed Wedge-tailed Shearwater chicks on the outer slope of the southwestern part of the island. The bodies were still very fresh and had probably only been killed a few hours before. The flesh from one side of the neck was eaten away but the bodies were otherwise intact, suggesting rat predation. In July 2002, we found three adult Bulwer's Petrels carcasses on the outer slope. In each case the flesh on the breast and neck had been eaten but the body was otherwise undamaged, suggesting the predator was a rat. Intensive rodent surveys need to be conducted to determine whether additional rodent species are present.

Rats are notorious predators of eggs and small chicks and have decimated entire seabird colonies (Atkinson 1985). Rat predation on seabirds is a well-documented fact in the Hawaiian Islands. Kepler (1967) documented *R. exulans* predation of Wedge-tailed shearwaters, Bonin Petrels and even Laysan Albatross on Kure Atoll. In one case, Kepler observed a rat to jump on the back of a nesting adult albatross and eat into its back muscles. Fisher and Baldwin (1946) attributed a drastic decline of Bulwer's Petrels on Popoia Island, off Oahu, to predation by *R. exulans*. The roof rat, *Rattus rattus*, is also an aggressive seabird predator and is blamed for the extinction of two Hawaiian bird species: the Laysan Rail and the Laysan Finch (Tomich 1986). Fortunately, the eradication of rats from islands can often result in rapid re-colonization by some seabird

species. For example, the recent eradication of *R. rattus* from Mokolii Islet, off of O‘ahu, resulted in a marked increase in Wedge-tailed Shearwater nesting success. Only 1 chick fledged in the 3 years prior to eradication, compared to 126 and then 185 chicks the two years following eradication (David Smith, personal communication).

In addition to feeding on seabird eggs, chicks and adults, rats consume fruits, seeds, seedlings, flower buds, young shoots and other vegetative parts. Seed predation by rats on Mokapu Island, off the north shore of Molokai, is suspected in causing the reproductive failure of multiple, rare endemic plants species (Wood, unpublished report). Rats are capable of altering entire vegetation communities where they are introduced, but research has just begun in this area (Campbell and Atkinson 2002). They have been implicated in declines of several Hawaiian plant species (Athens and Ward 1993; Athens *et al.* 1997) and along with the rabbits, have probably had a major impact on Lehua’s plant communities.

TERRESTRIAL ARTHROPODS

The authors are unaware of any reports concerning Lehua’s terrestrial arthropods made prior to the 2001-2004 surveys. The most intensive collection effort was made May—June 2003, yet opportunistic collections were also made in December 2001, February & July 2002, and March 2003. We are currently awaiting the identification of the majority of our collections and will submit that checklist in a future report. Our initial identifications include one indigenous, four endemic, and ten adventitious species.

Arthropod Survey Methods. Ants were collected in December 2001 using 12 index cards baited with Spam, peanut butter and honey. Cards were distributed in the small valley above the base camp and were collected after approximately one hour. Additional arthropods were collected during this trip in the same location using 10 pitfall traps which were collected after being left out for one night. The remainder of our collections were made with hand nets or gathered by hand while exploring the islet.

Table 5. Preliminary Checklist of Lehua's Terrestrial Arthropoda

Family	Species	Collector #	Common name	Identification	Status (END, IND, or ADV)
Coleoptera:	<i>Dermestes frischi</i>	KW 9310	carnivorous beetle	A. Samuelson	IND
Dermestidae	Kugelann				
Coleoptera:	<i>Protaetia fusca</i>	KW 9309	pollen beetle	A. Samuelson	ADV
Scarabaeidae	Herbst				
Diptera:	<i>Siphunculina</i>	KW 9312			ADV
Chloropidae	<i>striolata</i> Weideman				
Diptera:	<i>Hecamede granifera</i>	KW 9308	shore fly		ADV
Ephydridae	Thomson				
Diptera:	<i>Ephydra gracilis</i>	KW 9312	shore fly		ADV
Ephydridae	Parkard				
Diptera:	<i>Scatella sexnotata</i>	KW 9308	shore fly		ADV
Ephydridae	Cresson				
Diptera:	<i>Hydrophorus</i>	KW 9308	long-legged fly		END
Dolichopodidae	<i>pacificus</i>				
Diptera:	<i>Canaceoides</i>	KW 9312	beach fly		END
Canacidae	<i>hawaiiensis</i>				
Diptera:	<i>Canaceoides</i>	KW 9312	beach fly		ADV
Canacidae	<i>angulatus</i>				
Hemiptera:	<i>Nysius kinbergi</i>	KW 9313	seed bug	D. Polhemus	END
Lygaeidae	Usinger				
Hymenoptera:	<i>Hylaeus flavifrons</i>	KW 9299	yellow-faced bee	K. Magnacca	END
Colletidae	Kirby				
Hymenoptera:	<i>Pachyodynerus</i>	KW 9314	potter wasp		ADV
Vespidae	<i>nasidens</i> Latreille				
Hymenoptera:	<i>Pheidole</i>	CS	big headed ant	M. Richardson	ADV
Formicidae	<i>megacephala</i>				
Hymenoptera:	<i>Tetramorium</i>	CS		M. Richardson	ADV
Formicidae	<i>simillimum</i>				
Hymenoptera:	<i>Ochetellus glaber</i>	CS		M. Richardson	ADV
Formicidae					
Orthoptera:	<i>Gryllodes</i> sp.	CS	grasshopper	M. Richardson	???
Gryllidae					

AVIFAUNA

The history of avifauna on Lehua Islet is not well known. Previous information is available from only four sources: visits by Caum from 18-22 April 1931 and 17-18 August 1932 (Caum 1936); a one-day visit by Fisher sometime from 12-16 August 1947 (Fisher 1951); a visit by Richardson on 10-11 August 1960 (Richardson 1963); and one-day visits on 8 September 1966 and 10 September 1967 by R. Walker, then of the Hawai'i Division of Forestry and Wildlife (R. Walker unpubl. data). In addition, Harrison (1990) provided estimates of the number of breeding pairs of each species on Lehua, reported to be from 1981-1988, but no surveys appear to have been conducted during those years and the source of the estimates is not clear.

As part of a biological inventory and conservation assessment of Lehua Islet, thorough surveys of the avifauna on Lehua were conducted from 19-21 February 2002; 6-8 July 2002; and 30 May-1 June 2003. Additional observations on some species were made by Wood & Swenson (i.e., 20-21 December 2001; 7-9 March 2003; 27-28 September 2003; and Wood & Ono (i.e., 5-6 March 2004).

Survey Methods. Surveys were conducted by walking over the entire island and recording the number of individuals of each species, the number and status of nests, and any reproductive behavior. Special effort was made to search caves, crevices, and underneath ledges for species with cryptic nests, and to search for signs of predators. A few areas were not surveyed due to very steep terrain, including the cliffs on the west face and the deep chasms on the lower part of the inner slope.

We used one of three methods (census, sample, actual count) to estimate the population of each species. A complete census of the total population was attempted for larger species that perched or nested on the surface and were readily visible from a distance (Black-footed Albatross, Laysan Albatross, Red-footed and Brown Boobies, Great Frigatebird). For extremely abundant species or cryptic, burrow nesting species in which it was not practical to attempt a census, we sampled portions of the island and extrapolated to obtain an overall estimate (Wedge-tailed Shearwater, Red-tailed Tropicbird). For rare, cryptic species (Christmas Shearwater, Bulwer's

Petrel, Band-rumped Storm-petrel) and migrants that were not expected to occur in all parts of the island the values presented are simply the actual counts.

Accuracy of the population estimates likely varied among species depending on their nesting habits and behavior, and the survey method used. Estimates derived from censuses are likely to be slight underestimates of the actual populations because a few birds may have been missed in areas with particularly steep terrain. To reduce the chance of counting birds twice, only individuals on the ground were included. This may have resulted in lower counts, particularly of non-breeding birds, because some individuals were at sea when surveys were conducted. Number of nests included unattended eggs in nests that appeared to be active and adults that appeared to be incubating or brooding. Birds were not disturbed to ascertain nest contents. Cases where two conspecific birds were sitting within pecking distance of each other were assumed to be a pair and were counted as a single nest. In most areas counts were made at close range, but the number of Red-footed Boobies on the inner slope was counted from the northwest horn because it provided the best vantage point from which to observe the entire slope. The white coloration of this species made it easy to detect even at a distance.

Checklist of Bird Species. Thirty-one different bird species have been observed on Lehua during all visits since 1931, including 17 species of endemic and indigenous seabirds, six migratory species that visit Hawai‘i in the winter, and eight species of naturalized alien land-birds (Table 6). Twenty-five species were observed during surveys in 2002-2004, nine of which had not been recorded on the island previously. Wedge-tailed Shearwaters were by far the most numerous species, followed by Red-footed and Brown Boobies. Several species were represented by only one or a few individuals and may occur on the island irregularly. More detailed information about each species is provided in the species accounts below.

Over 25,000 pairs of at least eight seabird species were documented to breed on Lehua (Table 6), and three more species were suspected of breeding in small numbers, but their nests were not found. The nesting season varied among species, with the largest number of species breeding from March-July, and at least one species breeding in every month (Figure 2).

Species Accounts.

Black-footed Albatross (*Phoebastria nigripes*). Caum (1936) reported seeing a few individuals of this species on Lehua, none of which were known to be nesting. Harrison (1990) reported that breeding was suspected on Lehua, but that no nests or chicks had been found. In February 2002, we observed 10 adults tending eight small chicks, and 21 non-breeding adults. In July 2002 no adults, chicks, or carcasses were present, suggesting all eight chicks had fledged. In May 2003, we observed 11 chicks, all of which were large and appeared healthy. All nests were on the western end of the inner slope 20-100 meters below the summit.

It is difficult to determine when albatross began breeding on Lehua because most previous surveys occurred at times (August 1947, August 1960, September 1966 and 1967) when albatross are not breeding and would not be expected on the island. The only previous survey that occurred when albatross would have been breeding was in March 1931 by Caum, who reported only a few non-breeding adults. The Black-footed Albatross is a species of conservation concern due to its relatively small global population size of approximately 50,000 pairs, most of which breed in the northwestern Hawaiian Islands (Harrison 1990), and its restricted breeding distribution (USFWS 2002), so the breeding colony on Lehua is significant. The only other colony in the main Hawaiian Islands is on Ka'ula, where estimates of the number of breeding pairs range from 20-70 (Harrison 1990) to 100 (Fefer *et al.* 1987).

Laysan Albatross (*Phoebastria immutabilis*). This species has not been reported previously on Lehua. In February 2002, we observed 13 adults tending nine small chicks, and 37 non-breeding adults. The number of nonbreeding adults using the island likely was higher than the number observed because some birds were out at sea foraging when surveys were conducted. In July 2002, four chicks were present and no carcasses were found, suggesting the other 5 chicks had fledged. All four remaining chicks were large, retained only a small amount of down, and appeared healthy enough to fledge. In May 2003, we observed 27 live chicks and one dead chick, suggesting fledging success was high. All live chicks were large and appeared healthy. The single dead chick showed no internal or external signs of injury or predation, but did have a few small pieces of plastic in its crop. Nests were concentrated on the west end of the inner

slope, 20-100 meters below the summit. In 2002, two adults were present on the outer slope in and near Abutilon Gulch, and in 2003 a single nest was observed in this location.

Laysan Albatross went through a severe population decline and were extirpated from several islands in the early 1900s due to feather hunting (Whittow 1993), but increases have occurred recently in some areas. The number of Laysan Albatross nesting at Kilauea Point, Kaua‘i and at Kaena Point, Oahu has increased dramatically in the last 20 years (Harrison 1990, Sugimura *et al.* 2003), and new breeding colonies have been established recently in the Ogasawara Islands (Hasegawa 1978) and on islands off the west coast of Mexico, including Guadalupe Island, San Benedicto Island, Isla Clarion, and Alijos Rocks (Pitman 1985, 1988; Dunlap 1988; Howell and Webb 1989, 1992).

Wedge-tailed Shearwater (*Puffinus pacificus*). This species was reported to be very common in all previous surveys, but the number of breeding pairs estimated in this study was much higher than any previous estimate (Table 1). In July 2002, we counted a total of 2300 nests in areas comprising roughly 10% of the island. If this number is extrapolated to the entire island, which seems reasonable, then the total breeding population is approximately 23,000 pairs, making it the fifth largest breeding colony of this species in the Hawaiian Islands, after Laysan, Nihoa, Manana, and Lisianski (Fefer *et al.* 1987). Nests were distributed throughout the islet in a variety of caves, crevices, and burrows, under overhanging ledges, under vegetation, and even on the surface in the open. We observed several unusual nests in which dense grass had been pushed up to create a domed shelter over the egg. This species was highly seasonal in its occurrence, being abundant in July, absent in February, and present only in small numbers in March and May 2003 (Figure 2). This species typically returns to breeding areas in March-April to select nest sites and mate, then exhibits an exodus of roughly one month, returning to lay eggs in June (Whittow 1997).

In September 2003, we found two freshly killed chicks on the outer slope of the southwestern part of the island. The bodies were still very fresh and had probably only been killed a few hours before. The flesh from one side of the neck was eaten away but the bodies were otherwise intact, suggesting rat predation.

Christmas Shearwater (*Puffinus nativitatus*). Christmas Shearwaters are common in the northwest Hawaiian Islands, but in the main islands they occur only on Lehua and Moku Manu off Oahu in small numbers (Harrison 1990). On 6 July 2002 we observed two adults flying just offshore and over camp at dusk, and on 31 May 2003 we observed a single adult at dusk off the west horn. We did not find any nests, but it is unlikely that these birds would have flown over the island unless they were nesting.

Newell's Shearwater (*Puffinus auricularis newelli*). This endemic subspecies is federally listed as threatened under the Endangered Species Act, and has not been reported from Lehua previously. We heard one bird calling from the south shore on 30 May 2003. In addition, we found the remains of a juvenile with a partially ossified skull on the northwest horn, demonstrating that this species has nested on Lehua and perhaps still does. Newell's Shearwaters are thought to nest primarily among thick vegetation on mountain slopes (Ainley *et al.* 1997s), but they also are numerous on steep, sparsely-vegetated cliffs in remote valleys on the dry leeward side of Kaua'i (Wood *et al.* 2002), so their occurrence on Lehua is perhaps not surprising. If eradication of rabbits and rats from Lehua results in sufficient recovery of the vegetation, the suitability of the island as a nesting site for Newell's Shearwater might be enhanced.

Bulwer's Petrel (*Bulweria bulwerii*). This species was observed on Lehua previously by Richardson (1963). In July 2002 we found six nests, two each on the inner slope, west horn, and west horn past the arch. Two of the nests contained a single egg, the contents of the others was not determined. On 31 May 2003, we observed approximately 60 adults at dusk circling off the tip of the west horn. On the same date we found 13 adults in nine apparent nests near the tip of the west horn, although none yet contained eggs. All nests were located in small rock crevices that were difficult to see into and likely were inaccessible to Wedge-tailed Shearwaters, and most nests were first located by the soft barking calls of an adult. The actual population of this species on Lehua may be much larger than the number counted, because suitable nesting sites are abundant and the secretive habits of this species made it difficult to find nests. On Manana Island off Oahu and in other areas eggs have been recorded from early May through mid-June

and nestlings have been recorded from mid-June through the end of September (Whittow 1994, Megyesi and O'Daniel 1997), indicating the breeding season of Bulwer's Petrel on Lehua is somewhat later.

In July 2002 we found three adult Bulwer's Petrels carcasses on the outer slope. In each case the flesh on the breast and neck had been eaten but the body was otherwise undamaged, suggesting the predator was a rat. One of the carcasses was fresh and still soft, probably less than a day old. We also found bones of several Bulwer's Petrels in sediment under the roost of a Barn Owl in May 2003. Richardson (1963) reported finding the carcasses of eight adults. Although this species is abundant on some predator free islands in the northwestern chain (Fefer *et al.* 1987, Harrison 1990), it is vulnerable because its small size makes it particularly susceptible to predation by rats and owls. Bulwer's Petrels have disappeared from many islands where rats were introduced, but are beginning to recover on some islands where rats have been eradicated, such as Midway (Megyesi and O'Daniel 1997) and Kure (D. Smith pers. comm.; E. VanderWerf pers. obs.). Eradication of rats from Lehua and control of any Barn Owls observed on the island might help increase the population of this species.

Band-rumped Storm-petrel (*Oceanodroma castro*). This small seabird nests in remote cliff locations on Kaua'i and is suspected to nest on Hawai'i, but no active nests have been found in the Hawaiian Islands despite intensive searching (Slotterback 2002, Wood *et al.* 2002). It has not been reported previously from Lehua, but several specimens were collected from Ni'ihau in the late 1800s (Slotterback 2002). This species is a candidate for listing under the Endangered Species Act (USFWS 2002b).

We heard calls of this species on the outer slope west of the caves on three occasions from 2000-2130 hrs on 6 July 2002. In the first two cases the bird sounded as if it was on the slope above camp, while in the third case the bird sounded as if it was in flight. The slope directly above camp was searched from 1945-2100 on 7 July with a night vision scope, but no calls were heard and no storm-petrels were observed. On 1 June 2003 at 0130 hrs we heard the calls of a single bird over the tip of the west horn. The presence of this species on Lehua is significant because so few nesting locations are known, and because the relatively accessible terrain on Lehua may

make it more feasible to locate nests. As with Bulwer's Petrel, this species' small size may make it particularly vulnerable to predation by owls and rats, and eradication of rats from Lehua and control of any Barn Owls observed on the island might help increase its population.

Red-tailed Tropicbird (*Phaethon rubricauda*). This species was sparsely distributed over much of the island, and was difficult to survey because nests were located in caves and under ledges that were visible only at close range, and because many birds nested on steep slopes and cliffs that were difficult to access. In July 2002 we observed a total of 150 adults, and we counted 40 nests in areas comprising roughly 20% of the suitable habitat on the island. If this number is extrapolated to the entire island, then the actual breeding population was about 200 pairs, which is very similar to previous estimates (Table 1). In February 2002 only two nests were found, each with an egg, a sign that the breeding season had just started. In May-June 2003 most nests contained small to medium-sized chicks, and in July 2002 nests contained an egg (10%), and chicks ranging from small and downy (40%) to large and fully feathered (20%). On 28 September 2003 a large chick was observed, indicating this species continues to nest in the Fall.

White-tailed Tropicbird (*Phaethon lepturus*). Two birds were observed flying over Lehua by Fisher (1951), but no evidence of nesting was found. In 2002-2004 we observed several individuals in the channel between Kaua'i and Ni'ihau, but none on the island.

Masked Booby (*Sula dactylatra*). Caum reported a few nesting pairs on Lehua in 1931-32, but this species has not been observed since, indicating it no longer occurs on the island.

Brown Booby (*Sula leucogaster*). The numbers of adults and nests counted in this study are much larger than previous estimates (Table 1), indicating that either the population has increased substantially in the past few decades or that previous estimates were low, perhaps because surveys were conducted outside the main breeding season when fewer birds were present. On 30-31 May 2003 we counted 521 active nests, making Lehua the largest breeding colony for this species in the Hawaiian Islands (Harrison 1990). This count likely represents an accurate census of the total breeding population because nests were located in relatively exposed locations on the surface and were readily visible at a distance. This species was distributed over most of the

island, but the largest concentrations of nests were on the inner slopes (267) and the outer slope east of the caves (159). In addition, groups of up to 47 non-breeding birds often perched on the cliffs of the west face, the east end of the inner slope, and on the west horn. The total number of non-breeding birds was difficult to estimate because birds were skittish and took flight quickly. The number of adults reported in Table 1 includes all birds seen on the ground plus the maximum number of birds observed in the air simultaneously.

This species had a protracted breeding season extending from mid-February through at least September (Figure 2). On 19 February 2002 only 12 active nests were present, of which 6 contained 2 eggs, 3 contained 1 egg, and the contents of 3 were unknown. Approximately 20 more nests contained fresh green vegetation, a sign that eggs probably would be laid soon. Species of plants identified in Brown Booby nests included *Jacquemontia oliviformis*, *Pluchea indica*, and *Panicum torridum*. On 31 May 2003, nests contained eggs (20%), small naked chicks (50%), and medium-sized downy chicks (30%). In July 2002 nests contained eggs (5%), small naked chicks (5%), medium-sized downy chicks (30%), large mostly-feathered chicks (30%), and fledged juveniles (30%).

Red-footed Booby (*Sula sula*). In February 2002 we counted of 2352 birds, but this was an underestimate of the actual population because surveys were done during the late morning and afternoon, and many birds had left the island just after dawn to forage at sea. To correct for this, we compared the number of birds present in two gulches at dawn before birds left and during the middle of the day, and we used this proportion to estimate the total population. In one gulch on the outer slope containing *Abutilon grandifolium* shrubs (Abutilon Gulch), counts during the day yielded 154 and 187 birds, while a count at dawn revealed 318 birds, for a correction factor of 1.86. In the gulch directly behind the concrete generator pads (Generator Gulch), daytime counts yielded 69, 55, and 60 birds, while a dawn count revealed 109 birds, for a correction factor of 1.79. The average correction factor based on both gulches combined was thus 1.82, and the number of birds that would have been present at dawn in all parts of the island was $2352 \times 1.82 = 4288$.

In July 2002, we counted a total of 1294 nests island-wide, indicating that approximately 60% of the estimated 4288 birds present were breeders. This total likely is a slight underestimate (perhaps 10%) because nests were difficult to see in some areas, such as the steep lower parts of the inner slope and several large fissures on the west face. This number is very similar to previous estimates by Caum (1931) and Fisher (1951); the source of the estimate by Harrison (1990) of 150-200 nests is not clear and may be erroneous. The largest concentrations of nests were on the inner slope (896) and on the outer slope west of the caves (286).

In February 2002 no active nests were present, but many birds were gathering nest material and several nests contained fresh green sprigs of *Pluchea indica*. In July 2002 nests were in all stages of the breeding cycle, but compared to Brown Boobies more nests were at earlier stages; eggs (10%), small naked chicks (20%), medium-sized downy chicks (30%), large mostly-feathered chicks (30%), and fully-feathered chicks (10%), only a few of which could fly. On 28 September 2003 at least one nest contained a partly feathered chick, indicating the breeding season of this species continues into the Fall.

Most Red-footed Booby nests were on *Pluchea indica* shrubs, some were on the larger-leaved *Pluchea caroliniana*, and in one gulch on the outer slope some birds were nesting on *Abutilon grandifolium*. Most vegetation more than a few inches high was used for nesting by Red-footed Boobies, and a few birds were nesting on the ground, suggesting the population of Red-footed Boobies on Lehua may be limited by nest sites. Some of the larger *Pluchea* and *Abutilon* shrubs showed evidence of gnawing, probably from feral rabbits. Removal of rabbits might allow more plants to reach a larger size, thereby increasing the amount of potential nesting habitat for this species.

Great Frigatebird (*Fregata minor*). On 7 July 2002 we observed a total of 326 birds, most of which were on the west end of the inner slope (211) and the outer slope east of the caves (108). This count included a large group of birds that took flight early in the morning and all birds observed on the ground later in the day. A close inspection of *Pluchea* shrubs on the west end of the inner slope revealed that no nests were present. Caum (1936) reported a few nesting pairs, and it is possible that this species still nests sporadically on Lehua.

Great Blue Heron (*Ardea herodias*). A single individual was observed by boat on the island on 29 June 2000 and 8 September 2000 (D. Kuhn and P. Donaldson, pers. comm.).

Cattle Egret (*Bubulcus ibis*). Cattle Egrets were introduced to Kaua‘i, Oahu, Molokai, Maui, and Hawai‘i in July-August 1959 (Breese 1959), but have not been reported previously on Lehua. In February 2002 we observed up to 19 adults on Lehua, some of which were crossing between Ni‘ihau and Lehua. In July 2002 we found two active nests in large *Pluchea* shrubs in Abutilon Gulch, of which one had three small, downy chicks and the second had 3 large chicks. By May-June 2003 the number of egrets had increased to at least 87 adults and 21 nests, and birds frequently commuted to and from Ni‘ihau.

Cattle Egrets are known to be opportunistic predators of bird eggs and nestlings (Telfair 1994), and could pose a threat to nesting Red-footed Boobies and other seabirds on Lehua. Boobies may be particularly vulnerable to predation by egrets because their altricial young are very small and helpless upon hatching, and their nests are open and exposed. Although no evidence of predation was observed, boobies often acted defensively toward egrets and pecked at them. Cattle Egrets and Red-footed Boobies nested in close proximity in the limited areas of taller vegetation, and also may compete for nest sites. Cattle Egrets are not native to Hawai‘i and they should be removed from the island to protect nesting seabirds.

Peregrine Falcon (*Falco peregrinus*). This species is a rare winter visitor to the Hawaiian Islands (Pyle 2002), and has not been reported previously from Lehua. Recently it was removed from the Federal list of endangered species, but is still a species of conservation concern (USFWS 2002a). One individual was observed on 20 December 2001, and presumably the same bird was observed again on 20 February 2002, flying east along the south shore, then crossing the channel and heading toward Ni‘ihau. It has not been re-sighted since then.

Pacific Golden-Plover (*Pluvialis fulva*). This species is a common winter visitor throughout the Hawaiian Islands (Pyle 2002). In February 2002 we observed groups of 3-6 birds in several locations on the outer slopes, but none were seen in July 2002 or May 2003.

Wandering Tattler (*Heteroscelus incanus*). This species is a common winter visitor throughout the Hawaiian Islands (Pyle 2002). We heard one bird calling along the shore near the caves on 6 July 2002.

Ruddy Turnstone (*Arenaria interpres*). This species is a common winter visitor throughout the Hawaiian Islands (Pratt *et al.* 1987, Pyle 2002). In February and July 2002 we observed a minimum of nine and eight birds, respectively, including groups of up to eight birds.

Glaucous-winged Gull (*Larus glaucescens*). This species is a rare but regular winter visitor to the Hawaiian Islands (Pyle 2002), and has not been reported previously from Lehua. We observed one bird in first-year plumage on two occasions in February 2002; first flying toward Ni‘ihau on 20 February, then flying eastward along the south shore on 21 February.

Gray-backed Tern (*Sterna lunata*). Large numbers of this species nest in the northwest Hawaiian Islands and 500-600 pairs nest on Ka‘ula (Harrison 1990), but it has not been reported previously on Lehua. On 6 July 2002 we observed a single bird offshore from the caves in late afternoon. Suitable nesting habitat for this species and the next is present on Lehua, and their absence may be due to the presence of rats and Barn Owls.

Sooty Tern (*Sterna fuscata*). This species is an abundant breeder in the northwest Hawaiian Islands, on islets off Oahu, and on Ka‘ula (Harrison 1990), but surprisingly it has not been reported previously on Lehua. We observed one or two individuals flying and calling over the island on several occasions in February 2002 and May 2003. Lehua contains seemingly suitable nesting habitat for both Sooty and Gray-backed Terns, but these small species are vulnerable to predation by rats and owls, and their absence on Lehua may be due to the presence of rats and Barn Owls. Removal of predators might allow colonization of Lehua by nesting terns.

Brown Noddy (*Anous stolidus*). Caum (1936) described this species as fairly common, and Walker (unpubl.) reported approximately 500 individuals in 1967, but in 2002-2004 we observed only a single individual, foraging 100 meters off the south shore. Bones of several Brown Noddies were present in an accumulation of bones below an owl roost on the outer slope (see

below). The current absence of this species on Lehua may be due to predation by owls and/or rats.

Hawaiian (Black) Noddy (*Anous minutus melanogenys*). This subspecies is endemic to the main Hawaiian Islands, including Lehua, with *A. m. marcusii* occurring in the northwest Hawaiian Islands as far east as Nihoa (Gauger 1999). Caum (1936) reported that the Hawaiian Noddy was rare on Lehua, nesting in the caves with Brown Noddies, but Fisher (1951), Harrison (1990), and Walker (unpubl.) all reported several hundred birds. Brown Noddies generally do not nest in caves, and Caum's observation that Black Noddies were rare may have been caused by confusion with Brown Noddies. In July 2002 we observed a maximum of 365 birds in the large cave and an additional 40 birds entering and leaving the small cave. In July 2002 there were several nests with fresh green vegetation, but no eggs or chicks were visible. On 1 June 2003 we observed approximately 230 birds, with nests in all stages of the breeding cycle, including three pairs copulating, one nest with an egg, seven adults either incubating or brooding small chicks, and 10 recently fledged juveniles. This species may have persisted on Lehua while the Brown Noddy was extirpated because it nests on ledges in the back of sea caves that are inaccessible to rats.

Barn Owl (*Tyto alba*). One individual of this introduced species was seen on the south shore in 1997 (S. Montgomery, pers. comm.). During March of 2004, a single individual was observed around what we consider to be a long-term roost site on the south shore. Between 2002—2004 we collected several pellets from this site. Hundreds of bones from rats, small rabbits, and various bird species were recovered under the roost. One pellet contained the entire skull of a Wedge-tailed Shearwater, demonstrating that barn owls prey on relatively large species. An additional barn owl was observed during April 2004 roosting along the crest of the western horn (LeGrande and Ono, pers. comm.). Pellets collected at this roost site also contained bird bones.

Rock Dove (*Columba livia*). This widely naturalized species has not been reported from Lehua previously. On 30 May 2003 we observed two birds flying along the inner slope.

Zebra Dove (*Geopelia striata*). This Australian species is naturalized and abundant on all the main Hawaiian Islands. Fisher (1951) reported that Zebra Doves were the most numerous bird

species on Ni‘ihau, and that they were observed in flight between Lehua and Ni‘ihau. We observed active nests on rock ledges on the outer slope west of the caves during a preliminary visit in December 2001, and we collected one skull from under a Barn Owl roost in February 2002. Their absence during surveys in 2002-2004 may indicate they inhabit Lehua only sporadically.

Sky Lark (*Alauda arvensis*). This species is native to Eurasia but is naturalized and widespread on all the main Hawaiian Islands. It was reported on Lehua by Caum (1936) and Fisher (1951), but has not been observed there since. Like Zebra Doves, Sky Larks occasionally may disperse to Lehua from Ni‘ihau, but may be transient.

Northern Cardinal (*Cardinalis cardinalis*). This North American species is naturalized and common on all the main Hawaiian Islands (Pratt *et al.* 1987). A single individual was observed on Lehua in 1960 (Richardson 1963).

House Finch (*Carpodacus mexicanus*). This North American species is naturalized and common on all the main Hawaiian Islands (Pratt *et al.* 1987). Fisher (1951) reported that it had colonized Ni‘ihau from Kaua‘i on its own, and that it was the second most numerous species on Ni‘ihau. Richardson (1963) observed at least 20 in 1960, and Walker (unpubl.) reported up to 45 birds in 1967. On 7 July 2002, we observed two birds flying high over the summit of Lehua heading toward Ni‘ihau.

Nutmeg Mannikin (*Lonchura punctulata*). This species is native to southeast Asia and the Philippines, and is naturalized and common on all the main Hawaiian Islands (Pratt *et al.* 1987). Walker (unpubl.) first observed 16 birds on Lehua in 1967. In July 2002, we observed flocks of up to 20 birds on several occasions in grassy areas and flying along the shore on the outer slope west of the caves. In May 2003 we observed 15 birds, and we found a disused nest on a ledge on the outer slope.

Bird and Rat Skeletal Specimens. Skeletal specimens were collected opportunistically from several locations on the island. Some specimens were found in small caves and crevices that

likely were nest sites. An unusual concentration of bones was found under an overhanging cliff face on the side of a small gulch just east of the landing area. The bones were deposited in fine, loose sediment 1-2 meters deep that had eroded from the cliff. This deposit contained thousands of bones of rats and several bird species. Several Barn Owl (*Tyto alba*) pellets were found on the surface of this deposit, indicating the bones may represent the accumulated prey remains of Barn Owls over many years. Barn Owls are known to have preyed on large number of birds on Ka'ula Islet (R. Walker, U.S. Fish and Wildlife Service, and A. Silva, Hawai'i Division of Forestry and Wildlife, pers. comm.). Careful excavation of this site could provide a valuable historical record of vertebrate species present over time. Following are descriptions of some of the more interesting skeletal specimens.

Newell's Shearwater (*Puffinus auricularis*). In addition to bones of several Wedge-tailed Shearwaters, a partial skeletal specimen of a smaller shearwater was collected, consisting of the skull and articulated mandible, several articulated leg bones, and a few small wing bones. Comparison with reference specimens at Bishop Museum suggested the shape of the skull, particularly the nares and mandible sheath, were more similar to Newell's Shearwater than to Wedge-tailed Shearwater. The specimen was later sent to Dr. David Steadman, who confirmed the identification as Newell's.

Bulwer's Petrel (*Bulweria bulweri*). One mandible was collected from a small cave high on the inner slope below the summit. It is possible that other small bones of this species were collected but were not identified.

Storm-petrel species (*Oceanodroma*) sp. One partial skull was collected from a small cave on the northwestern horn. It did not closely match any of the species in the reference collection at Bishop Museum, including Band-rumped Storm-petrel (*O. castro*), Sooty storm-petrel (*O. tristrami*), or Leach's Storm-petrel (*O. leucorhoa*). Curvature of the bill and shape of the nares appeared most similar to Leach's Storm-petrel, a species not known to nest in the Hawaiian islands, but the cranium was very narrow and unlike any of the reference species. The specimen was sent to Dr. David Steadman for examination, who determined that it was not Leach's but

was not able to conclusively determine the species. The skull was from a young bird and was not fully developed, perhaps confounding the identification.

At the time this specimen was collected no storm-petrels had been reported from Lehua, but we subsequently heard and saw Band-rumped Storm-petrels on the island, and it is most likely that the skeletal specimen is of that species. Another possibility is the Sooty Storm-petrel (*O. tristrami*), which is an abundant breeder on Nihoa and should be looked for on Lehua.

Brown Noddy (*Anous stolidus*). One skull and several wing bones were collected from the large deposit in the gulch east of the landing site. More bones of this species were observed in the same location but were not collected.

Significance of Lehua to Nesting Seabirds. Lehua Islet is an important and interesting seabird nesting area for several reasons. Geographically, Lehua occupies an intermediate position in the Hawaiian Archipelago, at the juncture of the main Hawaiian Islands and the northwest Hawaiian Islands. It is the westernmost breeding location for Newell's Shearwater, Band-rumped Storm-petrel, and Hawaiian Noddy, which are typical of high islands, and contains the easternmost large colony of Red-tailed Tropicbirds. Lehua also contains the largest breeding colony of Brown Boobies in the Hawaiian Islands, and perhaps one of the largest in the eastern Pacific (Harrison 1990). The breeding colonies of Black-footed and Laysan Albatross, though not large, are significant because these species nest in relatively few sites. Lehua is already one of the most important seabird nesting areas in the Hawaiian Islands, but management actions such as removal of rabbits, rats, and other predators would further increase its significance by allowing species that currently inhabit the island to increase, and by possibly allowing additional species to colonize the island.

Temporal Changes. Some noteworthy changes have occurred in the avifauna of Lehua since Caum first visited in 1931. The Red-tailed Tropicbird was described by Caum (1936) as the commonest species on the island, and it is still common, but it has been far surpassed in number by several other species. All previous observers reported thousands of Wedge-tailed Shearwaters, but the 23,000 pairs estimated in 2002 may represent a substantial increase.

However, the numbers of extremely abundant animals are notoriously easy to underestimate. It is possible that previous estimates were too low and that this species has not changed in number that much.

Perhaps the most interesting change is the apparent colonization of Lehua by Black-footed and Laysan Albatross. Black-footed Albatross were observed in the past but were not known to nest, while Laysan Albatross had never been observed on the island before. Most previous surveys occurred at times (August 1947, August 1960, September 1966 and 1967) when albatross would not have been nesting, so it is difficult to determine when the colonies were established. The colonies of both species are still small (11 and 28 pairs, respectively), but appear to be growing, quite rapidly in the case of the Laysan.

Populations of Red-footed and Brown Boobies appear to have increased substantially. The increase in number of Red-footed Boobies may be due to an increase in availability of nest sites in *Pluchea* shrubs, which were not present at the time of Caum's visits, but the reason for the apparent increase in the Brown Booby population is unknown.

Two of the new records from 2002-2004 were uncommon seabirds that are primarily nocturnal and could have been missed during previous surveys (Newell's Shearwater and Band-rumped Storm-petrel), and two more new records were of common seabirds that for some reason do not nest on Lehua (Sooty and Gray-backed Terns). Two of the new records were migrants that are present only seasonally in small numbers (Peregrine Falcon, Glaucous-winged Gull). Two of the new records were of alien species that have become more abundant and widespread since the previous surveys (Cattle Egret and Rock Dove).

Four species were recorded in the past but not observed in 2002-2004, two of which were seabirds that may have visited the island only in small numbers (Masked Booby and White-tailed Tropicbird), and two of which were alien land-birds that may have visited the island only sporadically and still may continue to do so (Sky Lark and House Sparrow).

Impacts of Alien Species on Seabirds. Three alien predators of birds were found on the island, the Polynesian rat (*Rattus exulans*), Barn Owl (*Tyto alba*), and Cattle Egret (*Bubulcus ibis*). Evidence was found that two of these species, Barn Owl and Polynesian rat, were preying extensively on a variety of seabirds. Several fresh Barn Owl pellets were collected from a long-term roost site, and hundreds of bones of at least four bird species were found in the sediment deposited under the roost. The carcasses of several adult Bulwer's Petrels and two Wedge-tailed Shearwater chicks were found with evidence of predation by rats. A rapidly increasing number of Cattle Egrets also were present on the island, and are suspected of preying on nestlings and competing for nesting space with Red-footed Boobies.

At least one species of breeding seabird has been extirpated from Lehua, the Brown Noddy. This species was fairly common in the past, with 500 birds reported in 1966, but only a single individual was observed in 2002-2004, foraging offshore. Remains of several Brown Noddies were found among numerous bird bones under the long-term Barn Owl roost, suggesting predation may be responsible for the loss of this species. Bones of Bulwer's Petrels also were found beneath the owl roost, and the carcasses of several adult Bulwer's Petrels were found in 2002. Bulwer's Petrel, Band-rumped Storm-petrel, and other small species may follow the Brown Noddy if predators are not controlled. Brown Noddies, Sooty Terns, and Gray-backed Terns nest on nearby Ka'ula Islet, but they are conspicuously absent from Lehua. These species are small and nest on the surface, and may be particularly vulnerable to predation. Removal of Barn Owls and rats from Lehua might allow these and perhaps other small seabirds to colonize the island.

Rabbits have been present on Lehua since Caum's visit in 1931, and have seriously impacted the vegetation on the island. At least two species on Lehua nest only in taller vegetation (Red-footed Booby and Great Frigatebird). Aside from the obvious benefits to native plant species, eradication of rabbits likely would allow more plants to reach a larger size and provide nest sites to seabirds. Recovery of vegetation also would help prevent erosion and burying of burrow nest seabirds during heavy rains.

Timing of Surveys. Most bird species on Lehua nest from May-September, but the timing varies somewhat among species and surveys at different season can be expected to produce different results. Surveys in late May and early June are likely to produce the highest number of booby nests because most pairs have started nesting and relatively few nests have failed, but surveys at this season pose the greatest risk of causing nest failure because most chicks are very small. Booby chicks are semi-altricial upon hatching (very small and naked, but with eyes open), and are vulnerable to heat stress until they are covered in down and able to thermoregulate on their own. Surveys should avoid flushing adult boobies from nests, should be conducted during the cooler parts of the day, and should avoid the most sensitive period in late May through early June if possible.

MANAGEMENT RECOMMENDATIONS

Management tasks should initially focus the removal and maintenance of an alien mammal-free environment. Secondary management tasks involve the re-introduction of common and rare native species in order to bring their abundance up to a level whereby they can reproduce and maintain a self-sustaining population. Conservation results can be achieved in a relatively short period of time, as compared to larger islands. Because of its isolation, Lehua is less vulnerable to re-invasion by alien species and will benefit from these management actions as long as re-invasions can be prevented. Another advantage of working on small islets is the minimal infringement of local land use. This project can also serve to hone and advance conservation techniques and approaches which are being tested throughout Oceania. The involvement of graduate students at the University of Hawai‘i will help train future generations in the highly dynamic and important process of conservation biology.

Specific management recommendations include the following:

- Rabbits should be eradicated from the island as soon as possible. Restoration of vegetation, in addition to the obvious benefits to plant species, will provide greater cover and nesting platforms for seabirds, particularly Red-footed Boobies.
- Rats should be eradicated from the island as soon as possible. Rat removal likely would result in a decrease in predation on nesting seabirds, particularly smaller species such as

Band-rumped Storm-petrel and Bulwer's Petrel, and may allow colonization of the island by additional species such as Sooty Tern, Grey-backed Tern, and Brown Noddy.

- Make contingency plans to prevent re-introductions of rodents.
- Effects of rat and rabbit removal should be quantified by conducting pre- and post-eradication surveys of vegetation and nest predation.
- Barn Owls should be controlled whenever they are observed on the island. The large accumulation of bones from a variety of bird species under a Barn Owl roost indicates this alien predator is seriously impacting nesting seabirds on Lehua.
- Cattle Egrets should be removed as soon as possible through destruction of nests and removal of adults. Although no predation by egrets has been observed on Lehua, this opportunistic alien species is known to prey upon seabird nestlings, and also may compete with Red-footed Boobies for nest sites
- A system of marked paths should be established, especially in more heavily used areas near camp, to minimize the extent of anthropogenic impacts, including the risk of crushing Wedge-tailed Shearwater burrows, disturbance to nesting boobies, and trampling of vegetation that might confound comparisons involving plant abundance and diversity before and after eradication of rabbits and rats.
- Surveys should avoid flushing adult boobies from nests, should be conducted during the cooler parts of the day, and should avoid the most sensitive period in late May through early June if possible.
- The bone deposit under the Barn Owl roost should be carefully excavated to investigate the historical diversity of vertebrate species.

SUMMARY OF TRIPS TO LEHUA CONDUCTED FOR THIS SURVEY

20—21 Dec 2001

K. R. Wood, M. Maunder & C. Swenson

Observed that rabbits were still present [15 were seen but suspect a much greater number]; Began making vascular plant, arthropod, and seabird distribution and abundance observations.

19—21 Feb 2002

K. R. Wood, E. VanderWerf, D. Duffy & E. Campbell

Continued with vascular plant checklist; arthropod checklist; and seabird inventory.

6-8 Jul 2002

K. R. Wood & E. VanderWerf

Spent three days on Lehua; continued with vascular plant, arthropod, and seabird checklist/inventory.

7-9 Mar 2003

K. R. Wood, M. LeGrande, D. Boynton, G. Lagazo, & H. Eijzenga

Continued with vascular plant, arthropod, and seabird checklist/inventory; began macro-algae [limu] collections; reviewed H. Eijzenga's project which aims at quantifying the effects of rabbit removal on vegetation and nesting seabirds; numerous rabbits seen, including young; D. Boynton photo-documented islet.

30 May – 1 June 2003

K.R. Wood, M. LeGrande, E. VanderWerf, S. Montgomery, H. Eijzenga, G. Lagazo

Continued with vascular plant checklist and monitoring; arthropod checklist; seabird inventory; macro-algae collections; looked for cultural sites.

29-31 August 2003

K.R. Wood, M. LeGrande, D. Boynton, A. Hebshi, H. Eijzenga, G. Lagazo

Wedge-tailed Shearwater studies with A. Hebshi, vegetation studies with H. Eijzenga, photo documentation with D. Boynton.

27-28 September 2003

K.R. Wood, C. Swenson, N. McMahon, A. Carpenter, M. Yent

State of Hawai'i archaeologists conducted archaeological survey and mapping.

5-6 March 2004

K.R. Wood and M. Ono

Set up egg predation study; initiated owl and egret control; conducted albatross count.

25-30 April 2004

M. LeGrande, M. Ono, H. Eijzenga, L. Driscoll, R. Doratt

Vegetation monitoring; rodent evaluation; egret control.

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Table 6. Abundance of bird species on Lehua Islet in April 1931 and August 1932 (Caum 1936), August 1947 (Fisher 1951), 10-11 August 1960 (Richardson 1963), September 1966 and 1967 (R. Walker, Hawai'i Division of Forestry and Wildlife, unpubl. Data), and on visits during this study. Status codes: End = endemic; Ind = indigenous; WV = indigenous winter visitor; A = Alien; E = endangered; T = threatened; C = candidate; SoC = species of concern. Survey type codes: C = census; S = sample; A = actual count. See Methods for complete description of each survey type. An asterisk (*) indicates the species was present but its abundance was not estimated.

Species	Status	1931, 1932 (Caum 1936)	1947 (Fisher 1951)	1960 (Richardson 1963)	1966, 1967 (R. Walker unpubl.)	2002-2004 (this study)				
						Survey type	19-21 Feb 2002	6-8 Jul 2002	30 May-2 Jun 2003	5-6 Mar 2004
Black-footed albatross (<i>Phoebastria nigripes</i>)	Ind SoC	A few, no known nests	0	0	0	Adults C	31	0	2	14
						Nests C	8	0	11	6
Laysan Albatross (<i>Phoebastria immutabilis</i>)	Ind SoC	0	0	0	0	Adults C	50	0	10	25
						Nests C	9	4	28	6
Wedge-tailed shearwater (<i>Puffinus pacificus</i>)	Ind	Very common	1000s	1500 nests	1000-1200 nests	Nests S	0	23000	100	30
Christmas Shearwater (<i>Puffinus nativitatus</i>)	Ind SoC	0	*	0	0	Adults A	0	2	1	0
Newell's Shearwater (<i>Puffinus auricularis newelli</i>)	End T	0	0	0	0	Adults A	0	0	1	0
						Nests	1	0	0	0
Bulwer's Petrel (<i>Bulweria bulwerii</i>)	Ind	0	0	40	0	Adults A	0	6	60	0
				4		Nests A	0	6	9	0
				8		Carcasses A	0	3	0	0
Band-rumped Storm-Petrel (<i>Oceanodroma castro</i>)	Ind C	0	0	0	0	Adults A	0	1	6	0
						Skeletons A	1	0	0	0
Red-tailed Tropicbird (<i>Phaethon rubricauda</i>)	Ind	Commonest species	400 adults	250 adults	30-40 nests	Adults A	76	150	*	55
						Nests S	2	200	*	5
White-tailed Tropicbird (<i>Phaethon lepturus</i>)	Ind	0	2 adults	0	0	Adults A	0	0	0	0
Masked Booby (<i>Sula dactylatra</i>)	Ind	A few, 2-3 nesting pairs	0	0	0	Adults C	0	0	0	0
Brown Booby (<i>Sula leucogaster</i>)	Ind	A few nesting pairs	0	120 adults	170 young	Adults C	303	*	*	*
						Nests C	12	369	521	*

Red-footed Booby (<i>Sula sula</i>)	Ind	Not uncommon	3000 adults	500 adults	1500-1800 nests	Adults C	4288	*	*	*
						Nests C	0	1294	*	*
Great Frigatebird (<i>Fregata minor</i>)	Ind	Rare, 2-3 nesting pairs		18	25-30 adults	Adults C	38	326	77	*
				0		Nests C	0	0	0	*
Cattle Egret (<i>Bubulcus ibis</i>)	A	0	0	0	0	Adults C	19	9	87	ca. 100
						Nests C	0	2	21	45
Peregrine Falcon (<i>Falco peregrinus</i>)	WV SoC	0	0	0	0	Adults A	1	0	0	0
Pacific Golden-Plover (<i>Pluvialis fulva</i>)	WV SoC	Several	0	0	3,3	Adults A	6	0	0	*
Wandering Tattler (<i>Heteroscelus incanus</i>)	WV	0	0	2	1	Adults A	0	1	0	0
Ruddy Turnstone (<i>Arenaria interpres</i>)	WV	Several	0	20	3, 6	Adults A	9	8	0	2
Glaucous-winged Gull (<i>Larus glaucescens</i>)	WV	0	0	0	0	Adults A	1	0	0	0
Gray-backed Tern (<i>Sterna lunata</i>)	Ind	0	0	0	0	Adults A	0	1	0	0
Sooty Tern (<i>Sterna fuscata</i>)	Ind	0	0	0	0	Adults A	2	0	2	0
Brown Noddy (<i>Anous stolidus</i>)	Ind	Fairly common	0	0	500 adults	Adults A	1	0	0	0
Hawaiian Black Noddy (<i>Anous minutus melanogenys</i>)	End	Rare	200	350	335-360 adults	Adults C	136	405	230	*
Rock Dove (<i>Columba livia</i>)	A	0	0	0	0	Adults A	0	0	2	0
Zebra Dove (<i>Geopelia striata</i>)	A	0	A few	6	2,7	Skulls A	1	0	0	0
Sky Lark (<i>Alauda arvensis</i>)	A	Rather common	*	0	0	Adults A	0	0	0	0
Northern Cardinal (<i>Cardinalis cardinalis</i>)	A	0	0	1	0	Adults A	0	0	0	0
House Finch (<i>Carpodacus mexicanus</i>)	A	0	0	20	18,40-45	Adults A	0	2	0	0
Nutmeg Mannikin (<i>Lonchura punctulata</i>)	A	0	0	0	1,16	Adults A	0	20	15	*
House Sparrow (<i>Passer domesticus</i>)	A	0	0	10	12,0	Adults A	0	0	0	0

Figure 2. Breeding phenology of bird species on Lehua Islet. Dashed lines indicate eggs and solid line indicates chicks. Extent of each stage of the breeding cycle was extrapolated from survey dates based on incubation and fledging periods in other areas. Additional species suspected to nest on Lehua but for which there is insufficient information to determine breeding phenology include Christmas Shearwater, Newell’s Shearwater, and Band-rumped Storm-petrel.

Black-footed Albatross	-----										-----	-----
Laysan Albatross	-----	-----									-----	-----
Wedge-tailed Shearwater						-----	-----	-----				
Bulwer’s Petrel						?-----?			?			
Red-tailed Tropicbird		-----	-----	-----	-----	-----						
Brown Booby		-----	-----	-----	-----	-----	-----					
Red-footed Booby			-----	-----	-----	-----	-----	-----				
Cattle Egret				-----	-----	-----	-----					
Hawaiian Noddy			-----	-----	-----	-----						
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec