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A Natural History Survey of North Halawa Valley, O‘ahu, Hawai‘i

edited by
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Cover: North Halawa Valley looking upstream from near Pearl Harbor, toward the crest of the Koolau Mountains, Photo: D.A. Polhemus.

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PREFACE

This work represents a historical document from the early 1990s, detailing the results of a set of natural history surveys undertaken in North Halawa Valley, on leeward O‘ahu, by staff from the Department of Natural Sciences at the Bishop Museum. The museum had secured a large contract to assess the archaeological resources along the route of the proposed H-3 freeway that was eventually built up that valley, and this project, in conjunction with a new road to the valley headwall, facilitated access to what had been a previously remote area. Although the museum was not contracted to undertake biological surveys for the highway project, staff in the Department of Natural Sciences realized that the circumstances offered a unique opportunity to produce a biological profile of what was considered one of the more ecologically intact leeward valleys in the vicinity of Honolulu, and therefore made regular visits on their own time as other duties permitted.

The result was a series of reports detailing the geology, soils, botany and zoology of North Halawa Valley. Although containing a wealth of detail, these reports were never published, and ended up archived within various sections of the Natural Sciences department. In the late 1990s, the senior editor made a concerted effort to obtain copies of these reports, with the assumption they might provide a useful reference for future workers. Now, 30 years later, with the State of Hawaii’s Department of Land and Natural Resources in the process of acquiring the upper valley for placement in conservation status, and in the face of significant ecological transitions due to rapidly changing climate, it has seemed relevant to provide this information to researchers and natural resource managers as a baseline by which to judge subsequent ecological changes.

The series of reports presented here has not been significantly revised from their original form. As such, taxonomic names have not been updated, which would have been a considerable task in certain groups, particularly plants. Similarly, spellings of Hawaiian words are as in the original manuscripts, with or without diacritical marks depending on the authors involved. Finally, some of the authors are now deceased, or have married and adopted different surnames, and these events are referenced in footnotes.

Although this set of reports should be considered a period piece, it contains considerable information that is not duplicated elsewhere, and it is hoped that placing them into the academic record will prove of value to future generations.

— Dan Polhemus, December 2023

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ACKNOWLEDGMENTS

Authorship of the chapters in this report is ascribed to the individuals primarily responsible for their preparation, and most chapters have specific acknowledgments of others who helped. The overall study was a group effort by the Natural Sciences Department of Bishop Museum and included at least some input by most of the department's staff, as well as collaborators in the Department of Anthropology. We were assisted in identifications and background information, especially in entomology, by colleagues at the University of Hawai'i and many museums around the world. The study also used the Nature Conservancy Hawaii's Heritage Database. In addition, special thanks are due to the late Derral Herbst, of the U.S. Fish and Wildlife Service, who provided aid with botanical identifications. Finally, we thank the Hawaii State Department of Transportation and various contractors, who were helpful in allowing access to the valley during our surveys.

CHAPTER 1
INTRODUCTION

Francis G. Howarth & Dan A. Polhemus

North Halawa is a narrow, elongate valley located on the leeward slopes of the Koolau Mountains in southeastern Oahu (Fig. 1). The catchment drains west-northwest into the East Loch of Pearl Harbor, and is bordered on the north by Aiea Ridge, and on the south by North Halawa Ridge. The headwall at the back of the valley is part of the crest of the Koolau Range, and separates leeward North Halawa from windward Haiku Valley.

Unlike the situation in major valleys to the south, such as Moanalua, Kalihi and Nuuanu, no access road existed in North Halawa prior to 1987, when a narrow, paved track was built to the 300 meter elevation to allow test boring for the H-3 highway tunnel. Before this time access to the back of the valley was difficult, involving a long and strenuous hike, and as a result the knowledge of the flora and fauna at upper elevations was limited, although the extreme summit of the Koolau Crest itself was accessible via maintained trails along both bordering ridges. The initiation of the H-3 highway project changed this situation completely, ushering in large-scale environmental changes throughout the length of the valley, yet at the same time allowing intensive biological surveys of what had been up to then one of the most intact native ecosystems in close proximity to Honolulu. This report summarizes our biological knowledge of North Halawa both before and during its transition from a remote valley to a major highway corridor, drawing upon both historical information, such as found in the Bishop Museum and other major collections, and on the results of recent surveys that the highway development made possible.

The proximity of North Halawa Valley to metro Honolulu, with its rapidly growing population, has subjected the area, particularly its lower elevations, to a high level of disturbance. The bottom half of the valley is now an anthropogenic ecosystem supporting mostly alien plant species, the vegetation in this area being characterized by wasteland,

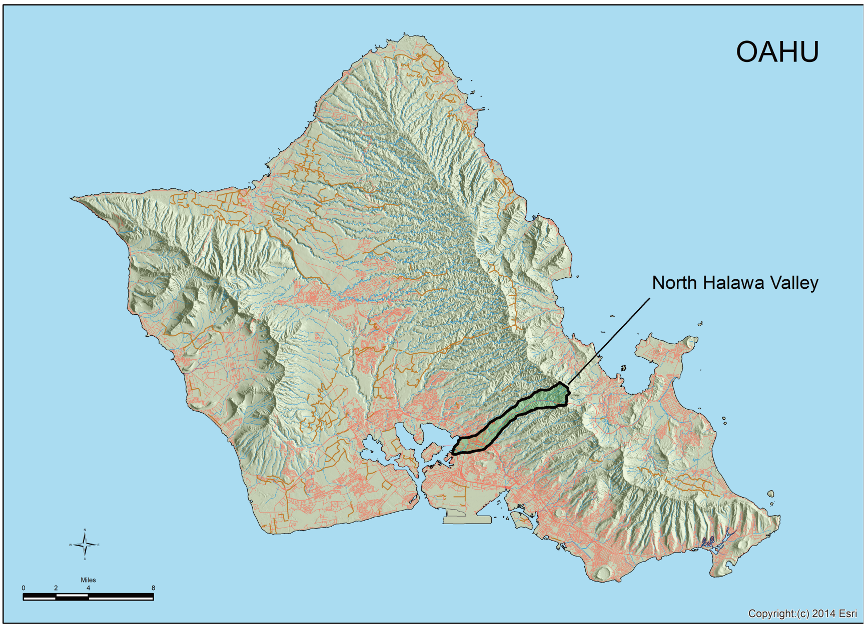

Fig. **1**. Location of North Halawa Valley on the island of Oahu.

forestry plantations of eucalyptus and ironwood, and alien introduced trees and shrubs. Certain agricultural plants also survive here, as do a few common native plants. By contrast, the upper section of the valley contains an increasing proportion of native mesic and rainforest species as one moves upslope, until at the headwall one finds a predominantly native rain forest, although still with a few introduced elements, such as guava. Views into the valley from trails on the adjoining ridges showed that well into the 1970s the area displayed a remarkably intact native forest, with many tree and bird species identifiable through binoculars, and indicated that North Halawa supported a more diverse native flora and fauna than other nearby valleys.

Several interrelated factors appear to have protected the upper portion of North Halawa from the disturbances and invasions of non-native species that affected other leeward Koolau drainages. The steep walls, especially the high headwall that interrupts the trade winds, coupled with a narrow valley floor, provided a more stable and wetter microclimate that allowed elements of the upper rain forest to persist at lower elevations than in nearby valleys, while at the same time limiting the success of many alien plants and animals, which are generally better adapted to drier and more open habitats. Cattle, particularly, and perhaps goats as well were not able to penetrate far into the valley, cattle because of the terrain, and goats because of the wet forest. The valley's accessibility to sport hunters was also beneficial in keeping feral ungulate populations, especially pigs and goats at low levels, which further benefitted the survival of native species.

The steep valley walls and narrow floor also discouraged agricultural development in comparison to neighboring valleys. Although native Hawaiians practiced extensive taro cultivation in the valley, the topography inhibited attempts to grow other crops during the last hundred years, with agricultural conversion, notably carnation farms, being limited to only the lower elevations. Alien plants and associated animals adapted to disturbed agricultural lands were thus slower to invade. This pattern is well illustrated by comparing North Halawa to nearby Moanalua Valley; in the latter the amphitheater is broader and more exposed to drying winds and evaporation, resulting in far greater disturbance from agricultural conversion and invasion of lowland drought-adapted plants during the last century.

Early natural history surveys in North Halawa Valley were largely the results of single trips by scientists who knew of the area's relatively intact biota, but who were looking only for species of interest to them. Published notes from these early visits are widely scattered in the literature as a result. Most of the voucher specimens collected by these workers are in the Bishop Museum, University of Hawaii, or Hawaii State Department of Agriculture collections. Others were deposited in non-Hawaiian museum natural history collections, in private collections, or have been lost. When available, this early information is included in this report, but most remains inaccessible.

The first intensive biological surveys of North Halawa Valley were undertaken in the late 1970s as part of the Environmental Impact Statement (EIS) for the (at that time) proposed H-3 interstate highway, after a previously proposed alignment through Moanalua Valley had been rejected (Herbst, 1977; Shallenberger, 1977). These studies, however, were hindered by the same logistical problems that had faced previous researchers. It was only with the construction of the road to the tunnel test bores years later that convenient access along the entire length of the valley was obtained. Realizing the opportunity that this presented, Bishop Museum staff began to undertake biological surveys in the valley in 1991, beginning with the setup and weekly maintenance of a Malaise trap (a device for catching flying insects) at the 300-meter elevation, not far from the test bores. This trapping program provided weekly catch data for three years, producing the most complete long term seasonal record of insect diversity and abundance for any site in the Hawaiian Islands at that time, as summarized in Chapters 7, 8, 9 and 10 of this report.

As the insect trapping project progressed, further collections were made using a variety of methods, in order to assess the overall insect diversity of North Halawa, and additional observations began to be made regarding other aspects of the area's natural history. Eventually various specialists on the museum staff were enlisted to undertake studies of the geology (Chapter 3), botany (Chapter 5), snails (Chapter 6) and birds (Chapter 11), producing a much more complete picture of the valley's environment and biota. The results of this research program have now provided a baseline survey of the flora and fauna of a leeward Hawaiian valley in the process of environmental transformation, and as such should be applicable to other similar situations throughout the state. In addition, the information can be used to interpret the results of archaeological studies concerning past land use and environmental disturbance in North Halawa, which has had a long history of human occupation, and to understand how the natural environment, particularly climate and vegetation zones, might have influenced human exploitation of the valley's resources.

There are three major objectives of the present report: 1) to provide an overview of the natural history of the valley; 2) to compile the baseline data on species currently occurring in the valley or previously known to have done so; and 3) to provide data on the physical and natural environment that can be used to interpret past human use of the valley.

The scope of the report is multidisciplinary, with specialists independently gathering data and writing reports in their own fields. Each chapter can thus stand alone, and yet all relate to a common subject. Since methods and availability of historical data varied among disciplines, specific methods are detailed in each chapter. Several specific study sites were selected, corresponding with the major vegetation types along altitudinal and precipitation gradients in the valley, and in collaboration with the archaeological studies in order to correlate the results with resource use patterns. In addition, the various specialists investigated sections of the valley beyond these study sites that they considered to be particularly significant to their particular interests.

No native vertebrates other than birds and and one species of fish are known from North Halawa Valley. The native bat, *Lasiuus cinereus semotus* has not been seen in the valley, and at the time of the survey there had been few, if any, authentic records of this bat from the island of Oahu in this century (although this situation has changed considerably in recent decades with the advent of more advanced monitoring tools). Other mammals were not specifically searched for during this survey, but those present are all detrimental non-native species, including three species of rats, the house mouse, the small Indian mongoose, the feral house cat, the feral domestic dog, and the feral European boar. The mongoose and pig were frequently observed during the natural history surveys, and the other species are certainly present. In the past feral cattle, and goats possibly roamed the valley as well. Axis deer may also have entered from the population living in Moanalua Valley and the Salt Lake area between 1910 and the early 1960s, but did not persist.

A complete inventory of all plant and animal species occurring in North Halawa Valley was beyond the scope of this study, since many species require specialized survey techniques to inventory or identify. Some conspicuous species are probably over-represented in the present analyses, while other cryptic and less obvious species were likely under-collected or missed entirely. Despite this, the three-year program in North Halawa has probably produced the most complete faunal inventory available for any site on Oahu, and perhaps in the Hawaiian Islands. As such, it constitutes a useful reference to workers across a wide range of disciplines in natural and cultural history.

Table 1. Totals for All Taxa Recorded from North Halawa Valley.

Taxa	Number of Species (taxa)
Plants	357
Land snails (& slugs)	65
Insects & related arthropods	381
Birds	32
Other vertebrates	20
Taxa Total	855

CHAPTER 2
GEOGRAPHY AND CLIMATE

Francis G. Howarth & Dan A. Polhemus

North Halawa Valley is located on the leeward side of the southern Koolau Mountains, and drains into the East Loch of Pearl Harbor. The floor of the valley is about 8 km (5 mi) in length, and slopes gently upward to the east-northeast from the valley mouth lying at about 50 m (160 ft) elevation to an upper amphitheater at around 300 m (1000 ft). From the amphitheater at the back of the valley several branches rise much more steeply to about 400 m (1,300 ft), after which they become progressively more vertical in profile as they meet the headwall that forms the Koolau Crest. Like many leeward Koolau valleys, North Halawa is relatively deep, narrow, and elongate, varying from 1.2 km (0.75 mi) to 2.1 km (1.3 mi) in width, and being bordered along its upper half by sharp-crested ridges that range from 450 m (1,500 ft) to 860 m (2,830 ft) in elevation.

The leeward exposure, extent, and shape of the valley create extreme climatic gradients within it. Temperatures near the mouth range from a high near 35 °C (95 °F) to a low near 10 °C (50 °F), with the difference between the average temperatures of the warmest and coolest months being only about 4 °C (7 °F). There is more diurnal variation than annual variation, with the daily temperature range averaging about 10.5 °C (19 °F) (Armstrong 1983), reflecting an old observation that "night is the winter of the tropics." Given an adiabatic lapse rate in Hawaii of approximately 5.5 °C per kilometer of elevation gained (3 °F for every 1,000 ft), one can predict that the temperature in the back of the valley should be 2 °C cooler than that at the mouth at any given time, but in fact the steep topography and frequent cloud cover probably combine to depress the temperature at the amphitheater a few degrees more. The high headwall and bordering ridges, combined with the narrow valley cross-section, create larger morning shadows and shorter periods or solar heating, thus moderating the daily and seasonal variations.

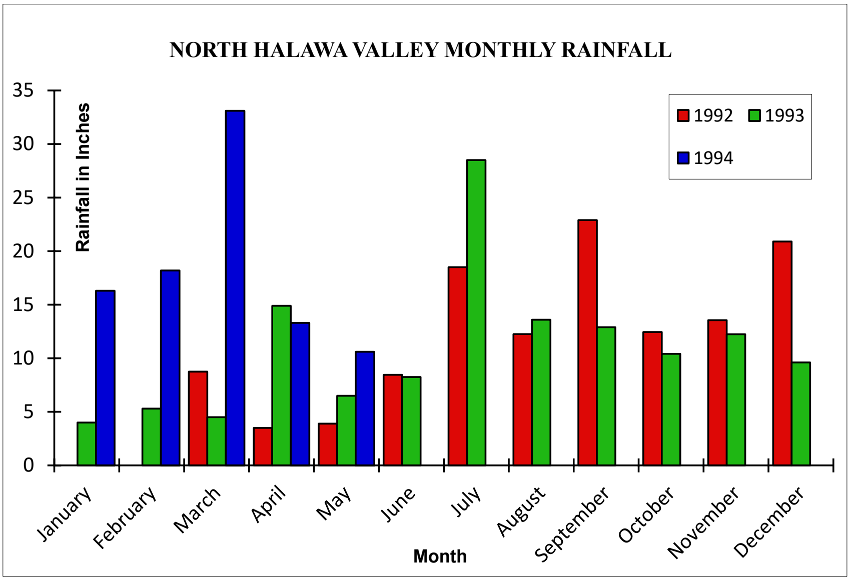

Fig. **2**. Monthly rainfall totals (in inches) as measured by a Hawaii Department of Transportation gauge at the south portal of the H-3 highway tunnel from March 1992 through May 1994. Note the unusually dry winter months in 1993 due to the presence of an El Niño event.

The average annual rainfall in North Halawa Valley increases more than three times from one end to the other, ranging from 100 cm (40 in) per year near the mouth to over 380 cm (150 in) per year below the headwall. Most of the precipitation, however, results from a few large storms, generally occurring in the winter. The moisture gradient in the valley is more pronounced than the temperature or rainfall gradients indicate, and is reflected in the vegetation cover, which grades from dry lowland scrub and grassland at the mouth to rain forest in the upper sections. The high eastern headwall, which ranges from 660 m (2,200 ft) to 860 m (2,830 ft), intercepts moisture carried on the tradewinds and is frequently obscured in mist. This cloud cover often extends leeward over the upper valley, increasing humidity and reducing evaporation.

Rainfall patterns over the three years covered by this report varied widely from month to month, and showed a reversed seasonality in 1992 and 1993 due to a strong El Niño event in the Pacific (Fig. 2). This latter phenomenon raised ocean surface temperatures south and east of Hawaii, and was a factor in the development and persistence of Hurricane Iniki, which passed by Oahu on 11 September 1992. The present natural history surveys were thus done during a climatologically anomalous period, although by early 1994 the precipitation pattern had returned to a more typical regime, with heavy late winter rains once again.

CHAPTER 3
GEOLOGY OF NORTH HALAWA VALLEY

Kevin T. M. Johnson

Introduction

North Halawa Valley is a narrow, V-shaped valley on the leeward, southwestern flank of the Koolau Range, the younger of two large shield volcanoes that make up the bulk of the island of Oahu (Fig. 1). The axis of the valley trends roughly northeast-southwest and extends 8 km from the crest of the northwest-southeast trending Koolau Range at the 730 m elevation, to where the Koolau Basalt dips under sediments and volcaniclastic deposits of the coastal plain at about 15 m elevation. Rainfall ranges from an annual average of 380 cm in the upper valley to 100 cm in the lower valley (Blumenstock & Price 1967).

The main shield-building stage of the Koolau Range ended approximately 2 million years ago. The original elongate form of the Koolau shield volcano, built principally by eruptions along a northwest-trending rift zone, has been carved by erosion (Macdonald *et al.* 1983). A thick sequence of lava flows constitute the basement rock in the study area. Material eroded from the shield has been deposited on the lower slopes and has partially filled the valley. The resulting topography consists of steep valley walls comprising basalt flows of the Koolau Range, a moderately sloping colluvial apron at the base of the valley walls, and nearly flat-lying alluvial sediments on the valley floor.

Tertiary Basalt Basement

The oldest geologic unit exposed in North Halawa Valley, the Koolau Basalt, was emplaced in the Pliocene Epoch. Rocks of the Koolau volcano consist primarily of tholeiitic basalts, olivine basalts, and small amounts of oceanite, an olivine-rich tholeiitic basalt (Stearns, 1939; Langenheim & Clague 1987). It appears that eruptive activity on the Koolau volcano did not reach the stage of transition to alkalic lavas by the time it ceased. Most outcrops in Halawa Valley consist of thin (0.3 to 3.0 m) ‘a‘a and pahoehoe flows of the Koolau Basalt. Outcrops of pahoehoe are characterized by smooth or rounded outlines and abundant spherical vesicles, some of which have been filled by secondary minerals.

‘A‘a flows display a two-part morphology consisting of clinker and core. ‘A‘a clinker is characterized by a rough, hackly surface and ‘a‘a core is generally dense and homogeneous. Alternate clinker/core layers in a succession of ‘a‘a flows can be recognized from a distance if not obscured by vegetation.

Minor deposits of vitric and lithic tuff, though rare in Koolau Basalt, can be found as small, discontinuous outcrops in the upper reaches of some valleys and near the crest of the Koolau Range. The deposits are generally a few centimeters to tens of centimeters thick and are exposed in cliffs near the head of the valley. The basalts and pyroclastics of the Koolau Basalt constitute the basement rock on which all the younger alluvium and colluvium were deposited. An erosional unconformity between the Koolau Basalt basement and the overlying sediments is exposed in many road cuts and in some parts of the channel of North Halawa Stream.

Quaternary Volcanics

The Quaternary Honolulu Volcanics primarily comprise tuff cones distributed throughout east Oahu. Deposits associated with the Aliamanu-Salt Lake Crater complex lie less than 1.6 km southwest of the North Halawa water shaft (Stearns & Vaksvik 1935). No volcanic rocks younger than the Tertiary Koolau Basalt were found in North Halawa Valley itself, although tuff encountered during the excavation of the Halawa shaft may be of Pleistocene age. No other evidence of Honolulu Volcanics was found in North Halawa Valley.

Sedimentary Deposits

Sedimentary deposits in North Halawa Valley are primarily gravels and conglomerates. These clastic deposits include Quaternary alluvium and colluvium, which are easily distinguished from each other in outcrop, but are difficult to distinguish if obscured by vegetation.

Alluvium

Alluvium includes the sediments deposited by North Halawa Stream, its tributaries, and their predecessors. These sediments, which consist of conglomerates, gravels, and cobbles have varied weathering and diagenetic histories and different lithologies. Previous investigators have subdivided the alluvium of Oahu into "older" and "younger" subunits on the basis of diagenetic and weathering criteria (Stearns & Vaksvik 1935; Wentworth 1951; Izuka 1992).

"Young alluvium" refers to the deposits of the active reaches of North Halawa Stream and its tributaries, and "old alluvium" refers to consolidated or highly weathered alluvium not deposited by the present stream, including deposits that are found well above the present stream system. Young alluvium consists of rounded, loose boulders, cobbles, pebbles, and sand in a clast-supported fabric. Silt and clay are only minor components.

Old alluvium is similar to young alluvium but is commonly cemented and slightly to highly weathered. In some outcrops, the weathering is superficial and the clasts are hard, but in other outcrops the alluvium has been weathered to a soft or friable consistency. Weathering has given rise to secondary clays, but because they coat grains rather than fill interstices, the secondary clays are easily distinguished from the detrital clays. With the exception of secondary clays, old and young alluvium contain little clay.

Colluvium

Colluvium includes the veneer of sedimentary deposits on the steep slopes of the valley walls as well as thicker deposits from mass wasting. Colluvium has a greater proportion of silt and clay than does alluvium (Stearns & Vaksvik 1935). The colluvial deposits contain clasts that are angular and poorly sorted and the fabric of the deposits is matrix supported.

Distribution of Sedimentary Deposits

Young alluvium forms thin, patchy deposits that line the channels of the present North Halawa Stream, its tributaries, and many of the interstream areas. Test borings near the stream show that young alluvium is 1–2 m thick in some places, but most of the sediment that fills the valley, particularly in the lower valley, is old alluvium (Izuka 1992). Old alluvial deposits occur along some banks of the stream at elevations above the present stream level in Halawa Valley.

The sediments of lower North Halawa Valley are thicker and more extensive than those in the upper valley. Borings near the Halawa shaft indicate that the total thickness of the sediment at the axis of the valley is more than 30 m (Izuka 1992). Midway up the valley, as also indicated by borings, the sediments are only about 9 m thick, and in the upper valley the sediment is absent or only up to one meter thick (Izuka 1992). The sediments thin away from the axis, and are overlain by the colluvial apron fringing the steep valley walls.

Weathering

Outcrops of Koolau Basalt in North Halawa Valley range in the degree of weathering from slightly weathered basalt in the lower valley (Fig. 3) to highly weathered basalt with a soft, clay-like consistency in the middle and upper valley (Fig. 4). Exposures of heavily weathered basalt lava flows are typically red-brown or tan and their original basaltic mineralogy has been completely altered to clay minerals and other phyllosilicate pseudomorphs, while still retaining the original flow structures. Despite extensive weathering, it is usually possible to distinguish basement rock from sedimentary cover, and \`a\`a from pahoehoe.

Fig. 3. An aerial view up North Halawa Valley from near the quarry, showing less weathered basalt in the stepped valley walls, with obvious small cliff lines, representing the remains of individual lava flows. Photo: D.A, Polhemus.

The topography of the valley partly reflects the extent of weathering. In the lower valley, the topography is characterized by small escarpments formed by the erosion-resistant cores of unweathered \`a\`a flows (Figs. 3, 5; Macdonald *et al.* 1983). In highly weathered areas in the humid upper valley, slopes are smoother and the small escarpments are absent (Figs. 4, 5). Landslide scars show that when the highly weathered rock fails, the newly formed slope cuts smoothly across both \`a\`a and pahoehoe flows. Because the rock is so thoroughly weathered, \`a\`a flows lose their distinctive hardness and resistance to erosion. The differences in slope morphology are helpful in estimating the areal extent of highly weathered rock.

Weathering of the bedrock is more extensive in the upper part of North Halawa Valley than in the lower part of the valley. In the upper valley, the basalt bedrock is deeply weathered over a wide area, even on steep slopes. Test borings indicate that the weathered layer in the upper valley is about 10 m thick (Izuka 1992), but because of removal by mass-wasting, the thickness probably varies. In contrast, the bedrock in the walls of the lower valley is only slightly weathered. Resistant cores of \`a\`a flows form small escarpments in the valley walls. However, weathered rock can be found in the lower and middle valley. Midway up the valley axis at about the 135 m elevation, test borings penetrated highly weathered rock below old alluvium (Izuka 1992). The occurrence of highly weathered basalt underlying old alluvium is common in alluvial valleys of Oahu (Mink & Lau 1980). A layer of highly weathered old alluvium occurs under the floor of the lower valley (Izuka 1992), and a layer of highly weathered basalt may underlie this.

The widespread distribution of highly-weathered rock in the upper valley results from the higher rainfall near the crest than on the leeward slopes of the Koolau Range (Macdonald *et al.* 1983; State of Hawaii Department of Land and Natural Resources, 1984; Giambelluca *et al.* 1984). In the lower valley, the occurrence of weathered rock is controlled by the rate of erosion, which is, in turn, governed by relief. Gentle slopes allow the development of thick weathered layers (Macdonald *et al.* 1983). Thus, although rocks in the steep walls of the lower valley are only slightly weathered, deeply weathered rocks occur under the valley floor and on the ridge top where slopes are gentler (Wentworth 1942).

Fig. **4**. An aerial view of upper North Halawa Valley, showing sloping walls without obvious cliff lines, due the greater degree of weathering in this wetter area near the crest of the Koolau Range. Photo: D.A. Polhemus.

Conclusions

The geologic units present in North Halawa Valley include Tertiary Koolau Basalt lava flows and Quaternary alluvial and colluvial sediments. Most rock outcrops in Halawa Valley consist of thin (0.3 to 3.0 m) ‘a‘a and pahoehoe flows of Koolau Basalt. Alluvium and colluvium range in thickness along the length of the valley from total thicknesses of more than 30 m in the lower valley, 9 m midway up the valley, and absent or only up to one meter in the upper valley. The sediments thin away from the axis, and are overlain by a colluvial apron fringing the steep valley walls. Weathering of Koolau Basalt in North Halawa Valley ranges from slightly weathered basalt in the lower valley to highly weathered basalt with a soft, clay-like consistency in the middle and upper valley. The weathered layer in the upper valley is about 10 m-thick, but bedrock in the walls of the lower valley is only slightly weathered. However, highly weathered rock frequently occurs below alluvium in North Halawa Valley.

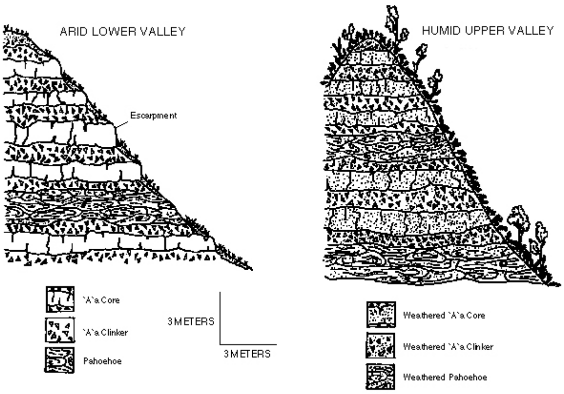

Fig. **5**. Stratigraphy diagrams for lower and upper sections of North Halawa Valley.

CHAPTER 4
SOILS OF NORTH HALAWA VALLEY

P. W. Malaspina

Introduction

A survey of the distribution and properties of the soils of the North Halawa Valley was undertaken to complement ongoing archaeological research. Fieldwork included the description of soil profiles at selected archaeological sites, as well as the examination of soils in the valley as a whole. Survey methods and field description terminology followed those recommended by Soil Survey Staff (1989). Limited chemical and mineralogical analyses of selected soil samples were undertaken. In addition, previously published soil surveys (Cline 1955; Foote *et al.* 1972) provided useful information.

Soil formation has been modeled as a complex process controlled by a number of different factors: parent material, topography, vegetation, climate and time (Jenny 1941). Although parent rock is relatively homogenous in the North Halawa Valley (Johnson, this volume), soil properties vary considerably within the valley due to variation in soil forming factors. The distribution of soil types and the related geomorphic zones of the North Halawa Valley will be described. General implications of soil properties for archaeological research will also be discussed.

Setting

North Halawa Valley is a narrow steep-sided valley located on the leeward side of the Island of Oahu. The valley can be divided into three main regions. The lower valley is characterized by a relatively flat valley floor. Thick alluvial fill resulted from stream base level changes due to sea level fluctuations (Wentworth 1951). During low stands of sea level, steam erosion cut the valley to elevations well below its present level. Following sea level rise, the valley floor was filled by terrigenous alluvium. This process may have occurred several times since there have been several high and low stands of the sea on Oahu, with direct evidence in the Pearl Harbor area (Ruhe 1965; Stearns 1978). In the middle valley region, numerous entrenched meanders of the North Halawa stream form a complex landscape of floodplain and terraces. In the upper valley, an amphitheater-headed section has developed and is characterized by numerous notched channels on the steep slopes. In the upper valley, areas of alluvial flood plains and terraces are confined to a narrow area surrounding the North Halawa stream and its tributaries.

The soils of North Halawa Valley can be grouped on the basis of parent material. First, colluvial soils form in gravity laid deposits which are poorly sorted and are characterized by the presence of angular to subangular cobbles and stones. The texture of colluvial deposits are dominated by silt and clay sized particles. Secondly, alluvial soils are found on flood plains and terraces. Alluvial deposits are well sorted and characterized by subrounded to rounded gravels and stones. Sand and silts predominate in alluvial deposits. Finally, residual soils form in basalt lava which was weathered in place and are found on the valley walls and ridges. It is usually possible to distinguish the type of parent material by landscape position and soil profile characteristics. However, field evidence demonstrates that these types of deposits are intermixed in some cases.

The climate, especially precipitation, varies considerably from the lower valley to the highest elevation at the crest of the Koolau Range. Median annual rainfall ranges from approximately 120 cm/year at the lowest section of the study to around 340 cm/year at the crest of the amphitheater ridge (Giambelluca 1986). Rainfall is seasonally distributed resulting in a significant dry period during the summer in the lower valley. This large variation in rainfall across a short distance is a prominent feature of the Hawaiian climate and results in significant differences in soil properties (Sherman & Ikawa 1968). High rainfall affects soil development by increasing the leaching of bases and accelerates the formation and translocation of secondary clay minerals. Low rainfall and poor drainage result in less developed soil profiles. The types of clay minerals which are formed are indicative of the soil moisture regime and the extent of soil development. Sherman & Uehara (1956) showed that weathering of olivine basalt under poorly drained conditions leads to formation of smectite minerals, such as montmorillonite. If rainfall and drainage are not limited, kaolinite and halloysite develop. Under conditions of more intense weathering, free oxides of aluminum, iron and manganese form. This transition in mineral weathering regimes is evident in the soils of the North Halawa Valley.

Soil-Geomorphic Zones

North Halawa Valley can be divided into several distinct soil-geomorphic regions. These zones of similar soil types and landforms will be described in general terms.

Alluvial Soils of the Lower Valley

Three major alluvial soil types were identified in the lower valley. The Kawaihāpai soil is a Mollisol, classified as a cumulic haplustoll (Foote *et al.* 1972). This soil occurs on the flood plain of the North Halawa Steam. It is distinguished by a thick, dark brown surface horizon which ranges in texture from clay loam to silty clay loam. The surface layer is characterized by an irregularly decreasing percentage of organic carbon resulting from repeated alluvial deposition. The surface horizon lies unconformably over a massive IIC horizon, which ranges in texture from sandy loam to silty clay loam. The Kawaihāpai soil is high in base saturation and pH is neutral. The mineralogy of secondary clays is mixed, composed primarily of kaolinite and smectite.

The Kaʻena soil series is a Vertisol, classified as a Typic Pelludert (Foote *et al.* 1972). This soil occurs by smectite which is characterized by shrinking and swelling with changing water content. The surface of the soil is covered with hardened soil granules due to drying and shrinking of the clays. When the soil dries, cracks occur and the surface soil falls down through these cracks. During wet periods, the subsoil is pushed upward. Over the years, the soil material is mixed and results in a "self-mulching" profile. The Kaʻena series is characterized by cracks which stay open less than 90 days per year. Workability is poor and the moist consistency is very sticky and very plastic.

Although not noted during previous soil surveys (Foote *et al.* 1972), well drained alluvial soil material is found in association with the Kaʻena soil. This soil is dominated by kaolinite and halloysite mineralogy. Typically, the surface horizon ranges from silt loam to silty clay loam. Soil reaction is moderately acid. Subsurface horizons often retain stratigraphy of alluvial episodes although evidence of pedogenesis, such as clay illuviation, is present. The transition from poorly drained, smectite-rich soils to well drained kaolinitic soils often forms a complex pattern in the landscape and is related to topography and soil drainage characteristics (MacDonald *et al.* 1983). In addition, this progression may occur in the same profile. Uehara & Sherman (1956) examined an alluvial soil profile in the lower North Halawa Valley and described a red, kaolinitic surface soil overlying a black smectite-rich subsoil.

Side slopes of the Lower Valley

These valley walls are characterized by steep slopes composed of alternating layers of resistant and less-resistant rock. Exposed rock makes up 25–90% of the surface. The parent rock is only slightly weathered. Very shallow soil material, dominantly clay and silty clay, is associated with the rock outcrops. The soil is usually dark gray to black and the moist consistency is very sticky and very plastic. Due to the presence of smectite clays, the soil reaction is neutral to slightly alkaline. Gravity fall and rainwash are important mass wasting processes on these slopes (MacDonald *et al.* 1983).

Colluvial Soils of the Lower Valley

Colluvial soils form in talus deposits at the base of the valley walls. Soils of the Kokokahi series develop in these deposits. The Kokokahi soil, a Vertisol, is classified as a Udorthentic Pellustert (Foote *et al*. 1972). It is high in shrinkswell clays, neutral to slightly alkaline pH, internal drainage is poor. The Kokokahi soil is characterized by a deep A horizon (around 60 cm thick) composed of dark gray clay with very sticky and very plastic moist consistency. Although the topsoil is dark, organic matter is generally low. Abundant angular cobbles and stones are relatively unweathered. Due to the shrink-swell properties of these clays, these colluvial footslopes are subject to soil creep (MacDonald *et al.* 1983). Repeated wetting and drying of the soil material results in slow, steady downhill movement of soil.

Facets of ʻAiea Ridge and Halawa Ridge

On both sides of North Halawa Valley, on the lower regions of Halawa Ridge and ʻAiea Ridge, roughly triangular shaped facets or planezes are erosional remnants of the original lava flow surface. Sheet erosion has lowered the original surface by 30–60 m (MacDonald *et al.* 1983). In comparison with the geomorphic surfaces found in the North Halawa Valley, these are relatively stable. Soils form predominantly in basalt residuum. The upper slopes of the facets are dominated by soils of the Manana series, an Ultisol classified as an Orthoxic Tropohumult (Foote *et al*. 1972). The Manana soil shows evidence of intense weathering and the mineralogy is composed primarily of gibbsite and kaolinite. The soil is very acid to extremely acid and shows evidence of significant clay illuviation. On the lower, more gradual slopes of the `Aiea facet, the Lahaina soil series predominates. The lower slopes of the Halawa facet have been removed by quarrying. The Lahaina soil is classified as an Oxisol, specifically a Typic Torrox (Foote *et al.* 1972). The soil is medium acid to slightly acid. Clay mineralogy is primarily oxidic, with abundant manganese concretions throughout the profile. This transition from Ultisols on steeper slopes grading to Oxisols on the lower, gradual slopes is common on Oahu. Topography is an important factor in the formation of the more highly weathered Oxisols on the more stable landscape.

Alluvial Soils of the Middle and Upper Valley

A more intense soil weathering regime due to increased rainfall changes the general pattern of soil distribution in the middle and upper valley. The Mollisols and Vertisols which form in alluvium of the lower valley are not found in the middle to upper valley. Alluvial soils develop primarily a koalinitic/halloysitic mineralogy reflecting the high rainfall and good drainage. These soils are found on flood plains and terraces of the North Halawa Stream and its tributaries. Slopes range from 0–6%.

A representative profile is described on a flood plain at an elevation of 235 m (770 ft). A dark brown, silty clay loam topsoil (14 cm thick) overlies several alternating layers of sandy clay loam. This type of stratification is caused primarily by episodic sedimentation rather than pedogenesis. Soil pH ranged from 5.3 in the topsoil to 5.6 in the subsoil. Rounded and subrounded alluvial gravel and cobbles ranged from 20–30% by volume in the subsoil layers but were absent in the topsoil. There is a broad range in characteristics of the alluvial soils which were examined in the middle to upper valley. Major factors which influence the variability of these soils are the particle size distribution of the initial deposit and the length of time during which these soils have formed.

Colluvial soils of the Middle and Upper Valley

Colluvial soils of the upper valley form in talus deposits at the base of the valley side slopes. Slopes range from 5–30%. These soils differ from the colluvial soils of the lower valley and do not display the vertic properties resulting from smectite mineralogy. Higher rainfall in these areas results in primarily kaolinite and oxide dominated mineralogy.

A profile at 198 m elevation (650 ft) consisted of a dark brown silty clay loam (17 cm thick) overlying a dark reddish brown silty clay horizon (36 cm thick). Clay illuviation was obvious due to the textural change and to the presence of clay films in the subsoil. Soil pH ranged from 4.7 in the topsoil to 5.3 in the subsoil. The percentage of angular cobbles increased from less than 5% in the topsoil to 30% in the subsoil. A number of soil profiles examined in the upper valley were formed in shallow colluvial deposits overlying alluvium. The surface horizons were ranged from silty clay loam texture to angular coarse fragments. A smooth to wavy, abrupt boundary separated the overlying colluvial soil from the underlying, sandy loam to loam alluvial soil material.

Side-slopes of the Middle and Upper Valley

The soil cover on the valley walls is a relatively thin (2 to 25 cm) layer of silt loam to silty clay loam. The soil is low in organic matter and strongly acid. The clay mineralogy is dominated by kaolinte, halloysite and free oxides of iron and aluminum. Below the shallow soil, in-situ basalt retains the outline of lava flow morphology but is highly weathered to saprolite. The weathered basalt is permeable to plant roots and water. The land surface is characterized by numerous intermittent drainageways in which soil material is generally deeper. These channels can be recognized by the narrow groves of kukui trees (*Aleurites moluccana*) which extend nearly to the crest of the ridges.

These slopes are characterized by 20–40% rock outcrops, soil slips and eroded areas. Soil avalanches are a dominant mass wasting process in this region. These have been correlated with specific rainfall events (Wentworth 1943) and vegetation types (Scott 1969). Soil avalanches may be transformed into mudflows and flow to the valley axis, becoming an important source of alluvial sediment (MacDonald *et al.* 1983).

Ridges of the Middle and Upper Valley

Narrow ridges border the North Halawa Valley in its middle and upper regions. The soil material on these ridges is similar to Inceptisols of the Amalu series, a Histic Placaquept, and the Oloku‘i series, a Typic Placaquept (Foote *et al.* 1972). Relative landscape stability and poor drainage on the ridge tops leads to the accumulation of a shallow mat of plant residue or peat-like material over a layer of massive clay or silty clay. The soil material is strongly acid and may be underlain by a thin iron stone sheet caused by the translocation of iron and aluminum sesquioxides. This iron stone sheet accounts, in part, for the poor drainage which is evident in the distinct mottling and gley colors of the overlying soil material. Highly weathered basalt residuum lies under the shallow soil material.

Conclusion

The soils of the North Halawa Valley show a wide range in characteristics. Five soil orders were documented in the region (Appendix). Soils formed in alluvium, colluvium and residuum retain features of the parent material. The drainage characteristics of the parent material are important in controlling soil development. The variation in precipitation in the valley leads to a more intense weathering environment in the middle and upper valley, and results in a general trend toward increasing soil acidity with increasing rainfall. Geomorphic processes in North Halawa Valley also affect the extent of soil development. Mass wasting and fluvial erosion/deposition processes result in limiting the time of soil formation. This accounts for the relatively young soils of the valley floor and side slopes, in comparison to the highly weathered soils of the more stable landscape of the ‘Aiea and Halawa facet regions.

Implications for Archaeological Research

Post-depositional Process

An understanding of soil properties is important in evaluating the post-depositional processes affecting an archaeological site. Chemical alteration of artifacts may be influenced by soil properties. For example, soil pH can effect the preservation of calcareous materials. In the very strongly acid (pH 4.5 to 5.0) soils of the upper valley, bones and other calcareous materials will be more easily dissolved. On the other hand, the neutral reaction (pH 6.6 to 7.3) of the Mollisols and Vertisols of the lower valley will favor the preservation of this type of artifact.

The physical properties of Vertisols, such as the Kaena and Kokahi soils, can have serious consequences for archaeological research. The self-mulching properties of these soils caused by the shrink-swell clays can disrupt the vertical arrangement of artifacts (Duffield 1970). This type of pedoturbation often results in the upward movement of artifacts to the soil surface (Johnson and Watson-Stegner 1990). Interpretation of stratigraphic context in these soils must be made with caution.

Detecting Archaeological Sites

Soil chemical analyses have been useful in the detection and interpretation of archaeological sites. In Hawaii, limited work has shown that chemical methods may be useful in distinguishing prehistoric agriculture soils from non-agricultural soils (Clark & Tamimi 1984). Morganstein (1977) analyzed soil samples at two archaeological sites in the North Halawa Valley in order to assess past vegetation and pre-historic agricultural practices. His methods included chemical analysis of phosphorous and organic matter in addition to paleobotanical examination. During the present sturdy, preliminary analysis at several archaeological sites suggests that organic carbon, extractable bases (calcium, magnesium, potassium, and sodium) and phosphorous are enriched in subsoil samples from various cultural features in comparison with control samples. However, the natural variability of soil chemical properties which was noted during this investigation may present a serious limitation for this method.

Table 2. Soil Orders of the North Halawa Valley.
(Adapted from McCall 1973, and Foote *et al*. 1972)

Order	Distinguishing Characteristic	Predominant Mineralogy	Location	Soil Series
Mollisols	Mineral soils that have soft surface horizon due to presence of organic matter; high base saturation	kaolinite, smectite, orders	floodplains and stream terraces	Kawaihapai
Vertisols	Soils high in shrink-swell clays, having large cracks for part of the year	Smectite, kaolinite	Low, nearly level areas	Kokokahi Kaena
Ultisols	Mineral soils that have an accumulation of silicate clays; low base saturation (less than 35%)	Kaolinite, oxides	Stable surfaces, but at edges of valleys where slopes become steep	Mahara
Oxisols	Mineral soils, highly weathered; relatively low in silicate clays	Free oxides of iron, aluminum, manganese and titanium	Smooth, gentle stable slopes	Lahaina
Inceptisols	Mineral soils with little profile development below surface horizon	Variable	Steep slopes, unstable landscapes	(See Note)

Note: The soils of the valley side slopes and ridge tops correspond to general criteria for the Inceptisol. However, soil series were not assigned to these areas which were classified as miscellaneous landtypes in earlier surveys. (Cline 1955, Foote *et al*. 1972)

CHAPTER 5
AN ASSESSMENT OF THE VEGETATION OF NORTH HALAWA VALLEY

Walter Appleby†, Clyde Imada, Heidi Lennstrom, & Barbara Hawley

Introduction

The flora of North Halawa Valley has been described in a very general way by Lamoureux (1971) but only the most important plants were mentioned and, because only common names were used, it is not always possible to determine what taxa were intended. Herbst *et al.* (1977) conducted a much more thorough and scientifically rigorous survey and evaluation of the valley's vegetation, but the sampling was not exhaustive, and many areas remained under-investigated. Also, significant disturbance related to highway construction has occurred since this last study and the introduction of new alien species during this time period would be likely. This study seeks to supplement and complement the past studies, and to evaluate the need for further studies or for monitoring areas of special botanical interest.

Methods

Vegetation surveys were conducted by Appleby, Imada, and Lennstrom at seven sites in North Halawa Valley during five field days from 9 December 1993 through 24 January 1994. Sites were chosen to include most of the vegetation types of Herbst *et al.* (1977); to span the study area; to include areas likely to be of particular botanical interest; and, when possible, to complement the studies of other biologists and archeologists from the Bishop Museum. At each site, comprehensive species lists for all vascular plants were generated, and unknown taxa were collected for further identification. Data were combined with those of Herbst *et al.* (1977) and data from the National Heritage Database of The Nature Conservancy (The Nature Conservancy 1994) to form a checklist (Table 3).

Vegetation types follow those of Herbst *et al.* (1977), except for the addition of loulu wetland. Taxonomy and nomenclature for flowering plants is based on Wagner *et al.* (1990), with a few exceptions resulting from more recent treatments. Gymnosperm nomenclature is based on Little and Skolmen (1989), and for ferns and fern allies, the treatment of Warren H. Wagner, Jr. (pers. comm.) is used.

Vegetation Types

The distribution of vegetation types in an area results from the complex interaction of a variety of factors including topography, edaphics, the physiological and reproductive characteristics of the plant taxa present, history, and chance effects associated with dispersal/colonization events. The topography of North Halawa Valley is varied and, as a consequence, microhabitats with differing environmental factors, such as rainfall amount, temperature, wind exposure, and flooding, are numerous. Edaphic factors, such as soil depth and drainage characteristics, interact with the topographic features to further diversify the microhabitats available to plants. The valley has a long history of anthropogenic disturbance beginning with the effects of Polynesian habitation and plant introductions, and continuing through the present with the effects of highway construction. The disturbance level is heightened by the activities of introduced animals, particularly feral pigs. The vegetation has been further impacted by the invasion of numerous alien plant taxa, some of which, in particular *Psidium guajava* (common guava) and *Schinus terebinthifolius* (Christmas berry), have become dominant components of the vegetation of most of the valley. Because of all of the above factors, vegetation types in North Halawa Valley are often not clearly definable or predictable entities. The following is a list with brief descriptions of the vegetation types used in this report.

Wasteland
Vegetation composed of weedy herbs and shrubs, most of which are alien. This vegetation type occurs in areas of high disturbance and the species found can vary between sites.

***Schinus* Forest**
Low stature forest dominated by the naturalized ornamental tree *Schinus terebinthifolius* (Christmas berry) and occurs mainly along the banks of the North Halawa Stream.

***Schinus* Scrubland**
This vegetation type is similar to Schinus Forest except the trees are smaller. This vegetation is common on the valley slopes where shallow soil and wind limit the stature of the trees. The scrubland and forest forms of *Schinus* vegetation represent the extremes of a continuum in *S. terebinthifolius* variation rather than distinct vegetation types, but were retained as distinct types to facilitate the adaptation of the vegetative map of Herbst *et al.* (1970) for the use of this report.

***Schinus-Syzygium* Forest**
This is found along the stream, especially toward the mouth of the valley, and is an association dominated by roughly equal numbers of *Schinus terebinthifolius* and *Syzygium cumini* (Java plum).

***Psidium* Forest**
This vegetation type is dominated by *Psidium guajava* (common guava) or *Psidium cattleianum* (strawberry guava) and occurs over much of the valley floor, often intergrading with kukui, koa, and ʻõhiʻa forests.

Kukui Forest
Forest dominated by the Polynesian introduction *Aleurites moluccana* (kukui); can be found in patches along the drainages of the valley and in gullies on the valley's slopes.

Planted Forest
This is a vegetation type resulting from the remains of arboricultural plantations of species such as *Eucalyptus robusta* (swamp mahogany), *Syncarpia glomulifera* (turpentine tree), and *Casuarina glauca* (saltmarsh ironwood).

***Andropogon* Grassland**
This vegetation type is dominated by *Andropogon virginicus* (broomsedge), an alien grass, and occurs as occasional patches in the valley.

Hau Thicket
This consists of dense stands of the arborescent shrub *Hibiscus tiliaceus* (hau). These impenetrable thickets are found as generally small patches along the stream and adjacent slopes.

Koa Forest
An open forest of moderate to high stature, fairly widely spaced *Acacia koa* (koa) with an understory dominated by the fern *Dicranopteris linearis* (uluhe). This type of vegetation generally occurs on slopes, especially slopes toward the rear of the valley. It has become more extensive in the years following the construction of the highway, likely due to scarification of seeds during construction.

ʻŌhi'a forest
This is another open forest type found in the more mesic areas in the back part of the valley. The dominant tree is *Metrosideros polymorpha* (ʻōhiʻa) and the understory is mainly *uluhe*.

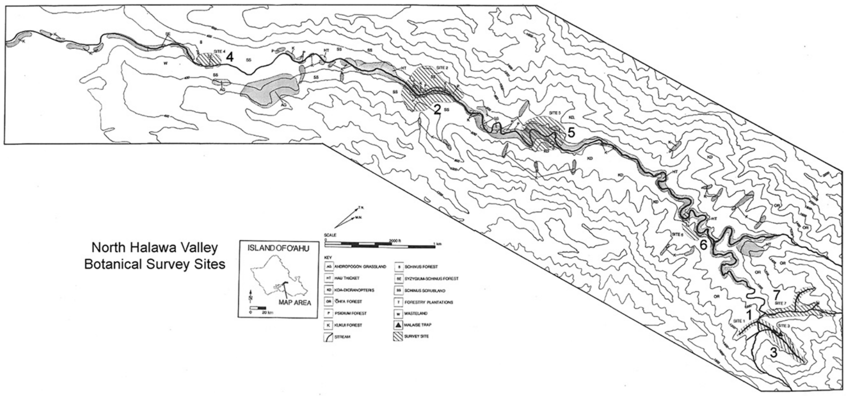

Fig. 6. Map of North Halawa Valley showing number botanical survey sites.

Loulu Wetland

This is a rare vegetation type consisting of populations of the palm *Pritchardia martii* (loulu). Two populations are known to occur in secondary drainages in the valley.

Site Descriptions

The following descriptions are of the sites surveyed for this study. For a complete list of the species found at these sites see Table 3. Data on numbers of endemic, indigenous, exotic, and Polynesian-introduced taxa are given in Table 4.

Site 1

Site 1 is an area near the construction headquarters buildings, and includes the lower slopes of the north-facing valley wall at the headquarters parking lot and along the unpaved road leading to the parking lot, and a secondary drainage that is accessible from this road. The steep slopes near the parking lot and road, and the slopes that form the drainage include two vegetation types, koa forest and ‘ōhi‘a forest. These vegetation types are often intermixed at this site. Kukui forest and *Psidium* forest occur along the bottom of the drainage, and, once again, these vegetation types often intergrade. Wasteland vegetation is found in areas adjacent to the road and parking lot.

On the steep slopes, the koa forest, dominated by *Acacia koa* (koa), and the ‘ōhi‘a forest, dominated by *Metrosideros polymorpha* (‘ōhi‘a), have a similar appearance, both consisting of widely spaced trees with a dense groundcover of the fern *Dicranopteris linearis* (uluhe). Other species that occur occasionally include the tree *Bobea elatior* (‘ahakea lau nui), the tree fern *Cibotium chamissoi* (hāpu’u pulu), and the woody climber *Freycinetia arborea* (‘ie‘ie). The groundcover is relatively uniform, but among the uluhe weedy annuals, such as *Bidens pilosa* (beggartick), occur at low frequencies.

The drainage bottom consists of a boulder-strewn main channel bordered by kukui forest and *Psidium* forest, both of which occur as fairly dense, closed-canopy forests. The *kukui* forest is dominated by *Aleurites moluccana* (*kukui*), while the *Psidium* forest is dominated by *Psidium guajava* (common guava), but the vegetation types intergrade. Other trees, including *Spathodea campanulata* (African tulip tree) and *Syzygium cumini* (Java plum), are distributed sporadically within both vegetation types. The most common shrub in the drainage area is the weedy *Clidemia hirta* var. *hirta* (Koster’s curse), and the dominant herbaceous species of the understory are *Oplismenus hirtellu*s (basketgrass) and various fern species, including *Nephrolepis exaltata* (common swordfern) and *Thelypteris dentata* (downy wood fern).

Wasteland vegetation is found in the highly disturbed areas adjacent to the parking lot and road and consists of an assortment of weedy species. Most of the species are herbaceous, including *Oplismenus hirtellus* (basketgrass), *Spathoglottis plicata* (Malayan ground orchid), and *Emilia fosbergii* (pualele), but occasional shrubs, such as *Rubus rosifolius* (thimbleberry), can also be found.

Site 2

Site 2 comprises an area on both sides of the North Halawa Stream and on both sides of the paved access road, and includes archeological site #85 on the north side of the road. The vegetation of the archeological site is kukui forest, which occurs as a dense, closed-canopy plant community along the relatively level valley floor and the associated south-facing slopes. Between the paved access road and the stream lies a highly disturbed area with vegetation of the wasteland and planted forest types. Finally, on the south side of the stream kukui forest and planted forest are the main vegetation types of the valley floor and the lower levels of the north-facing slopes, although some areas along the south side of the stream are *Psidium* forest.

The area that includes archeological site #85 is covered by *kukui* forest, and contains commonly cultivated Polynesian species, such as ti and ʻawapuhi. The dense kukui forest is dominated by *Aleurites moluccana* (*kukui*) and *Schefflera actinophylla* (umbrella tree). *Psidium guajava* (common guava) is also fairly common. *Mangifera indica* (mango) and *Roystonia regia* (royal palm) occur occasionally in this area. Common shrubs include *Cordyline fruticosa* (ti), *Clidemia hirta* var. *hirta* (Koster's curse), and *Rubus rosifolius* (thimbleberry). The herbaceous species include *Oplismenus hirtellus* (basketgrass), the fern *Phymatosorus scolopendria* (lauaʻe), and *Zingiber zerumbet* (ʻawapuhi).

Along the paved access road and to the south, between the road and North Halawa Stream, is an area that contains mainly wasteland vegetation composed of assorted herbaceous weeds, such as *Commelina diffusa* (honohono), *Emilia sonchifolia* (Flora's paintbrush), and *Chamaesyce hirta* (hairy spurge), and some weedy shrubs, such as *Pluchea indica* (indian fleabane). *Phaseolus vulgaris* (green bean) has recently been planted (planter unknown), but is doing poorly and will likely die before setting seed. Remnants of past cultivation include *Cucurbita pepo* (pumpkin) and *Dioscorea bulbifera* (hoi).

The wasteland area is bordered by planted forest composed mainly of three cultivated tree species, *Eucalyptus robusta* (swamp mahogany), *Syncarpia glomulifera* (turpentine tree), and *Casuarina glauca* (saltmarsh ironwood). The understory contains herbaceous species, such as the fern *Phymatosorus scolopendri*a (lauaʻe) and *Oplismenus hirtellus* (basketgrass). The planted forest continues on the south side of the stream, where it is bordered by kukui forest. This kukui forest area is similar to the kukui forest described above, but occasionally intergrades along the stream with *Psidium* forest dominated by *Psidium guajava* (common guava).

Site 3

Site 3 is located near the construction headquarters building and includes a section of North Halawa Stream and adjacent slopes. The vegetation is a composite of *Psidium* forest and ʻōhiʻa forest, but since *Psidium guajava* (common guava) is very common throughout the site, the vegetation type will be considered *Psidium* forest. Entomology has a malaise trap in this area.

The vegetation is dominated by *P. guajava* and *Metrosideros polymorpha* (ʻōhiʻa, although other trees, including *Hibiscus arnottianus* subsp. *arnottianus* (kokiʻo keʻokeʻo), *Spathodea campanulata* (African tulip tree), and *Bobea elatior* (ʻahakea lau nui), are common. The trees form a dense closed canopy, causing the understory to be deeply shaded. The most common shrub is *Clidemia hirta* var. *hirta* (Koster's curse) and it is abundant throughout the area. The climber *Freycinetia arborea* (ʻieʻie) is also very common, and the dominant herbaceous plants of the understory are *Oplismenus hirtellus* (basketgrass) and the fern *Thelypteris parasitica*. There are various native taxa at this site, including all growth forms, and one particularly significant species is the uncommon endemic *Gardenia mannii* (nanu).

Site 4

Site 4, just inland from Bridge #2 and on the northwest side of the paved access road, consists of a relatively flat, bulldozed area of approximately 0.5 ha and the surrounding *Schinus* forest. In this area, *Schinus* forest is the main vegetation type along the river banks and adjacent areas of the valley floor. As the vegetation extends up the steep slopes of the valley walls to the northwest, it becomes *Schinus* scrubland. The bulldozed area was surely *Schinus* forest before the disturbance, but now consists of wasteland vegetation. Judging by the dense cover of exotic herbaceous weeds and the lack of well developed woody plants, the area was bulldozed ca. one year before the current survey and then abandoned.

The *Schinus* forest vegetation is dominated by *Schinus terebinthifolius* (Christmas berry), which forms a dense, closed forest with occasional individuals of other tree species, such as *Psidium guava* (common guava), *Syzygium cumini* (Java plum), and *Aleurites moluccana* (kukui), scattered among the *Schinus*. Ground cover is dominated by herbs, especially *Phymatosorus scolopendria* (laua‘e), and *Oplismenus hirtellus* (basketgrass). Other species, such as the vines *Paederia scandens* (maile pilau) and *Momordica charantia* (bitter melon), occur as part of the *Schinus* forest vegetation, but primarily along the edge of the forest where it borders wasteland vegetation.

The wasteland vegetation is confined to the bulldozed area and along the sides of the paved access road and is dominated by grasses, such as *Panicum maximum* (Guinea grass) and *Setaria palmifolia* (palmgrass), and assorted other weedy herbs, such as *Emilia* spp. Immature individuals of shrub species, including *Lantana camara* (lantana) and *Indigofera suffruticosa* (indigo), occur especially along the interfaces with *Schinus* forest.

Site 5

Site 5 is an area on the north side of the paved access road that extends from bridge #5 to approximately 200 m past bridge #6. Most of the area is steeply sloped and impenetrable hau thicket is the main vegetation type on these slopes and along the banks of North Halawa Stream. *Psidium* forest occurs along the crest of one ridge that extends out from the south-facing valley wall, and *Andropogon* grassland occurs on top of a flat mesa that runs parallel to the road near bridge #6 (Site 2016 [B1-91]). A fourth vegetation type, wasteland vegetation, is found in the highly disturbed areas along the roadside.

Hau thicket is the most common vegetation type at Site 5, and is characterized by very dense stands of the arborescent shrub *Hibiscus tiliaceus* (hau). Hau thicket covers most of the slopes of the site as well as the flatter areas along the stream. The densest portions of the thicket are nearly pure stands of hau, but other species occur occasionally, especially along the stream and on the steepest slopes. Woody species include the trees *Syzygium cumini* (Java plum), *Metrosideros polymorpha* (‘ōhi‘a), and *Acacia koa* (koa), and the shrubs *Lantana camara* (lantana) and *Pluchea carolinensis* (sourbush). The vines *Paederia scandens* (maile pilau) and *Passiflora edulis* (liliko’i) are found in some areas along the thicket edges.

Psidium forest is found along one ridge crest and is bordered by hau thicket on the adjacent slopes. This *Psidium* forest is unusual in that the dominant species is *Psidium cattleianum* (yellow strawberry guava) rather than *P. guajava* (common guava). Other tree species, including *Acacia koa* (koa) and *Schefflera actinophylla* (umbrella tree) occur infrequently. The climber *Freycinetia arborea* ‘ie‘ie) is common in some areas. The densely shaded understory is sparsely vegetated with scattered ferns, such as *Dicranopteris linearis* (uluhe), and grasses, especially *Oplismenus hirtellus* (basketgrass).

A low alluvial terrace with a flat top of approximately 1.5 ha runs along the north side of the paved road near bridge #6. The northern and western edges of the mesa are bordered by North Halawa Stream. The vegetation on the top and sides of this mesa is *Andropogon* grassland dominated by the grass *Andropogon virginicus* (broomsedge). Other species are generally also herbaceous, such as *Arundina graminifolia* (bamboo orchid), *Sacciolepis indica* (Glenwood grass), and *Pityrogramma austroamericana* (gold fern), but some shrub species occur occasionally, especially along the stream and along the edge of the road where the broomsedge grassland borders wasteland vegetation, and include *Rubus rosifolius* (thimbleberry), *Buddleia asiatica* (dog tail), and *Pluchea carolinensis* (sourbush).

The final vegetation type at Site 5 is wasteland with scattered shrubs such as those just mentioned, and assorted herbaceous weeds. The herbaceous species include *Chloris radiata* (radiate fingergrass), *Commelina diffusa* (honohono), *Bidens pilosa* (beggartick), and *Mimosa pudica* var. *unijuga* (sensitive plant). This vegetation type is limited to areas adjacent to the road where disturbance has been heavy.

Site 6

Site 6 is a rocky secondary drainage and its associated slopes on the south side of the access road, approximately 0.96 km (0.6 miles) inland from bridge #9 (Site 2090 [B1-99]). The vegetation is mainly of the *Psidium* forest type, but some patches of koa forest occur on the steepest slopes. Remnants of Polynesian cultivation can be found along this drainage.

Most of the vegetation associated with this drainage is *Psidium* forest dominated by *Psidium guajava* (common guava). These trees, along with other tree species, form a dense canopy over the drainage. Other common tree species include *Spathodea campanulata* (African tulip tree) and *Aleurites moluccana* (kukui). The vegetation is dominated by aliens, but elements of native vegetation include the tree species *Hibiscus arnottianus* subsp. *arnottianus* (kokiʻo keʻokeʻo), *Syzygium sandwicensis* (ʻōhiʻa ha), and *Pittosporum glabrum* (hoʻawa). The weedy shrub *Clidemia hirta* var. *hirta* (Koster's curse) is common in the shaded understory. The herbaceous plants most common in the understory are *Oplismenus hirtellus* (basketgrass) and numerous fern species, many of which, including *Asplenium kaulfussii* (kuau), *Microlepia strigosa* (palai), and *Tectaria gaudichaudii* (ʻiwaʻiwa lau nui), are native. Remnants of Polynesian cultivation are common along the drainage, including *Colocasia esculenta* (taro), *Zingiber zerumbet* (ʻawapuhi), and *Piper methysticum* (ʻawa).

In areas where the slopes of the drainage are steepest, the *Psidium* forest is replaced by koa forest. This forest has a more open canopy than the *Psidium* forest and is dominated by *Acacia koa* (koa). Other common species include the tree *Bobea elatior* (ʻahakea lau nui) and the tree fern *Cibotium chamissoi* (hāpu'u pulu). The understory is dominated by the fern *Dicranopteris linearis* (uluhe).

Site 7

Site 7 is a rocky secondary drainage on the north side of the paved access road near Site 6. The main vegetation type is a closed canopy form of ʻōhi'a forest that covers most of the area along the banks of the drainage as well as the associated slopes. Along much of the drainage bottom, loulu wetland vegetation is common. Site 7, unlike Site 6, has few remnants of Polynesian cultivation.

The ʻōhiʻa forest is dominated by *Metrosideros polymorpha* (ʻōhiʻa) in association with *Aleurites moluccana* (kukui), *Acacia koa* (koa), *Psidium guajava* (common guava), and *Schefflera actinophylla* (umbrella tree). This forest is really a composite of four vegetation types, ʻōhiʻa forest, kukui forest, koa forest, and *Psidium* forest, but since ʻōhiʻa is the only dominant species found throughout the forest, it will be referred to as ʻōhiʻa forest. The trees form a dense canopy beneath which shrubs such as *Clidemia hirta* var. *hirta* (Koster's curse), *Rubus rosifolius* (thimbleberry), and *Lantana camara* (lantana) are common. The most common herbaceous species are *Oplismenus hirtellus* (basketgrass) and the fern *Dicranopteris linearis* (uluhe). Scattered elements of native vegetation include *Diospyros hillebrandii* (lama), *Cyrtandra cordifolia* (hahala), *Pipturus albidus* (mamaki), and various fern species.

Loulu wetland is found along the rocky drainage bottom, and is characterized by the presence of *Pritchardia martii* (loulu hiwa). There are more than fifty of these endemic palms along this drainage, and they constitute a significant population of this species. Loulu wetland is considered a “rare vegetation type” by TNC. Other than the presence of the palms, the vegetation in the loulu wetland is the same as that of the ‘ōhi‘a forest described above.

Analysis and Discussion

While it is generally accepted that no floristic study is ever truly complete (Moran, 1992), a floristic inventory can not be considered even close to completion until there is a significant decrease in the rate of new taxa discovered for further field time expended. The results of this study indicate that much more floristic work is needed in North Halawa Valley. Of the 194 taxa identified during the course of this study, 64 had not been reported in the study of Herbst *et al.* (1977), and previously undocumented taxa continued to be discovered throughout the course of the study. Some of these species have probably been introduced since the 1977 study, but 24 additional native species were found, indicating that more survey work is needed before the flora of North Halawa Valley can be considered well known.

The valley will continue to be subjected to construction-related disturbance, and the effects of vehicular traffic on the environment once construction is completed may further affect the vegetation. Effects to plants may be indirect. For instance, feral pigs, whose deleterious effects on native vegetation are well known (e.g. Stone 1989; Stone *et al.* 1992), may change their areas of activity due to construction activity or subsequent traffic, and move into previously undisturbed areas. Environmental monitoring is needed to provide information to ensure the survival of sensitive taxa in the valley.

Further monitoring would also be desirable because the vegetation of the valley is undergoing major changes in community composition and dominance/diversity relations due to the spread of alien species, especially *Psidium guajava*. Most of the vegetation types in the valley are alien-dominated associations. Exceptions are hau thicket, loulu wetland, koa forest, and ‘ōhi’a forest. Hau thicket is dense enough to resist alien invasion and loulu wetland is probably more sensitive to the effects of feral pigs and Norwegian rats (Hodel 1980) than to effects of alien plant species, but koa and ‘ohi’a forests are in the process of being replaced by *Psidium* forest. The changes in vegetation composition can lead to secondary changes, such as changes in the distribution and activity of feral pigs, which can lead to further effects on the vegetation of the valley.

Site 7 is an area of particular botanical interest and a prime candidate for further study and monitoring. Loulu wetland has become uncommon and Site 7 has one of the largest populations of *Pritchardia martii* (loulu hiwa) on O‘ahu. Feral pig activity was obvious at this site, but their presence may be only recent. Feral pigs are known to have a negative effect on *Pritchardia* regeneration (Hodel 1980), and no plants appear to have germinated recently. Further studies at this site would be required to determine the impact of feral pigs on the *Pritchardia* population, and monitoring is needed to ensure the continued existence of this population.

Site 7 also serves as an illustration of why extensive walk-through surveys are needed in a topographically complex area such as North Halawa Valley. Based on the surveys of topographically similar drainages at Sites 1, 3, and 6, the existence of the *Pritchardia* population would not have been predicted. Also, the presence of *P. martii* is not observable from the access road and would probably not be discernible even during a helicopter survey because the palms are mainly found in the shade of the closed-canopy ‘ōhi’a forest. The walk-through survey was the only method by which the palms could have been discovered.

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu.

	Occurrence on inventory lists				Occurrence on BISH survey sites						
Scientific name	**Status**	**Herbst**	**TNC**	**BISH**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
PTERIDOPHYTES											
Aspleniaceae											
Asplenium contiguum Kaulf.	E	Y	N	N							
Asplenium horridum Kaulf.	I	N	N	Y	1						
Asplenium kaulfussii Schlechtend.	E	N	N	Y	1		3			6	7
Asplenium lobulatum Mett.	I	N	N	Y			3			6	7
Asplenium nidus L.	I	Y	N	Y	1		3			6	7
Asplenium unilaterale Lam.	I	N	N	Y							7
Diellia falcata Brack.	E	N	Y	N							
Blechnaceae											
Blechnum occidentale L.	X	Y	N	Y	1	2	3			6	7
Sadleria cyatheoides Kaulf.	E	Y	N	N							
Cyatheaceae											
Cibotium chamissoi Kaulf.	E	Y	N	Y	1		3		5	6	7
Cibotium menziesii Hook.	E	Y	N	N							
Dennstaedtiaceae											
Microlepia speluncae (L.) T. Moore	I	N	N	Y						6	
Microlepia strigosa (Thunb.) Presl	I	Y	N	Y	1					6	7
Pteridium decompositum Gaud.	E	Y	N	N							
Dryopteridaceae											
Ctenitis honolulensis (Hook.) Copel.	E	N	N	Y			3				7
Deparia marginalis (Hillebr.) M. Kato	E	Y	N	N							
Deparia petersenii (Kunze) M. Kato	X	N	N	Y	1		3			6	7
Deparia prolifera (Kaulf.) Hook. & Grev.	E	Y	N	N	1		3				7
Diplazium sandwichianum (Presl) Diels	E	N	N	Y							7
Elaphoglossum crassifolium (Gaud.) Anderson & Crosby	E	Y	N	Y	1		3			6	7
Nephrolepis cordifolia (L.) Presl	I	N	N	Y	1		3				7
Nephrolepis exaltata (L.) Schott	I	Y	N	Y	1		3			6	7
Nephrolepis multiflora (Roxb.) Jarrett ex Morton	X	N	N	Y	1	2			5	6	7
Tectaria gaudichaudii Brack.	E	N	N	Y	1		3			6	7
Gleicheniaceae											
Dicranopteris linearis (N. L. Burm.) Underw.	I	Y	N	Y	1		3		5	6	7
Diplopterygium pinnatum (Kunze) Nakai	I	Y	N	N							
Grammitidaceae											
Adenophorus abietinus (D. C. Eaton) K. A. Wilson	E	Y	N	N							
Adenophorus haalilioanus (Brack.) K. A. Wilson	E	Y	N	Y							7
Adenophorus hymenophylloides (Kaulf.) Hook. & Grev.	E	N	N	Y							7
Adenophorus pinnatifidus Gaud.	E	Y	N	Y			3				7
Adenophorus tamariscinus (Kaulf.) Hook. & Grev.	E	Y	N	Y	1					6	7
Adenophorus tripinnatifidus Gaud.	E	Y	N	N							
Grammitis tenella Kaulf.	E	Y	N	Y	1		3			6	7
Hymenophyllaceae											
Gonocormus minutus (Bl.) van den Bosch	I	N	N	Y			3			6	7
Mecodium recurvum (Gaud.) Copel.	E	Y	N	Y			3				7
Sphaerocionium obtusum (Hook. & Arnott) Copel.	E	N	N	Y			3				7
Vandenboschia cyrtotheca (Hillebr.) Copel.	E	Y	N	Y	1		3			6	7
Vandenboschia davallioides (Gaud.) Copel.	E	N	N	Y			3			6	7

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu (continued).

	Occurrence on inventory lists				Occurrence on BISH survey sites						
Scientific name	Status	Herbst	TNC	BISH	1	2	3	4	5	6	7
Lindsaeaceae											
Lindsaea repens (Bory) Thwaites var. macraeana (Hook. & Arnott) Mett. & Kuhn	E	N	Y	N							
Odontosoria chinensis (L.) J. Sm.	I	Y	N	Y	1		3		5	6	7
Lycopodiaceae											
Palhinhaea cernua (L.) Franco & Carv. Vasc.	I	Y	N	Y					5		
Phlegmariurus phyllanthus (Hook. & Arnott) Dixit	I	Y	N	Y	1					6	7
Marattiaceae											
Angiopteris evecta (G. Forster) Hoffm.	X	N	N	Y						6	
Ophioglossaceae											
Ophioderma pendula (L.) Presl	I	Y	N	Y	1		3		5	6	7
Polypodiaceae											
Lepisorus thunbergianus (Kaulf.) Ching	I	Y	N	Y	1		3			6	7
Phlebodium aureum (L.) J. Sm.	X	Y	N	Y	1	2	3		5	6	7
Phymatosorus scolopendria (N. L. Burm.) Pichi-Serm.	X	Y	N	Y		2		4			
Psilotaceae											
Psilotum nudum (L.) Beauv.	I	Y	N	Y					5	6	7
Pteridaceae											
Adiantum capillus-veneris L.	I	Y	N	N							
Adiantum raddianum Presl	X	N	N	Y	1		3			6	7
Pellaea viridis (Forssk.) Prantl	X	Y	N	N							
Pityrogramma austroamericana Domin	X	N	N	Y					5	6	
Pityrogramma calomelanos (L.) Link	X	Y	N	Y					5		
Schizaeaceae											
Schizaea robusta Baker	E	Y	N	N							
Selaginellaceae											
Selaginella arbuscula (Kaulf.) Spring	E	Y	N	Y			3				7
Thelypteridaceae											
Thelypteris cyatheoides (Kaulf.) Fosb.	E	Y	N	Y			3				7
Thelypteris dentata (Forssk.) E. St. John	X	Y	N	Y	1	2				6	7
Thelypteris parasitica (L.) Fosberg	X	N	N	Y	1	2	3			6	7
Thelypteris sandwicensis (Brack.) Fosb.	E	N	N	Y							7
Thelypteris sp.	E	Y	N	N							
Vittariaceae											
Vittaria elongata Sw.	I	Y	N	Y						6	7
GYMNOSPERMS											
Araucariaceae											
Araucaria heterophylla (Salisb.) Franco	X	Y	N	N							
Taxodiaceae											
Cryptomeria japonica (L. f.) D. Don	X	N	N	Y		2					
MONOCOTS											
Agavaceae											
Cordyline fruticosa (L.) A. Chev.	P	Y	N	Y		2	3		5	6	7
Pleomele halapepe St. John	E	Y	N	N							
Araceae											
Colocasia esculenta (L.) Schott	P	Y	N	Y						6	
Arecaceae											
Archontophoenix sp.	X	Y	N	N							
Orbignya cohune (Mart.) Dahlgren ex Standl.	X	Y	N	N							
Phoenix dactylifera L.	X	Y	N	N							
Pritchardia martii (Gaud.) H. A. Wendl.	E	Y	Y	Y						6	7
Roystonea regia (Kunth) O. F. Cook	X	Y	N	Y		2			5		

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu (continued).

	Occurrence on inventory lists				Occurrence on BISH survey sites						
Scientific name	Status	Herbst	TNC	BISH	1	2	3	4	5	6	7
Commelinaceae											
Commelina diffusa N. L. Burm.	X	Y	N	Y		2		4	5	6	
Cyperaceae											
Carex wahuensis C. A. Mey.	E	Y	N	N							
Cyperus rotundus L.	X	Y	N	N							
Fimbristylis dichotoma (L.) Vahl	I	Y	N	Y		2					
Gahnia aspera Spreng. subsp. globosa (H. Mann) J. Kern	I	Y	N	N							
Gahnia beecheyi H. Mann	E	Y	N	N							
Kyllinga brevifolia Rottb.	X	Y	N	N							
Machaerina angustifolia (Gaud.) T. Koyama	I	Y	N	N							7
Machaerina mariscoides (Gaud.) J. Kern subsp. meyenii (Kunth) T. Koyama	E	Y	N	Y	1						
Pycreus polystachyos (Rottb.) P. Beauv. subsp. polystachyos	I	N	N	Y		2					
Rhynchospora rugosa (Vahl) Gale subsp. lavarum (Gaud.) T. Koyama	I	Y	N	N							
Rhynchospora sclerioides Hook. & Arnott	I	Y	N	N							
Dioscoreaceae											
Dioscorea bulbifera L.	P	Y	N	Y		2			5		
Dioscorea pentaphylla L.	P	Y	N	Y						6	
Joinvilleaceae											
Joinvillea ascendens Gaud. ex Brongn. & Gris var. ascendens	E	N	Y	N							
Liliaceae											
Dianella sandwicensis Hook. & Arnott	I	Y	N	N							
Musaceae											
Musa ×paradisiaca L.	P	Y	N	N							
Orchidaceae											
Arundina graminifolia (D. Don) Hochr.	X	N	N	Y					5		7
Phaius tankarvilleae (Banks ex L'Her.) Blume	X	N	N	Y			3				7
Spathoglottis plicata Blume	X	Y	N	Y	1	2	3		5	6	7
Vanda sp.	X	N	N	Y							
Pandanaceae											
Freycinetia arborea Gaud.	I	Y	N	Y	1		3		5	6	7
Pandanus tectorius S. Parkinson ex Z	I	Y	N	N							
Poaceae											
Andropogon virginicus L.	X	Y	N	Y					5		
Axonopus fissifolius (Raddi) Kuhlm.	X	Y	N	N							
Brachiaria mutica (Forssk.) Stapf	X	Y	N	N							
Cenchrus ciliaris L.	X	Y	N	N							
Cenchrus echinatus L.	X	Y	N	Y	1						
Chloris barbata (L.) Sw.	X	Y	N	Y		2					
Chloris radiata (L.) Sw.	X	Y	N	Y		2		4	5		
Chloris virgata Sw.	X	Y	N	N							
Chrysopogon aciculatus (Retz.) Trin.	X	Y	N	N							
Coix lachryma-jobi L.	X	Y	N	N							
Cynodon dactylon (L.) Pers.	X	Y	N	Y				4			
Digitaria ciliaris (Retz.) Koeler	X	Y	N	N							
Digitaria insularis (L.) Mez ex Ekman	X	Y	N	Y				4			
Digitaria setigera Roth	X	Y	N	N							
Echinochloa colona (L.) Link	X	Y	N	N							
Echinochloa crus-galli (L.) P. Beauv.	X	Y	N	N							
Eleusine indica (L.) Gaertn.	X	Y	N	Y		2		4			
Eragrostis pectinacea (Michx.) Nees	X	Y	N	N							
Eragrostis tenella (L.) P. Beauv. ex Roem. & Schult.	X	N	N	Y		2					

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu (continued).

Scientific name	Occurrence on inventory lists				Occurrence on BISH survey sites						
	Status	Herbst	TNC	BISH	1	2	3	4	5	6	7
Poaceae (continued)											
Eragrostis variabilis (Gaud.) Steud.	E	Y	N	N							
Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult.	I	Y	N	N							
Isachne pallens Hillebr.	E	N	N	Y							7
Melinis minutiflora P. Beauv.	X	Y	N	N							-
Oplismenus hirtellus (L.) P. Beauv.	X	Y	N	Y	1	2	3	4	5	6	7
Panicum maximum Jacq.	X	Y	N	Y				4	5		
Paspalum conjugatum Bergius	X	Y	N	Y		2		4	5		7
Paspalum dilatatum Poir.	X	Y	N	N							
Paspalum scrobiculatum L.	I	Y	N	Y					5		
Pennisetum clandestinum Chiov.	X	Y	N	N							
Rhynchelytrum repens (Willd.) Hubb.	X	Y	N	Y	1				5		
Sacciolepis indica (L.) Chase	X	Y	N	Y					5	6	7
Schizostachyum glaucifolium (Rupr.) Munro	P	Y	N	N							
Setaria gracilis Kunth	X	Y	N	Y					5		7
Setaria palmifolia (J. Konig) Stapf	X	Y	N	Y		2		4			
Setaria verticillata (L.) P. Beauv.	X	Y	N	N							
Sorghum halpense (L.) Pers.	X	Y	N	Y				4			
Sporobolus diander (Retz.) P. Beauv.	X	Y	N	N							
Smilacaceae											
Smilax melastomifolia Sm.	E	Y	N	N							
Zingiberaceae											
Zingiber zerumbet (L.) Sm.	P	Y	N	Y		2				6	
DICOTS											
Acanthaceae											
Asystasia gantetica (L.) T. Anderson	X	Y	N	N							
Ruellia graecizans Backer	X	Y	N	N							
Aizoaceae											
Aptenia cordifolia (L.) N. E. Br.	X	N	N	Y							
Amaranthaceae											
Amaranthus cf. dubius Mart. ex Thell.	X	N	N	Y	1			4			
Amaranthus spinosus L.	X	Y	N	Y				4			
Amaranthus viridis L.	X	Y	N	N							
Charpentiera ovata Gaud.	E	N	N	Y						6	
Charpentiera sp.	E	Y	N	N							
Anacardiaceae											
Mangifera indica L.	X	Y	N	Y		2		4	5		7
Schinus terebinthifolius Raddi	X	Y	N	Y	1	2		4	5		
Apiaceae											
Centella asiatica (L.) Urb.	X	Y	N	N							
Sanicula purpurea St. John & Hosaka	E	N	Y	N							
Apocynaceae											
Alyxia oliviformis Gaud.	E	Y	N	Y							7
Rauvolfia sandwicensis A. DC	E	Y	N	N							
Aquifoliaceae											
Ilex anomala Hook. & Arnott	I	Y	N	N							
Araliaceae											
Cheirodendron trigynum (Gaud.) A. Heller	E	Y	N	N							
Schefflera actinophylla (Endl.) Harms	X	Y	N	Y		2			5		7
Tetraplasandra gymnocarpa (Hillebr.) Sherff	E	N	Y	N							
Tetraplasandra sp.	E	Y	N	N							
Asteraceae											
Acanthospermum australe (Loefl.) Kuntze	X	Y	N	N							
Adenostemma lavenia (L.) Kuntze	I	N	N	Y						6	

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu (continued).

	Occurrence on inventory lists				Occurrence on BISH survey sites						
Scientific name	**Status**	**Herbst**	**TNC**	**BISH**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Asteraceae (continued).											
Ageratina adenophora (Spreng.) R. King & H. Robinson	X	N	N	Y	1				5		
Ageratina riparia (Regel) R. King & H. Robinson	X	Y	N	Y	1	2	3		5	6	7
Ageratum conyzoides L.	X	Y	N	Y		2		4	5		7
Bidens alba (L.) DC var. radiata (Schultz-Bip.) Ballard ex Melchert	X	N	N	Y	1			4	5		
Bidens macrocarpa (A. Gray) Sherff	E	Y	N	N							
Bidens pilosa L.	X	Y	N	Y	1			4	5		
Bidens sandvicensis Less. subsp. sandvicensis	E	N	N	Y							7
Conyza bonariensis (L.) Cronq.	X	N	N	Y					5		7
Conyza canadensis (L.) Cronq.	X	Y	N	N							
Crassocephalum crepidioides (Benth.) S. Moore	X	N	N	Y		2		4	5		
Dubautia laxa Hook. & Arnott	E	Y	N	N							
Eclipta alba (L.) Hassk.	X	Y	N	N							
Emilia fosbergii Nicolson	X	N	N	Y	1	2		4	5		
Emilia sonchifolia (L.) DC	X	Y	N	Y	1	2		4	5	6	
Erechtites hieracifolia (L.) Raf.	X	Y	N	N							
Erechtites valerianifolia (Wolf) DC	X	N	N	Y	1		3			6	7
Erigeron karvinskianus DC	X	N	N	Y							7
Hesperomannia arborescens A. Gray	E	N	Y	N							
Pluchea carolinensis (Jacq.) G. Don	X	Y	N	Y	1	2		4	5	6	7
Pluchea ×fosbergii Cooperr. & Galang	X	N	N	Y					5		
Pluchea indica (L.) Less.	X	Y	N	Y	1	2			5		
Sonchus oleraceus L.	X	Y	N	Y		2			5		
Tridax procumbens L.	X	Y	N	N							
Verbesina encelioides (Cav.) Benth. & Hook.	X	Y	N	N							
Vernonia cinerea (L.) Less. var. parviflora (Reinw.) DC	X	Y	N	Y		2		4		6	
Wedelia trilobata (L.) Hitchc.	X	Y	N	N							
Xanthium strumarium L. var. canadense (Mill.) Torr. & A. Gray	X	Y	N	N							
Youngia japonica (L.) DC	X	N	N	Y		2	3		5	6	7
Bignoniaceae											
Spathodea campanulata P. Beauv.	X	Y	N	Y	1		3			6	7
Brassicaceae											
Lepidium virginicum L.	X	Y	N	N							
Buddleiaceae											
Buddleia asiatica Lour.	X	Y	N	Y	1	2			5	6	7
Cactaceae											
Opuntia ficus-indica (L.) Mill.	X	Y	N	N							
Campanulaceae											
Clermontia kakeana Meyen	E	Y	N	N							
Clermontia oblongifolia Gaud.	E	Y	N	N							
Cyanea angustifolia (Cham.) Hillebr.	E	Y	N	N							
Lobelia hypoleuca Hillebr.	E	N	Y	N							
Lobelia oahuensis Rock	E	N	Y	N							
Rollandia st.-johnii Hosaka	E	N	Y	N							
Trematolobelia singularis St. John	E	N	Y	N							
Cannabaceae											
Cannabis sativa L. subsp. indica (Lam.) E. Small & Cronq.	X	Y	N	N							
Caricaceae											
Carica papaya L.	X	Y	N	Y				4			

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu (continued).

	Occurrence on inventory lists				Occurrence on BISH survey sites						
Scientific name	Status	Herbst	TNC	BISH	1	2	3	4	5	6	7
Caryophyllaceae											
Drymaria cordata Willd. ex Roem. & Schult. var. pacifica Mizush.	X	Y	N	N							
Casuarinaceae											
Casuarina equisetifolia L.	X	Y	N	N							
Casuarina glauca Siebold ex Spreng.	X	N	N	Y		2					
Celastraceae											
Perrottetia sandwicensis A. Gray	E	Y	N	N							
Convolvulaceae											
Ipomoea alba L.	X	Y	N	N							
Ipomoea cairica (L.) Sweet	X	Y	N	N							
Ipomoea indica (J. Burm.) Merr.	I	Y	N	N							
Ipomoea obscura (L.) Ker-Gawl.	X	Y	N	Y		2		4			
Ipomoea triloba L.	X	Y	N	Y		2		4	5		
Merremia aegyptia (L.) Urb.	X	Y	N	N							
Merremia tuberosa (L.) Rendle	X	Y	N	N							
Crassulaceae											
Kalanchoe pinnata (Lam.) Pers.	X	Y	N	N							
Cucurbitaceae											
Coccinia grandis (L.) Voigt	X	N	N	Y				4			
Cucurbita pepo L.	X	N	N	Y		2					
Momordica charantia L.	X	Y	N	Y				4			
Ebenaceae											
Diospyros hillebrandii (Seem.) Fosb.	E	Y	N	Y	1		3				7
Diospyros sandwicensis (A. DC) Fosb.	E	Y	N	Y		2			5		7
Elaeocarpaceae											
Elaeocarpus bifidus Hook. & Arnott	E	Y	N	N							
Epacridaceae											
Styphelia tameiameiae (Cham. & Schlecht.) F. v. Muell.	I	Y	N	N							
Euphorbiaceae											
Aleurites moluccana (L.) Willd.	P	Y	N	Y	1	2		4	5	6	7
Antidesma platyphyllum H. Mann var. platyphyllum	E	Y	N	Y	1		3				7
Chamaesyce celastroides (Boiss.) Croizat & Degener var. amplectens (Sherff) Degener & I. Degener	E	Y	N	N							
Chamaesyce hirta (L.) Millsp.	X	Y	N	Y		2		4			
Chamaesyce hypericifolia (L.) Millsp.	X	Y	N	Y		2			5		
Chamaesyce prostrata (Aiton) Small	X	Y	N	N							
Euphorbia heterophylla L.	X	Y	N	N							
Euphorbia tirucalli L.	X	Y	N	N							
Manihot esculenta Crantz	X	Y	N	N							
Phyllanthus debilis Klein ex Willd.	X	Y	N	Y		2		4	5		
Phyllanthus distichus Hook. & Arnott	E	Y	N	N							
Ricinus communis L.	X	Y	N	N							
Fabaceae											
Acacia farnesiana (L.) Willd.	X	Y	N	N							
Acacia koa A. Gray	E	Y	N	Y	1		3		5	6	7
Adenanthera sp.	X	Y	N	N							
Albizia sp.	X	Y	N	N							
Alysicarpus vaginalis (L.) DC	X	Y	N	N							
Caesalpinia decapetala (Roth) Alston	X	N	N	Y		2					
Chamaecrista nictitans (L.) Moench subsp. patellaria (DC ex Collad.) H. Irwin & Barneby	X	Y	N	Y		2		4	5		
Crotalaria incana L.	X	Y	N	N							
Crotalaria pallida Aiton	X	Y	N	Y				4			
Crotalaria retusa L.	X	Y	N	N							
Desmanthus virgatus (L.) Willd.	X	Y	N	Y		2		4	5		

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu (continued).

	Occurrence on inventory lists				Occurrence on BISH survey sites						
Scientific name	Status	Herbst	TNC	BISH	1	2	3	4	5	6	7
Fabaceae (continued).											
Desmodium incanum DC	X	N	N	Y				4	5		
Desmodium sandwicense E. Mey.	X	Y	N	N							
Desmodium tortuosum (Sw.) DC	X	Y	N	Y		2		4	5		
Desmodium triflorum (L.) DC	X	Y	N	Y		2			5		
Indigofera suffruticosa Mill.	X	Y	N	Y				4			
Leucaena leucocephala (Lam.) de Wit	X	Y	N	Y				4	5		
Macroptilium lathyroides (L.) Urb.	X	Y	N	Y		2			5		
Mimosa pudica L. var. unijuga (Duchass. & Walp.) Griseb.	X	Y	N	Y		2		4	5		
Phaseolus vulgaris L.	X	N	N	Y		2					
Pithecellobium dulce (Roxb.) Benth.	X	Y	N	N							
Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth	X	Y	N	N							
Samanea saman (Jacq.) Merr.	X	Y	N	N							
Senna occidentalis (L.) Link	X	N	N	Y				4			
Senna perioula (Humb. & Bonpl. ex Willd.) H. Irwin & Barneby var. advena (Vogel) H. Irwin & Barneby	X	Y	N	Y				4			
Senna surattensis (N. L. Burm.) H. Irwin & Barneby	X	Y	N	N							
Flacourtiaceae											
Xylosma hawaiiense Seem.	E	Y	N	N							
Gesneriaceae											
Cyrtandra cordifolia Gaud.	E	N	N	Y	1		3				7
Cyrtandra grandiflora Gaud.	E	N	N	Y	1		3			6	
Cyrtandra cf. hawaiiensis C. B. Clarke	E	N	N	Y			3				
Cyrtandra pruinosa St. John & Storey	E	N	Y	N							
Cyrtandra waiolani Wawra	E	N	Y	N							
Cyrtandra sp.	E	Y	N	Y							7
Goodeniaceae											
Scaevola ×cerasifolia Skottsb.	E	Y	N	N							
Scaevola gaud1chaudiana Hook. & Arnott	E	Y	N	N							
Scaevola mollis Hook. & Arnott	E	Y	N	N							
Hydrangeacaeae											
Broussaisia arguta Gaud.	E	Y	N	Y			3				
Lamiaceae											
Hyptis pectinata (L.) Po1t.	X	Y	N	Y		2		4	5		
Leonotis nepetifolia (L.) R. Br.	X	Y	N	N							
Phyllostegia hirsuta Benth.	E	N	Y	N							
Salvia coccinea Juss. ex J. A. Murray	X	N	N	Y							7
Lythraceae											
Cuphea carthagenensis (Jacq.) Macbr.	X	Y	N	Y		2					
Lythrum maritimum Kunth	I	N	N	Y							7
Malvaceae											
Abutilon grandifolium (Willd.) sweet	X	Y	N	N							
Abutilon incanum (Link) Sweet	I	Y	N	N							
Hibiscus arnottianus A. Gray subsp. arnottianus	E	Y	N	Y			3			6	7
Hibiscus tiliaceus L.	I	Y	N	Y		2		4	5	6	7
Malvastrum coromandelianum (L.) Garcke	X	Y	N	Y							
Sida fallax Walp.	I	Y	N	Y				4			
Sida rhombifolia L.	X	Y	N	Y				4			
Sida spinosa L.	X	Y	N	Y				4			
Melastomaceae											
Clidemia hirta (L.) D. Don var. hi	X	Y	N	Y	1	2	3		5	6	7
Pterolepis glomerata (Rottb.) Miq.	X	N	N	Y							

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu (continued).

	Occurrence on inventory lists				Occurrence on BISH survey sites						
Scientific name	Status	Herbst	TNC	BISH	1	2	3	4	5	6	7
Meliaceae											
Toona ciliata M. Roem. var. australis (F. v. Muell.) C. DC	X	Y	N	N							
Menispermaceae											
Cocculus trilobus (Thunb.) DC	I	Y	N	N							
Moraceae											
Artocarpus altilis (Parkinson ex Z) Fosb.	P	Y	N	N							
Artocarpus heterophyllus Lam.	X	Y	N	N							
Ficus microcarpa L. fil.	X	Y	N	N							
Myrsinaceae											
Myrsine fosbergii Hosaka	N	N	Y	N							
Myrsine lessertiana A. DC	E	Y	N	N							
Myrtaceae											
Eucalyptus deglupta Bl.	X	Y	N	N							
Eucalyptus robusta Sm.	X	N	N	Y		2					
Lophostemon confertus (R. Br.) Peter U. Wilson & Waterhouse	X	Y	N	Y		2					
Melaleuca quiquenervia (Cav.) S. T. Blake	X	Y	N	N							
Metrosideros polymorpha Gaud.	E	Y	N	Y	1	2	3		5	7	
Metrosideros tremuloides (A. Heller) P. Knuth	E	Y	n	N							
Psidium cattleianum Sabine forma cattleianum	X	Y	N	N							
Psidium cattleianum Sabine forma lucidum Degener	X	Y	N	Y					5		
Psidium guajava L.	X	Y	N	Y	1	2	3	4	5	6	7
Syncarpia glomulifera (Sm.) Niedenzu	X	Y	N	Y		2					
Syzygium cumini (L.) Skeels	X	Y	N	Y	1	2		4	5		
Syzygium jambos (L.) Alston	X	Y	N	N							
Syzygium malaccense (L.) Merr. & Perry	P	Y	N	Y		2				6	7
Syzygium sandwicensis (A. Gray) Nied.	E	Y	N	Y	1	3				6	7
Nyctaginaceae											
Pisonia umbellifera (G. Forster) Seem.	I	Y	N	Y						6	7
Oleaceae											
Fraxinus uhdei (Wenzig) Lingelsh.	X	Y	N	N							
Nestegis sandwicensis (A. Gray) Degener, I. Degener & L. Johns	E	Y	N	N							
Onagraceae											
Ludwigia octovalvis (Jacq.) Raven	P	Y	N	N							
Oxalidaceae											
Oxalis corniculata L.	P	Y	N	N							
Passifloraceae											
Passiflora edulis Sims	X	Y	N	Y		2		4	5		
Passiflora foetida L.	X	Y	N	Y				4			
Passiflora suberosa L.	X	Y	N	N							
Phytolaccaceae											
Rivina humilis L.	X	N	N	Y		2					
Piperaceae											
Peperomia ellipticibacca C. DC	E	Y	N	N							
Peperomia membranacea Hook. & Arnott	E	Y	N	Y			3			6	
Peperomia tetraphylla (G. .Forster) Hook. & Arnott	I	Y	N	Y			3				7
Piper methysticum G. Forster	P	N	N	Y						6	
Pittosporaceae											
Pittosporum glabrum Hook. & Arnott	E	Y	N	Y							
Polygonaceae											
Antigonon leptopus Hook. & Arnott	X	Y	N	N							

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu (continued).

	Occurrence on inventory lists				Occurrence on BISH survey sites						
Scientific name	Status	Herbst	TNC	BISH	1	2	3	4	5	6	7
Portulacaceae											
Portulaca oleracea L.	X	Y	N	N							
Proteaceae											
Grevillea robusta A. Cunn. ex R. Br.	X	Y	N	Y		2					
Rosaceae											
Osteomeles anthyllidifolia (Sm.) Lindl.	I	Y	N	N							
Rubus rosifolius Sm.	X	Y	N	Y	1	2	3		5	6	7
Rubiaceae											
Bobea elatior Gaud.	E	Y	N	Y	1		3			6	7
Coffea arabica L.	X	Y	N	N							
Coprosma longifolia A. Gray	E	Y	N	N							
Gardenia mannii St. John & Kuykendall	E	Y	Y	Y			3				
Hedyotis terminalis (Hook. & Arnott) W. L. Wagner & Herbst	E	Y	N	Y	1					6	
Paederia scandens (Lour.) Merr.	X	Y	N	Y		2		4		6	7
Psychotria kaduana (Cham. & Schlechtend.) Fosb.	E	Y	N	Y			3				7
Psychotria mariniana (Cham. & Schlechtend.) Fosb.	E	N	N	Y							7
Psydrax odorata (G. Forst.) A. C. Sm. & S. Darwin	I	Y	N	N							
Spermacoce sp.	X	N	N	Y					5		
Rutaceae											
Citrus ×limonia Osbeck	X	Y	N	N							
Citrus sp.	X	N	N	Y		2					
Melicope sp.	E	Y	N	N							
Zanthoxylum oahuense Hillebr.	E	N	Y	N							
Santalaceae											
Exocarpos gaudichaudii. A. DC	E	N	Y	N							
Santalum freycinetianum Gaud.	E	Y	N	N							
Sapindaceae											
Dodonaea viscosa Jacq.	I	Y	N	N							
Sapotaceae											
Pouteria sandwicensis (A. Gray) Baehni & Degener	E	Y	N	Y							7
Solanaceae											
Capsicum annuum L.	X	Y	N	N							
Lycopersicon pimpinellifolium (Jusl.) Mill.	X	Y	N	N							
Nicandra physalodes (L.) Gaertn. -	X	Y	N	N							
Nicotiana glauca Grah.	X	Y	N	N							
Solanum americanum Mill.	I	Y	N	Y		2		4			
Solanum seaforthianum Andr.	X	Y	N	Y				4			
Sterculiaceae											
Waltheria medica L.	I	Y	N	Y				4			
Theaceae											
Eurya sandwicensis A. Gray	E	N	Y	N							
Thymelaeaceae											
Wikstroemia sp.	E	Y	N	Y						6	7
Tiliaceae											
Heliocarpus popayanensis Kunth	X	N	N	Y					5		
Ulmaceae											
Trema orientalis (L.) illume	X	N	N	Y		2		4	5		
Urticaceae											
Boehmeria grandis (Hook. & Arnott) A. Heller	E	Y	N	Y							7
Pipturus albidus (Hook. & Arnott) A. Gray	E	Y	N	Y	1		3			6	7

Table 3. Checklist of the Vascular Plants of North Halawa Valley, Oahu (continued).

	Occurrence on inventory lists				Occurrence on BISH survey sites						
Scientific name	**Status**	**Herbst**	**TNC**	**BISH**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Verbenaceae											
Lantana camara L.	X	Y	N	Y	1		3	4	5	6	7
Stachytarpheta dichotoma (Ruiz & Pav.) Vahl	X	N	N	Y			3	4		6	7
Stachytarpheta jamaicens1s (L.) Vahl	X	Y	N	Y	1			4			
Stachytarpheta urticifolia (Salisb.) Sims	X	N	N	Y		2		4	5		7
Verbena litoralis Kunth	X	Y	N	N							
Violaceae											
Viola oahuensis C. Forbes	E	N	Y	N							
Viscaceae											
Korthalsella complanata (Tiegh.) Engl.	X	Y	N	N							

Biogeographic status

E endemic; occurring naturally only in the Hawaiian Islands
I indigenous; occurring naturally here as well as other parts of the world
P Polynesian introduction; introduced by Polynesian migration
X alien; introduced subsequent to rediscovery of the Hawaiian Islands in 1778

Inventories

Herbst Vegetation survey of North Halawa Valley (Herbst *et al.*, August 1977)
TNC Printout of rare, endangered, and extinct plants of Halawa Valley and surrounding ridges (The Nature Conservancy of Hawaii, National Heritage Database, January 1994)
BISH Field survey by Bishop Museum botanists (December 1993—January 1994)

Y Presence
N Absence

Table 4. Biogeographic status of species collected during BISH survey. (Note: Percentages in parentheses refer to specific survey site)

BISH Site	**Endemic**	**Indigenous**	**Polynesian**	**Introduced**	**Total Species**
1	19 (31.2%)	11 (18.0%)	1 (1.6%)	30 (49.2%)	61
2	2 (2.7%)	4 (5.5%)	5 (6.9%)	62 (84.9%)	73
3	30 (50.9%)	11 (18.6%)	1 (1. 7%)	17 (28.8%)	59
4	0 (0%)	4 (7.0%)	1 (1.8%)	52 (91.2%)	57
5	4 (5.5%)	8 (11.0%)	3 (4.1%)	58 (79.4%)	73
6	20 (28.2%)	17 (23.9%)	7 (9.9%)	27 (38.0%)	71
7	40 (41.7)	20 (20.8%)	3 (3.1 %)	33 (34.4%)	96

Combined plant species list [Herbst *et al*. (1977), TNC, BISH]

Endemic	**Indigenous**	**Polynesian**	**Introduced**	**Total Species**
104 (29.1%)	47 (13.2%)	13 (3.6%)	193 (54.1%)	357

CHAPTER 6
THE LAND SNAIL FAUNA OF NORTH HALAWA VALLEY

Robert H. Cowie

Introduction

The native land snail fauna of the Hawaiian Islands is extremely diverse. Over 750 described species are currently recognized, of which approximately 280 are from the island of Oahu (Cowie et al., 1995). Many of these species are highly localized, often to single valleys or ridges.

It is well known that the land snail fauna of the Hawaiian Islands has suffered drastic extinction (Hadfield, 1986; Solem, 1990; USFWS, 1993). This has been the result of the clearing of lowland habitats by early Polynesian settlers, introduction of non-native plants unsuitable as snail habitat, agricultural and urban development subsequent to the discovery of the islands by Europeans and especially during the twentieth century, and the introduction of non-native animals that destroyed habitat or preyed on the native snails. It is clear that the native land snail fauna of North Halawa Valley has been seriously impacted by these various factors (Hadfield, 1981). Recent surveys for land snails have been undertaken in North Halawa Valley (Hadfield, 1981; Hadfield & Miller, 1989a), and although these surveys focused on the genus *Achatinella*, endemic to Oahu, incidental observations of other taxa were recorded. These surveys indicate the almost total demise of the native land snail fauna and its replacement by a small number of introduced species.

Systematic monographs have been produced for most of the native land snail groups, generally in the early part of this century, and based in large part on the immense collections of the Bishop Museum (Baker, 1940, 1941; Hyatt & Pilsbry, 1910-1911; Neal, 1934; Pilsbry, 1916-1918, 1918-1920, 1920-1921; Pilsbry & Cooke, 1912-1914, 1914-1916). A limited amount of historical distributional information can be gleaned from these works.

Post-1945 records, from the literature, from recent survey reports, from the Bishop Museum collections, from the field notes of professional malacologists (archived at the Bishop Museum), and from the more recent personal observations of others, have been incorporated in the Hawaii Heritage Database (HHD) of the Nature Conservancy of Hawaii (TNC). However, the HHD only deals with taxa that TNC considers rare, although information on other taxa may be included if those taxa are associated with a rare taxon.

The purpose of the present report is to provide an overview of the former land snail fauna of North Halawa Valley, based on the published literature, the HHD records and a survey of the Bishop Museum collections. The present status of the fauna is then reviewed, based on more recent survey work, including records from field work undertaken during the present study.

Methods

A review of the major monographs dealing with most of the major land snail families has been carried out. For those taxa that have not been monographed, other literature, including the original descriptions, has been reviewed. Records derived from this literature, mostly based on shell collections from around the turn of the century and up to about 1920, are rarely specific to North Halawa Valley, often simply indicating “Halawa”. Other taxa may have occurred in Halawa but are not recorded as such in the literature.

The HHD records for North Halawa Valley, including the adjacent ridges, have been obtained. Many taxa in the Hawaiian land snail fauna are notoriously difficult to identify to species level, and some of the HHD records, particularly of *Achatinella* spp., may represent incorrect identifications. However, all taxa recorded in the HHD are included in the present report, but this caveat must be born in mind.

The entire general collection of the Bishop Museum (but excluding other collections not yet incorporated into the general collection) has been searched and all taxa recorded from Halawa (often just "Halawa" in the information associated with the collection) are included here. Again, the possibility of mis-identifications must be born in mind.

The detailed field notes of former Bishop Museum malacologists (C.M. Cooke, Jr., Y. Kondo, C.C. Christensen) have not been reviewed. They would, no doubt, add more detailed locality information, but probably would not add additional taxa to the current list.

Field wrk was undertaken in January, February and April 1994 (with casual observations continuing until November 1994) to confirm or augment the survey results of Hadfield (1981), which indicated that the native land snail fauna of North Halawa Valley was by that time virtually extinct and replaced by introduced species. Stations were investigated at the head of the valley above the tunnel entrances (above Site 3 - see map, Figure 6, included with the overall natural history report; elevation c. 330 m) and at lower stations in the middle part of the valley (Sites 2 and 4; elevations c. 120 m and 60 m, respectively).

The Fauna

Table 5 lists all land snail (and slug) taxa recorded from Halawa, indicating the source of the information. Family classifications are according to Vaught (1989). At least 52 native and 13 non-native species have been recorded. Typically, Hawaiian land snails are extremely difficult to identify with certainty, as many species are not only very small but often are only distinguishable by very subtle differences. Therefore, these numbers may be inflated because of mis-identifications or may be too low because some species that in fact are or were present have never been recorded. Most of the native Hawaiian species have not been recorded living for many decades.

Table 5. The Recorded Land Snail Fauna of North Halawa Valley and the Adjacent Ridges. [For explanation of superscripts see notes at end of table]

HELICINIDAE					
Orobophana uberta var. *beta* (Pilsbry & Cooke, 1908)		C1			
Orobophana uberta var. *hibrida* Neal, 1934	L[2]	C1			
Orobophana uberta var. *percitrea* Neal, 1934	L				
Orobophana sp.		C			
Pleuropoma laciniosa var. *gamma* (Pilsbry & Cooke, 1908)	L[2]	C[1]			
Pleuropoma rotelloidea (Mighels, 1845)	L[2]				
ACHATINELLIDAE					
Achatinella (*A.*) *apexfulva* (Dixon, 1789)			D		
Achatinella (*A.*) *lorata* Férussac, 1825	L[2]	C	D		
Achatinella (*A.*) *lorata pulchella* Pfeiffer, 1855		C			
Achatinella (*A.*).) *turgida* Pfeiffer, 1854			D		
Achatinella (*A.*) *turgida ovum* Pfeiffer, 1857	L	C			
Achatinella (*Achatinellastrum*) *juddii* Baldwin, 1895	L	C	D[3]		
Achatinella (*Achatinellastrum*) vulpina Férussac, 1825	L		D	H	
Achatinella (*Bulimella*) *pupukanioe* Pilsbry & Cooke, 1913[4]			D		
Auriculella castanea (Pfeiffer, 1853)		C[1]	D		
Auriculella diaphana Smith, 1873		C[1]			
Auriculella montana Cooke, 1915		C[1]			
Auriculella pulchra Pease, 1868	L[2]	C	D		
Auriculella sp(p).		C	D	H	
Elasmias sp.		C	D		S
Lamellidea lanceolata (Cooke & Pilsbry, 1915)		C1			
Lamellidea sp.		C1			
Tornatellaria newcombi Pfeiffer, 1857	L[2]	C1			
Tornatellaria sp.		C			

Table 5. (continued).

ACHATINELLIDAE (continued).					
Tornatellides (?group of *T. euryomphala* (Ancey, 1889))		C			
Tornatellides (?group of *T. compactus* (Sykes, 1900))		C			
Tornatellides (?group of *T. perkinsi* (Sykes, 1900))		C			
Tornatellides sp.		C	D		
Pacificella sp.[5]		C[1]			
"tornatellinid sp."[6]				H	
AMASTRIDAE					
Amastra (*Amastrella*) *elliptica* Gulick, 1873[7]		C[1]			
Amastra (*Amastrella*) *rubida* Gulick, 1873[8]				H	
Amastra (*Amastrella*) *tenuilabris* Gulick, 1873[7]		C[1]			
Amastra (*Amastrella*) *tenuilabris rubicunda* (Baldwin, 1895)		C			
Amastra (*Amastrella*) *tristis* (Férussac, 1825)		C			
Amastra (*Metamastra*) *badia* (Baldwin, 1895)		C			
Amastra (*Metamastra*) *breviata* Baldwin, 1895	L[2]	C1			
Amastra (*Metamastra*) *montagui* Pilsbry, 19137		C1			
Amastra (*Metamastra*) *textilis* (Férussac, 1825)	L[2]	C			
Amastra (*Metamastra*) *reticulata errans* Hyatt & Pilsbry, 1911	L[2]				
Amastra (*Metamastra*) *reticulata* ssp.		C1			
Amastra (*Paramastra*) *turritella* (Férussac, 1821: 60)	L[2]	C	D	H	
Amastra sp(p).		C			
Laminella gravida (Férussac, 1825)		C			
Leptachatina (*Ilikala*) *nematoglypta* Pilsbry & Cooke, 1914	L[2]				
Leptachatina (*L.*) *corneola* (Pfeiffer, 1846)	L[2]	C[1]			
Leptachatina (*L.*) *costulata* (Gulick, 1856)		C[1]			
Leptachatina (*L.*) *gracilis* (Pfeiffer, 1855)		C[1]			
Leptachatina (*L.*) *gummea* (Gulick, 1856)		C[1]			
Lepatachatina (*L.*) *pyramis* (Pfeiffer, 1846)	L[2]				
Leptachatina (*Pauahia*) *artata* Cooke, 1911	L[2]				
Leptachatina sp(p).		C			
VERTIGINIDAE					
Lyropupa lyrata (Gould, 1843)	L[2]				
Lyropupa microthauma Ancey, 1904	L[2]				
Nesopupa (*Nesodagys*) sp.		C[1]			S
Nesopupa (*Nesopupilla*) *plicifera* Ancey, 1904	L[2]				
Nesopupa sp.					S
Pronesopupa (*P.*) *acanthinula* (Ancey, 1892)		C[1]			
Pronesopupa (P.) *boettgeri* Cooke & Pilsbry, 1920		C[1]			S
Pronesopupa (*P.*) *hystricella* Cooke & Pilsbry, 1920					S
Pronesopupa sp(p).		C			
ENDODONTIDAE					
Nesophila sp.		C1			
SUCCINEIDAE					
Succinea caduca Mighels, 1845		C[1]			
Succinea "*oostoma*"[9]		C[1]			
Succinea (*Catinella*) *rotundata* Gould, 1846		C	D		
Succinea sp.		C	D	H	
GASTRODONTIDAE					
Striatura (*Pseudohyalina*) sp.		C1			
HELICARIONIDAE					
Philonesia (*P.*) *striata* Baker, 1940	L[2]				
Philonesia (*Piena*) *grandis* Baker, 1940[7]		C			
Philonesia sp.		C	D		

Table 5. (continued).

Non-indigenous taxa - snails					
ACHATINELLIDAE					
Lamellidea oblonga (Pease, 1865)10		C[1]			
SUBULINIDAE					
Subulina octona (Bruguière, 1792)					S
Subulina sp.				H	
Allopeas clavulinum var. *hawaiiense* (Sykes, 1904)[11]		C[7]			
Allopeas mauritianum (Pfeiffer, 1854)[11]		C[7]			S[7]
Opeas opella Pilsbry & Vanatta, 1906[12]		C			
Paropeas achatinaceum (Pfeiffer, 1866)		C			S[7]
SPIRAXIDAE					
Euglandina rosea (Férussac, 1821)			D	H	S
HELICARIONIDAE					
Zonitoides arboreus (Say, 1817)		C			
VITRINIDAE					
Hawaiia minuscula (Binney, 1840)					S
BRADYBAENIDAE					
Bradybaena similaris (Férussac, 1821)		C	D	H[13]	
Non-indigenous taxa - slugs					
VERONICELLIDAE					
unidentified					S
LIMACIDAE					
Limax maximus Linnaeus, 1758					S
Deroceras sp.			D		S
"unidentified"				H	

L = pre-1945 literature records; C = Bishop Museum collection; D = Hawaii Heritage Database; H = Hadfield (1981); S = 1994 survey.

1. Collection label information not specific to North Halawa Valley or its continuation below the confluence of North and South Halawa Streams.
2. Literature records not specifically located in North Halawa Valley or its continuation below the confluence of North and South Halawa Streams.
3. HHD has records of *Achatinella* (*Achatinellastrum*) *juncea* Gulick, 1856, but this probably represents a misidentification of *A. juddii* (see HHD).
4. *Achatinella* (*Bulimella*) *fuscobasis* Smith, 1873, according to Y. Kondo, but referred to *A. pupukanioe* by HHD on the basis of identification by D. Chung (see HHD).
5. As "*Tornatellinops*" in the collection. Tentative identification.
6. Small achatinellids, formerly classified in the family Tornatellinidae. Probably *Tornatellides* sp(p)., *Tornatellaria* sp(p)., *Tornatellinops* sp(p)., *Elasmias* sp(p). or *Lamellidea* sp(p).
7. Tentative identification.
8. Tentative identification (Hadfield, 1981).
9. An unpublished manuscript name only. Possibly *S. oregonensi*s Lea, 1841. Possibly introduced.
10. Probably introduced by early Polynesian settlers (Cooke & Kondo, 1960).
11. Labelled as such on the individual lot(s) but in trays labelled "*opella* type".
12. Collection trays labelled "*opella* type". True identity doubtful.
13. Hadfield (1981) recorded only "*Bradybaena* sp."

Discussion

The majority of the native land snail species once known from North Halawa Valley are probably now extinct. As with much of the native biota of the Hawaiian Islands, the process of extinction no doubt began with the arrival of Polynesian settlers. However, catastrophic extinction of the land snail fauna probably only occurred during the last hundred years or so, with their ultimate disappearance due in large part to predation by the introduced snail *Euglandina rosea*. This carnivorous snail was introduced to Oahu from the southeastern U.S.A. in 1955 in an ill conceived attempt to control the Giant African Snail, *Achatina fulica*, which had become an agricultural pest. While there is no evidence that *E. rosea* was successful in controlling *A. fulica*, it has since spread throughout the island and has been responsible for the destruction of many native snail populations (Hadfield, 1986, and references therein), including those of North Halawa Valley (Hadfield, 1981). The larger species in the families Achatinellidae and Amastridae are particularly vulnerable to predation by introduced animals because of their slow rates of growth and reproduction (at least of the Achatinellinae - e.g., Hadfield & Miller, 1989b). Other species, because of their faster growth and reproduction and higher fecundity may be less immediately susceptible and this may be the explanation of the finding of living *Succinea* sp. and "tornatellinids" in 1981 (Hadfield, 1981); and of *Pronesopupa hystricella*, once considered "common" on Oahu but not specifically recorded from Halawa (Pilsbry, 1920-1921), in 1994 (this study). The construction of the H-3 freeway has probably had an impact on populations of these species, but it remains possible that some of them are still extant, albeit in low numbers.

It is not possible, with certainty, to say when the native taxa in North Halawa Valley became extinct. However, elsewhere on Oahu, most native land snail species had gone extinct prior to about 1960, and in some cases much earlier (Kondo, 1980). The extinct populations of *Achatinella vulpina* and *Amastra* spp. reported by Hadfield (1981) were, however, thought to have perhaps been thriving "within the last decade" (i.e., 1971-1981). The HHD records *Achatinella pupukanioe* last seen alive in 1980 and *Auriculella pulchra* in 1974; all the other taxa in the HHD, except *Succinea* sp., which was recorded in 1981 (see above), have not been seen alive since at least 1962.

The non-native taxa recorded are common, widespread elements of the introduced fauna of the Hawaiian Islands and of other islands in the Pacific and elsewhere. *Euglandina rosea* and the subulinids are common in North Halawa Valley, shells of three subulinid species often being seen in great numbers amongst the leaf litter. *Euglandina rosea* and one of the subulinid species (tentatively identified as *Paropeas achatinaceum*) were recorded alive during the present study. The Giant African Snail, *Achatina fulica* has not been recorded from North Halawa Valley, but no doubt would be found if survey work were extended into the completely disturbed low elevation areas closer to Pearl Harbor. *Bradybaena similaris* was not found during the present study; it may perhaps have succumbed to predation by *E. rosea*, although it seems never to have been common in the valley.

Acknowledgments

I thank Richard Preece and David Preston for additional records during 1994.

CHAPTER 7
THE INSECT AND RELATED ARTHROPOD FAUNA OF NORTH HALAWA VALLEY. PART 1: OVERALL PROFILE

David J. Preston, Francis G. Howarth, and Gordon M. Nishida

Introduction

Insects and related arthropods (jointed legged animals such as spiders, mites, and isopods) are the dominant animals in most terrestrial ecosystems both in terms of numbers of species and numbers of individuals. Many are also good dispersers and were early colonists to isolated oceanic islands like Hawaii. Hawaii has a remarkably diverse native arthropod fauna. There are about 5,100 native insects known to science, of which more than 98% are endemic or found only in Hawaii, and about 300 native species representing other arthropod groups, mostly spiders and mites. Oahu harbors nearly 2,000 native insect species of which 1,102 or 55% are found only on Oahu (Nishida, 1992). Many are restricted to single hosts or to limited geographic areas on the island. As impressive as these numbers are, many new species still await discovery, and it is estimated that there are probably more than 10,000 native insect species in Hawaii (Howarth and Mull, 1992). There are also about 2,500 non-native (that is either purposefully or inadvertently introduced by humans) species of insects established in Hawaii.

This great diversity makes identification and assessment of their status difficult. Populations of many native insects have declined drastically from habitat destruction and the effects of non-native species. Those associated with rare or extinct native plants or animals were especially vulnerable, and many insect species are extinct. Introduced predators, parasites and competitors can also drive native species to extinction even when the habitat appears otherwise suitable.

The purpose of the present report is to provide an overview of what is known on the arthropod fauna of North Halawa Valley, based primarily on recent collections. The present status of significant or notable species will be described.

Methods

In the past most insect surveys on Oahu were mainly restricted to the relatively more accessible ridge tops and lowland areas. The deeper dissected valleys and headwalls remained poorly known. Before the mid-1980s North Halawa Valley was accessible only along a poorly maintained trail into the valley, and the fauna was little studied. Surveys along neighboring Aiea and Halawa ridge trails provided overlooks into the back of the valley and revealed a diverse native plant community. In November 1991, after the construction of the access road made the back of North Halawa Valley easily accessible, entomologists at Bishop Museum established a study site at 300 m (1,000 ft.) elevation in one of the side streams near the tunnel portals (Site 3, see Figure 6). A Malaise trap (a large tent-like net stretched across a natural flyway) was set up and serviced once a week from November 1991 through February 1994. Additional specimens were collected using yellow pan traps, pitfall traps, cup-bark traps, insect nets, and by searching foliage and other habitats at selected sites throughout the valley. Night collecting using an ultraviolet light was done on several occasions. The collected material was brought to Bishop Museum and processed for specialists to examine and identify. A few additional records were added from the literature as were data from the historic collections at the museum, but a full search for these historic records was beyond the scope of this study. The status of the species identified was checked using literature and known host ranges.

This insect report is divided into several separate parts; each prepared by a specialist on the group concerned. The first part lists the arthropod species collected and authoritatively identified to date. Many species belong to groups for which there are no specialists available, and these have had to be excluded from the report.

Results

Table 6 lists 381 taxa of insects and related arthropods captured in North Halawa Valley. Of these 381 species, 121, or 32 percent of the total, are native to the Hawaiian Islands.

It should be noted that the table includes only those taxa that could be identified at least to genus, and thus provides a minimum diversity figure. If all unidentified taxa captured during the course of the study could be accurately determined to species the total taxon count might well double. In addition, for the purposes of the above species tally the notation "spp." in Table 6 was taken to mean that at least two (and often more) species were present for a given genus in the material at hand, and such groups were scored as containing two species for the purposes of the overall diversity estimate. The table also provides notations indicating whether the included species are indigenous, adventive, or purposefully introduced.

Table 6. Entomofauna Collected in North Halawa Valley

TAXON	STATUS
ACARI	
Camerobiidae	
Tycherobius n. sp. A	?
Cryptognathidae	
Favognathus pictus Summers & Chaudhri, 1965	?
Laelapidae	
Hypoaspis nr. *glabrosimilis* Hirschmann, 1969	adv
Syigmaeidae	
Eustigmaeus kauaiensis Swift, Gerson & Goff, 1985	end
Eustigmaeus n. sp. B	?
Stigmaeus n. sp. D	?
Uropodidae	?
Oppiidae ?	
AMPHIPODA	
Talitridae	
2*Floresorchestia pickeringi* (Dana, 1853)	end
Talitroides topitotum Burt, 1934	adv
ARANEAE	
Araneidae	
Argiope sp.	adv
Argiope trifasciata (Forskal, 1775)	adv
Cyclosa sp.	end?
Heteropodidae	
Heteropoda venatoria (Linnaeus, 1767)	adv
Lynyphiidae	
Labulla sp.	end
Neoscona sp.	adv
Pholcidae	
Pholcus phalangioides (Fuesslin, 1775)	adv
Scytodidae	
Scytodes sp.	adv
Tetragnathidae	
Tetragnatha hawaiiensis Simon, 1900	end
Tetragnatha tantalus Gillespie, 1991	end
Tetragnatha new sp.	end
Tetragnatha new sp.	end
Theridiidae	
Argyrodes argyrodes (Walckenaer, 1841)	adv
Latrodectus geometricus C.L. Koch, 1841	adv
Steatoda grossa C.L. Koch, 1838	adv

Table 6 (continued).

TAXON	STATUS
ARANAEIDAE (continued).	
Thomisidae	
Misumenops spp.	end
BLATTARIA	
Blaberidae	
Pycnoscelus indicus (Fabricius, 1775)	adv
Blattellidae	
Balta similis (Saussure, 1869)	adv
Blattella germanica (Linnaeus, 1767)	adv
COLEOPTERA	
Blattidae	
Periplaneta americana (Linnaeus, 1758)	adv
Periplaneta australasiae (Linnaeus, 1775)	adv
CHILOPODA	
Cryptopidae	
Cryptops sp.	adv
Lithobiidae	
Lithobius sp.	end?
Scolopendridae	
Scolopendra subspinipes Leach, 1818	adv
COLEOPTERA	
Aglycyderidae	
Proterhinus sp. A	end
Proterhinus sp. B	end
Proterhinus sp. C	end
Proterhinus spp.	end
Anobiidae	
Xyletobius nr. *dollfusi* Perkins, 1910	end
Anthribidae	
Araecerus sp.	adv?
Bruchidae	
Callosobruchus chinensis (Linnaeus, 1758)	adv
Callosobruchus phaseoli (Gyllenhal, 1833)	adv
Stator limbatus (Horn, 1873)	adv
Cerambycidae	
Ceresium unicolor (Fabricius, 1778)	adv
Coptops aedificator (Fabricius, 1778)	adv
Curtomerus flavus (Fabricius, 1775)	adv
Chrysomelidae	
Epitrix hirtipennis (Melsheimer, 1847)	adv
Azya sp. nr. *orbigera* Mulsant	adv
Diomus notescens (Blackburn, 1889)	pur
Hyperaspis silvestrii Weise, 1909	pur
Orcus australasiae Boisduval, 1835	pur
Scymnus sp.	pur
Stethorus punctum picipes Casey, 1899	pur
Telsimia nitida Chapin, 1926	pur
Corylophidae	
Sacium angusticolle Scott, 1908	end?
Cucujidae	
Cryptolestes sp.	adv
Psammoechus pallidipennis (Blackburn, 1885)	adv
Psammoechus sp.	adv

Table 6 (continued).

TAXON	STATUS
COLEOPTERA (conituned).	
Dytiscidae	
Copelatus parvulus (Boisduval, 1835)	adv
Elateridae	
Conoderus exsul (Sharp, 1877)	adv
Hydrophilidae	
Cryptopleurum sp.	adv
Limnoxenus sp.	ind
Paromicrus sp.	adv
Mycetophagidae	
Litargus vestitus Sharp, 1879	ind
Nitidulidae	
Conotelus mexicanus Murray, 1864	adv
Haptoncus mundus Sharp, 1778	adv
Platypodidae	
Crossotarsus externedentatus (Fairmaire, 1850)	adv
Rhizophagidae	
Hesperobaenus capito Fairmaire, 1850	ind?
Scarabaeidae	
Adoretus sinicus Burmeister, 1855	adv
Protaetia fusca (Herbst, 1790)	adv
Scolytidae	
Xyleborinus saxeseni (Ratzeburg, 1837)	adv
Xyleborus affinis (Eichhoff, 1867)	adv
Xyleborus perforans (Wollaston, 1857)	adv
Xyleborus sp.	adv
Xylosandrus compactus (Eichhoff, 1875)	adv
Scydmaenidae	
Cephennodes sp.	nat
Staphylinidae	
Aleochara sp.1	adv
Anotylus sp.	adv
Atheta? sp.	adv
Coproporus sp.	adv
Ctenandropus sp.	adv
Myllaena sp.	nat
Osorius rufipes Motschulsky, 1857	adv
Philonthus longicornis Stephens, 1832	adv
Philonthus nr. *discoideus* (Gravenhorst, 1827)	adv
Philonthus sp.	adv
Rugilus sp.	adv
Thyreocephalus albertisi Fauvel, 1877	pur
Tenebrionidae	
Archeoglenes nemoralis Ford, 1968	end
COLLEMBOLA	
Entomobryidae	
Entomobrya sp.	end?
Salina celebensis (Schaeffer, 1898)	adv
Seira sp.	end?
DERMAPTERA	
Carcinophoridae	
Euborellia eteronoma (Borelli, 1909)	end
Chelisochidae	
Chelisoches morio (Fabricius, 1775)	adv

Table 6 (continued).

TAXON	STATUS
DIPTERA	
Agromyzidae	
Liriomyza brassicae (Riley, 1885)	adv
Liriomyza sativae Blanchard, 1938	adv
Liriomyza trifolii (Burgess, 1880)	adv
Calliphoridae	
Calliphora vomitoria (Linnaeus, 1758)	adv
Chrysomya megacephala (Fabricius, 1794)	adv
Chrysomya rufifacies (Macquart, 1843)	adv
Phormia regina (Meigen, 1826)	adv
Cecidomyidae	
Dasineura mangiferae Felt, 1927	adv
Ceratopogonidae	
Atrichopogon jacobsoni (de Meijere, 1907)	adv
Ceratopogonidae	
Forcipomyia hardyi Wirth & Howarth, 1982	end
Forcipomyia kaneohe Wirth & Howarth, 1982	end
Chironomidae	
Cricotopus bicinctus (Meigen, 1818)	adv
Culicidae	
Aedes albopictus (Skuse, 1894)	adv
Culex quinquefasciatus Say, 1823	adv
Wyeomyia mitchellii (Theobald, 1905)	adv
Dolichopodidae	
Campsicnemus gloriosus Van Duzee, 1933	end
Campsicnemus miritibialis Van Duzee, 1933	end
Campsicnemus n.sp. A	end
Campsicnemus n.sp. B	end
Campsicnemus ornatus Van Duzee, 1933	end
Campsicnemus patellifer Grimshaw, 1902	end
Drosophilidae	
Drosophila lanaiensis Grimshaw, 1901	end
Drosophila oahuensis (Grimshaw, 1901)	end
Drosophila punalua Bryan, 1934	end
Drosophila immigrans grp.	adv
Drosophila suzukii (Matsumura, 1931)	adv
Idiomyia crucigera (Grimshaw, 1902)	end
Scaptomyza spp.	end
Ephydridae	
Scatella hawaiiensis Grimshaw, 1901	end
Fanniidae	
Fannia pusio (Wiedemann, 1830)	adv
Muscidae	
Lispocephala sp.	end
Musca domestica Linnaeus, 1758	adv
Musca sorbens Wiedemann, 1830	adv
Muscina stabulans (Fallen, 1817)	adv
Stomoxys calcitrans (Linnaeus, 1758)	adv
Neriidae	
Telostylinus lineolatus (Wiedemann, 1830)	adv
Otitidae	
Acrosticta apicalis (Williston, 1896)	adv
Phoridae	
Chonocephalus pallidulus Beyer, 1964	end?
Megaselia scalaris (Loew, 1866)	adv
Megaselia spp.	?
Puliciphora sp.	adv

Table 6 (continued).

TAXON	STATUS
DIPTERA (continued).	
Psychodidae	
Clogmia albipunctata (Williston, 1893)	adv
Psychoda spp.	?
Sarcophagidae	
Parasarcophaga albiceps (Meigen, 1826)	adv
Ravinia iherminieri (Robineau-Desvoidy, 1830)	adv
Sphaeroceridae	
Leptocera sp.	adv?
Syrphidae	
Allograpta exotica (Wiedemann, 1830)	pur
Stratiomyidae	
Neoexaireta spinigera (Wiedemann, 1830)	pur
Wallacea albiseta de Meijere, 1907	adv
Tachinidae	
Archytas cirphis (Curran, 1927)	pur
Trichopoda pilipes (Fabricius, 1805)	pur
Tephritidae	
Bactrocera curbitae (Coquillett, 1899)	adv
Bactrocera dorsalis (Hendel, 1912)	adv
Procecidochares utilis Stone, 1947	pur
Tipulidae	
Limonia hawaiiensis (Grimshaw, 1901)	end
Limonia jacobus (Alexander)	end
Limonia perkinsi (Grimshaw, 1901)	ind
Limonia stygipennis (Alexander, 1919)	end
HETEROPTERA	
Anthocoridae	
Lasiochilus sp. A	end
Orius persequens (White, 1877)	adv
genus A	?
Aradidae	
Mezira membranacea (Fabricius, 1803)	adv
Cydnidae	
Geotomus pygmaeus (Dallas, 1851)	adv
Miridae	
Cyrtopeltis confusus Perkins	end
Halticus chrysolepis Kirkaldy, 1904	adv
Hyalopeplus pellucidus (Stal, 1859)	end
Kamehameha sp.	end
New Genus	end
Orthotylus sp. A	end
Orthotylus sp. B	end
Nabidae	
Nabis kerasphoron (Kirkaldy, 1907)	end
Nabis lusciosus White, 1877	end
Nabis subrufus White, 1877	end
Nabis sp.	end
Pentatomidae	
Nezara viridula (Linnaeus, 1858)	adv
Reduviidae	
Scadra rufidens Stål, 1859	adv
Zelus renardii Kolenati, 1856	adv
Saldidae	
Saldula exulans (White, 1878)	end
Saldula procellaris (Kirkaldy, 1908)	end

Table 6 (continued).

TAXON	STATUS
HETEROPTERA (continued).	
Scutelleridae	
Coleotichus blackburniae White, 1881	end
Tingidae	
Teleonemia lantana Distant	pur
Veliidae	
Microvelia vagans White, 1878	end
HOMOPTERA	
Aleurodidae	
Aleurodicus dispersus Russell, 1965	adv
Aphididae	
Aphis sp.	adv
Aphrophoridae	
Clastoptera xanthocephala Germar	adv
Cicadellidae	
Circulifer tenellus (Baker, 1896)	adv
Draeculacephala minerva Ball, 1927	adv
Empoasca solana DeLong, 1931	adv
Exitianus exitiosus (Uhler, 1880)	adv
Nesophrosyne gouldiae Kirkaldy, 1910	end
Nesophrosyne perkinsi (Kirkaldy, 1904)	end
Nesophrosyne ponapona Kirkaldy, 1910	end
Sophonia rufofascia (Kuoh & Kuoh)	adv
Cixiidae	
Oliarus kaiulani Giffard, 1925	end
Coccidae	
Ceroplastes rubens Maskell, 1893	adv
Coccus viridis (Green, 1889)	adv
Eucalymnatus tessellatus (Signoret, 1873)	adv
Parasaissetia nigra (Nietner, 1861)	adv
Pulvinaria psidii Maskell, 1892	adv
Saissetia coffeae (Walker, 1852)	adv
Dactylopiidae	
Pseudoparlatoria parlatorioides (Comstock, 1883)	adv
Delphacidae	
Nesosydne halia Kirkaldy, 1908	end
Nesosydne spp.	end
Nesothoe sp. A	end
Nesothoe sp. B	end
Nesothoe sp. C	end
Peregrinus maidis (Ashmead, 1890)	adv
Perkinsiella saccharicida Kirkaldy, 1903	adv
Diaspididae	
Abgrallaspis cyanophylli (Signoret, 1869)	adv
Aspidiotus destructor Signoret, 1869	adv
Diaspis boisduvalii Signoret, 1869	adv
Hemiberlesia lataniae (Signoret, 1869)	adv
Lepidosaphes araucariae Beardsley, 1965	adv
Pinnaspis buxi (Bouche, 1851	adv
Flatidae	
Melormenis basalis (Walker, 1851)	adv
Siphanta acuta (Walker, 1851)	adv
Halimococcidae	
Colobopyga pritchardiae (Stickney, 1934)	end
Membracidae	
Vanduzeea segmentata (Fowler, 1895)	adv

Table 6 (continued).

TAXON	STATUS
HOMOPTERA (continued).	
Pseudococcidae	
Chaetococcus bambusae (Maskell, 1892)	adv
Ferrisia virgata (Cockerell, 1893)	adv
Geococcus coffeae Green, 1933	adv
Pseudococcidae	
Laminicoccus pandani (Cockerell, 1895)	adv
Planococcus citri (Risso, 1833)	adv
Psyllidae	
Heteropsylla mimosae Crawford, 1914	adv
Trioza spp.	end
HYMENOPTERA	
Agaonidae	
Pleistodontes sp.	pur?
Anthophoridae	
Xylocopa sonorina F. Smith, 1874	adv
Apidae	
Apis mellifera Linnaeus, 1758	pur
Bethylidae	
Undetermined	?
Braconidae	
Bracon sp.	adv
Macrocentrus calacte Nixon, 1938	adv
Opius spp.	pur?
Dryinidae	
Undetermined	adv?
Encyrtidae	
Anagyrus spp.	end?
Metaphycus sp.	adv
Ooencyrtus sp.	pur?
Eulophidae	
Undetermined spp.	?
Evaniidae	
Evania appendigaster (Linnaeus, 1758)	adv
Formicidae	
Anoplolepis longipes (Jerdon, 1851)	adv
Ochetellus glaber (Mayr, 1862)	adv
Undetermined (3 spp.)	adv
Ichneumonidae	
Casinaria infesta (Cresson, 1872)	adv
Diadegma blackburni (Cameron, 1883)	adv
Echthromorpha agrestoria fuscator (Fabricius, 1793)	end
Enicospilus sp.	end
Trathala flavoorbitalis (Cameron, 1907)	adv
Megachilidae	
Megachile gentilis Cresson, 1872	adv
Megachile umbripennis Smith, 1853	adv
Mymaridae	
Anagrus spp.	?
Polynema spp.	?
Pteromalidae	
Pteromalus spp.	adv
Sphecidae	
Ampulex compressa (Fabricius, 1781)	pur
Chalybion bengalense (Dahlbom, 1845)	adv
Ectemnius sp.	end

Table 6 (continued).

TAXON	STATUS
HYMENOPTERA (continued).	
Sphecidae (continued).	
Liris aurulenta (Fabricius, 1787)	adv
Tachysphex apicalis Fox, 1893	adv
Trichogrammatidae	
Trichogramma spp.	pur?
Vespidae	
Delta curvata (Saussure, 1854)	adv
Delta pyriformis philippinense (Bequaert, 1928)	adv
Odynerus sp.	end
Pachodynerus nasidens (Latreille, 1812)	adv
Polistes aurifer Saussure, 1857	adv
Polistes olivaceus (DeGeer, 1773)	adv
ISOPODA	
Armadillidae	
Spherillo sp.	end?
Ligiidae	
Ligia sp.	end
Porcellionidae	
Porcellio sp.	adv
ISOPTERA	
Rhinotermitidae	
Coptotermes formosanus Shiraki, 1909	adv
LEPIDOPTERA	
Alucitidae	
Alucita objurgatella (Walsingham, 1907)	adv
Carposinidae	
Carposina sp.1	end
Carposina sp.2	end
Cosmopterigidae	
Hyposmocoma spp.	end
Crambidae	
Eudonia geraea (Meyrick, 1899)	end
Eudonia sp. A	end
Eudonia sp. B	end
Eudonia sp. C	end
Eudonia sp. D	end
Eudonia sp. E	end
Glyphodes cyanomichla (Meyrick, 1899)	end
Herpetogramma licarsisalis (Walker, 1859)	adv
Mestolobes nr. *abnormis* (Butler, 1882)	end
Mestolobes minuscula (Butler, 1881)	end
Salbia haemorrhoidalis (Guenee, 1854)	pur
Usingeriessa onyxalis (Hampson, 1897)	adv
Gelechiidae	
Pectinophora sp.	adv
Geometridae	
Cyclophora nanaria (Walker, 1861)	adv
Macaria abydata Guenee, 1857	adv
4*Scotorythra caryopis* Meyrick, 1899	end
Scotorythra rara (Butler, 1879)	end
Semiothisa abydata (Guenee, 1857)	adv
Hesperiidae	
Hylephila phyleus (Drury, 1773)	adv

Table 6 (continued).

TAXON	STATUS
LEPIDOPTERA (conitnued).	
Lycaenidae	
Lampides boeticus (Linnaeus, 1767)	adv
Strymon bazochii (Godart, 1834)	pur
Tmolus echion (Linnaeus, 1767)	pur
Udara blackburni (Tuely, 1878)	end
Noctuidae	
Agrotis hephaestaea Meyrick, 1904	end
Agrotis ipsilon (Hufnagel, 1766)	adv
Ascalapha odorata (Linnaeus, 1758)	adv
Athetis thoracica (Moore, 1884)	adv
Bocana manifestalis Walker, 1858	adv
Elaphria nucicolora (Guenee, 1852)	adv
Helicoverpa n.sp.	end
Hypocala deflorata (Fabricius, 1793)	adv
Melipotis indomita (Walker, 1857)	adv
Ophiusa indiscriminata (Hampson)	adv
Pandesma anysa Guenee, 1852	adv
Schrankia sp.	end
Spodoptera mauritia (Boisduval, 1833)	adv
Nymphalidae	
Agraulis vanillae (Linnaeus, 1758)	adv
Danaus plexippus (Linnaeus, 1758)	adv
Vanessa cardui (Linnaeus, 1758)	adv
Vanessa tameamea Eschscholtz, 1821	end
Oecophoridae	
Autosticha pelodes (Meyrick 1883)	adv
Stoeberhinus testaceus Butler, 1881	adv
Papilionidae	
Papilio xuthus Linnaeus, 1767	adv
Pieridae	
Pieris rapae (Linnaeus, 1767)	adv
Psychidae	
Brachycyttarus griseus De Joannis, 1929	adv
Pterophoridae	
Anstenoptilia marmorodactyla (Dyar, 1903)	adv
Pyralidae	
Cryptoblabes gnidiella (Milliere, 1864)	adv
Sphingidae	
Agrius cingulata (Fabricius, 1775)	adv
Macroglossum pyrrhostictum (Butler, 1875)	adv
Psilogramma menephron (Cramer, 1780)	adv
Tineidae	
Decadarchis minuscula (Walsingham, 1907)	adv
Decadarchis simulans (Butler, 1882)	adv
Opogona omoscopa (Meyrick, 1893)	adv
Tortricidae	
Amorbia emigratella Busck, 1910	adv
Bradleyella chlorocalla (Walsingham, 1907)	end
Cryptophlebia illepida (Butler, 1882)	adv
Cydia conspicua (Walsingham, 1907)	end
Cydia sp.	end
Epinotia lantana (Busck, 1910)	pur
Episimus utilis Zimmerman, 1978	pur
Spheterista sp.	end

Table 6 (continued).

TAXON	STATUS
MANTODEA	
Mantidae	
Hierodula patellifera (Serville, 1839)	adv
Orthodera burmeisteri Wood-Mason, 1889	adv
Tenodera angustipennis Saussure, 1869	adv
Tenodera australasiae (Leach, 1814)	adv
NEUROPTERA	
Chrysopidae	
Chrysoperla comanche (Banks, 1938)	adv
Hemerobiidae	
Hemerobius pacificus Banks, 1897	adv
ODONATA	
Aeshnidae	
Anax junius (Drury, 1773)	ind
Anax strenuus Hagen, 1867	end
Coenagrionidae	
Megalagrion hawaiiense (McLachlan, 1883)	end
Megalagrion koelense (Blackburn, 1884)	end
Megalagrion leptodemas (Perkins, 1899)	end
Megalagrion nigrohamatum nigrolineatum (Perkins, 1899)	end
Megalagrion oahuense (Blackburn, 1884)	end
Libellulidae	
Nesogonia blackburni (McLachlan, 1883)	end
Orthemis ferruginea (Fabricius, 1775)	adv
Pantala flavescens (Fabricius, 1798)	ind
ORTHOPTERA	
Acrididae	
Oedaleus abruptus (Thunberg, 1815)	adv
Oxya japonica (Thunberg, 1824)	adv
Schistocerca nitens (Thunberg, 1815)	adv
Gryllidae	
Laupala spp.	end
Prognathogryllus sp. nr. *oahuensis* Perkins, 1899	end
Trigonidium spp.	end
Tettigoniidae	
Banza unica (Perkins, 1899)	end
Conocephalus saltator (Saussure, 1859)	adv
Elimaea punctifera (Walker, 1869)	adv
Euconocephalus nasutus (Thunburg, 1815)	adv
Xiphidiopsis lita Hebard, 1922	adv
PSOCOPTERA	
Ectopsocidae	
Ectopsocus sp.	adv
Elipsocidae	
Palistreptus sp.	end
Psocidae	
Ptycta spp.	end
SCORPIONIDA	
Buthidae	
Isometrus maculatus (DeGeer, 1778)	adv

Table 6 (continued).

TAXON	STATUS
THYSANURA	
Nicoletidae	
Nicoletia sp.	?
TRICHOPTERA	
Hydropsychidae	
Cheumatopsyche pettiti (Banks, 1908)	adv
Hydroptilidae	
Oxyethira maya Denning, 1947	adv

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CHAPTER 8
THE INSECT AND RELATED ARTHROPOD FAUNA OF NORTH HALAWA VALLEY. PART 2: NOTABLE INSECT SPECIES FOUND

David J. Preston

A complete annotation on the biology and status of each species listed in Table 7 is beyond the scope of this report. A few species collected from the valley, however, are notable either because of rarity or significance to science. These records are briefly elaborated below. The arrangement follows the same order as in Table 6. Other records undoubtedly also deserve treatment here, but the species are too poorly known to warrant inclusion.

Coleoptera

Aglycyderidae (Proterinid Weevils): These tiny (less than 3 mm long) primitive weevils are remarkably diverse in Hawaii. About 175 species are known only from the Hawaiian Islands; these constitute more than 90% of the world's fauna in the family. The larvae are wood borers, mostly in twigs and stems of native plants, and most species are host specific. In Halawa, two species were associated with *Pritchardia* palms, and another was collected on *Cyrtandra cordifolia*. Additional unidentified species were collected in the Malaise trap and during general collecting.

Diptera

Drosophilidae (Pomace Flies): Hawaiian Drosophilidae represent one of the best studied examples of adaptive radiation. Over 600 species have been described, and another 200 species are known but not yet named. The common pomace fly (*Drosophila melanogaster*) has been a favorite animal for genetic studies for over 75 years; thus, the existence of such a diverse fauna in Hawaii provides an ideal natural laboratory for comparative studies in evolutionary biology (Carson 1987; Kaneshiro and Boake 1987).

Four species belonging to the large "picture wing" group used in these studies were collected in the valley. Prior to this survey, *D. lanaiensis*, known from only Lanai and Oahu, was feared to be extinct. The species remains very rare; only three specimens were collected in four years of Malaise trapping in the valley and only a few other specimens exist in collections.

Drosophila oahuensis (Grimshaw, 1901), endemic to Oahu, *D. punalua* (Bryan, 1934), endemic to Oahu and Maui, and *Idiomyia crucigera* (Grimshaw, 1902), endemic to Kauai and Oahu were recovered from the Malaise trap. *Drosophila oahuensis* was very uncommon with only 2 specimens collected thus far. *D. punalua* and *I. crucigera* are very common in the Valley.

Muscidae (House Flies and relatives): The endemic genus *Lispocephala* contains over 100 known species, which are all predatory on other insects. 21 species are known from Oahu, and one unidentified species was occasionally collected in the Malaise trap.

Heteroptera

Miridae (Plant Bugs): Hawaiian plant bugs remain poorly known. About 50 species have been named, but at least another 100 undescribed species are in collections. Most species are plant feeders, but many are predaceous or omnivorous. Many species are found only in a small geographical area and feed on a single species of plant. Six native species were found in Halawa, of which 4 are undescribed. *Hyalopeplus pellucidus* is a common species with a wide host range, including guava and other alien plant species. One undescribed species belongs to a recently discovered new genus of bugs restricted to native loulu palms (*Pritchardia*). These bugs are extremely flat and live hidden in the leaf folds of palm fronds. *Cyrtopeltis confusus* is only known from *Cyrtandra* on Oahu and was found on *C. cordifolia* in the valley.

Nabidae (Damsel Bugs): The damsel bugs are all predatory on other insects. There are 30 Hawaiian species, but new species continue to be discovered. Four species were collected in the Malaise trap and from vegetation in the valley.

Pentatomidae (Shield Bugs): *Coleotichus blackburniae*, the koa bug, is the largest and most conspicuous native true bug. It is nearly an inch long and iridescent blue, green, maroon, and yellow. Once common on koa (*Acacia koa*) and a'alii (*Dodonea* sp.) on all of the main islands, it has become rare following the introduction, beginning in the 1960s, of several parasites for biological control of the pestiferous southern green stink bug, *Nezara viridula*. Historically this species was known from the valley, but none were seen during this survey.

Homoptera

Halimococcidae (Palm Scales): The native Hawaiian palms (*Prichardia*) support an interesting complex of scales and other native insects. As their hosts become rare, these associated insects become more vulnerable to extinction. The loulu palm grove in Halawa supports populations of a number of Pritchardia-associated insects, including the rare Oahu palm coccid, *Colobopyga pritchardiae*.

Hymenoptera

Ichneumonidae (Ichneumon Wasps): Ichneumon wasps are parasites of other insects; the adult female searches for, and lays eggs in, suitable hosts. Individuals of several species were collected sporadically in the Malaise trap as expected. On one occasion, surprisingly, hundreds of individuals in the native genus, *Enicospilus*, were discovered roosting together beneath a dead palm frond hanging on a *Pritchardia* tree.

Lepidoptera

Crambidae (Crambid Moths): The crambids are a diverse group of mostly small moths, which are exceptionally well-represented in Hawaii. There are 206 named species, but many more have not yet been named. The genus *Mestolobes* with 33 species is endemic to Hawaii. *M. minuscula* is a common moth in the lowlands, including Honolulu; yet nothing is known of its biology. *M. abnormis* is endemic to the Koolau Mountains and is rarely collected. Adults of many *Eudonia* species resemble pieces of the lichens upon which they roost, and the larvae are probably associated with lichens. There are over 100 species in the genus, but most remain undescribed. Some species are common even in Honolulu; others are rare. Population densities for the 6 species collected in the Valley are unknown as only a few specimens were collected during the a few nights of light trapping. Small moths recovered from the Malaise trap proved too difficult to accurately determine.

Geometridae (Inchworms): The genus *Scotorythra* contains 38 species, all endemic to the Hawaiian Islands. *Scotorythra rara* (Butler) was frequently collected in the Malaise trap. The species occurs on Kauai, Oahu, Molokai, Maui, and Hawaii and is of the more common species in the genus. Its larvae feed on koa and many other native plants.

Specimens of the other *Scotorythra* species, *S. caryopis* were collected at a sheet using a UV light. This delicate species, which feeds on koa, is less frequently seen and only recorded from the islands of Kauai and Oahu.

Lycaenidae and Nymphalidae (Blue and Brush-footed Butterflies): Only two species of butterflies are native to Hawaii, a blue (Blackburn's butterfly or *Udara blackburni*, which feeds on koa, a`alii and other legumes) and an admiral or brush-footed butterfly (Kamehameha butterfly or *Vanessa tameamea*, which feeds on mamaki and other Urticaceae). Both species are locally common where their hosts are found, and were frequently seen in the valley.

Noctuidae (Army worms and Cutworms): The Hawaiian noctuids are one of the most diverse groups of moths in Hawaii. More than 72 endemic species have been named with many remaining to be described. Little is known about the biology of many of these species other than where they are known to occur.

The genus *Helicoverpa* contains 6 named and one undescribed species. A new species of *Helicoverpa* was collected in the Malaise trap. This species has also been collected from the Tantalus area on Oahu. We do not as yet know what the host plant is for this new moth.

The genus *Agrotis* contains 27 endemic species with 10 occurring on Oahu. A single specimen of the endemic cut worm *Agrotis hephaestaea* Meyrick was collected at a sheet using UV light. The species is endemic to Kauai and Oahu. The larvae are known to feed on *Wikstroemia.*

Orthoptera

Gryllidae (Crickets): There are 243 native species of crickets known from Hawaii (Otte 1994), which is more than twice as many as the total number known from the rest of the United States. Most native species have restricted ranges; some are known from only small areas within single islands. Their great diversity makes them ideal for evolutionary studies (Otte, 1994). Hawaiian crickets live mostly in trees and shrubs, but a few forage in the leaf litter. They are omnivores, feeding on both plant and animal material. Representatives of four native genera were collected in Halawa: two swordtail cricket genera (*Trigonidium* and *Laupala*) and two tree cricket genera (*Leptogryllus* and *Prognathogryllus*).

Tettigoniidae (Katydids): There are only two native genera of long-horned grasshoppers, in the Hawaiian islands (Strazanac, 1986). One specimen in the endemic genus *Banza* was recovered from the Malaise trap. An adult female *B. unica* was collected at the upper end of Halawa Valley. No other specimens were seen over the 4-year long survey. It appears that this species is rare in the valley.

CHAPTER 9
THE INSECT AND RELATED ARTHROPOD FAUNA OF NORTH HALAWA VALLEY. PART 3: DOLICHOPODIDAE (LONG LEGGED FLIES)

NEAL L. EVENHUIS

Genus *Campsicnemus* Haliday

This genus of dolichopodids is one of the most diverse genera of flies in the Hawaiian Islands in numbers of species (136). Only the genus *Drosophila* currently surpasses it (estimated 500). However, there are indications that further study on *Campsicnemus* will show that it has as many or more than *Drosophila* (especially so because the previous concepts of *Drosophila* are being revised and many species previously attributed to it in Hawaii actually belong to other genera).

Campsicnemus is a prominent component of the forest biota in Hawaii both in biomass and number of different species. Both adults and immatures are predators on other insects and small arthropods, especially springtails (Collembola) and possibly soil mites (Oribatida). Males of most *Campsicnemus* species have legs with species-specific structural modifications (some developed into bizarre prominences and tufts of hair) which they use to signal females for mating. Females have no peculiar markings and are often difficult to associate with males. Two different groups of species of *Campsicnemus* occur in Hawaii: 1) water striders and 2) terrestrial species (resting on the forest floor on leaf litter or on low growing vegetation and leaves of overhanging limbs of trees).

Of the 136 described species occurring throughout the Hawaiian Islands, 38 are known from Oahu. The following have been collected with Malaise traps in North Halawa Valley during this study (in order of frequency of collection). An additional species (*C. miritibialis*), a water skater very common in the area, was collected only by sweeping in the stream area and did not occur in the Malaise trapping samples. It is not included in the following list [see report by Polhemus (p. 59) for more details on this species].

***Campsicnemus ornatus* Van Duzee**

This species was by far the most common species collected during the survey. Over 500 individuals were collected from 1991 through 1993. It is a common forest floor species throughout the Koʻolau Range on Oahu. It is endemic to Oahu. It is easily identified by the metallic green coloration on its mesonotum. The biology of this species is not known, but it probably preys on collembola occurring in the leaf litter.

***Campsicnemus gloriosus* Van Duzee**

Approximately two dozen individuals of this species were collected during the survey. It is recorded from Oahu, Lanai, and Molokai. It is known as a fairly common water strider on small pools of water where is has been collected. See report by Polhemus (this volume, p. 59) for observations on this species in North Halawa. Males of this species have conspicuously long hairs on the mid legs used for signaling females.

***Campsicnemus patellifer* Grimshaw**

This small *Campsicnemus* species is endemic to the island of Oahu and was reported by Hardy & Kohn (1964) to be very common on the ground litter in the mountains. It was not found all that commonly in this survey. It is interesting that it is the only described species of *Campsicnemus* worldwide to have modifications to the tip of the antennae in the males to attract females (the tip is conspicuously clavate); instead of having modifications to the legs. An undescribed species with this same type of antennal modification is known from Waikamoi Flume Trail on Maui. A total of 6 individuals of *C. patellifer* were collected during the survey.

***Campsicnemus* sp. A**

A total of 7 individuals of this species were collected during this study. The species is a large yellow fly, which is strikingly different to most other *Campsicnemus* which are typically dark brown. Its biology and behavior is unknown, but given its morphological characters, it appears to be a forest floor dweller and not a water strider.

***Campsicnemus* sp. B**

This small fly looks superficially close to *gloriosus* Van Duzee, but has some differences to leg modifications in the male, which are not found in other species of this genus. It is probably undescribed, but more individuals of it are needed before a good description of it can be made and before it can be named. A total of 2 individuals were collected during this survey.

CHAPTER 10
THE INSECT AND RELATED ARTHROPOD FAUNA OF NORTH HALAWA VALLEY. PART 4: THE LIMNOLOGY AND AQUATIC INSECT FAUNA

DAN A. POLHEMUS

Habitat Description

North Halawa Valley is an elongate catchment approximately 8 kilometers in length, lying on the leeward side of the Koolau Mountains, in the southeast quadrant of the island of Oahu (Figure 1). The valley is one of two major tributaries that form Halawa Stream, the other being South Halawa, which occupies a similarly elongate and parallel valley immediately to the southeast. North Halawa Stream begins as a series of springs emerging from leaks in the perched Koolau Aquifer at elevations between 300 and 600 meters. The waters from these seeps and rheocrenes exist as permanent surface flow in bedrock channels along portions of the headwater reach, until encountering the alluvial fill on the valley floor at approximately 300 meters elevation, a transition interpreted herein as marking the upper boundary of the midreach in this system (for definition of ecological terms see Polhemus *et al.* 1992). From this point downstream the bed substrate consists of rounded rocks and cobbles, and the flow is naturally interrupted, being primarily subsurface during base flow conditions, except in a few areas where bedrock sills force the water to the surface once again. As with most leeward Koolau drainages, the discharge rate of North Halawa stream is flashy and unpredictable, being subject to rapid variations on both a daily and annual basis.

The channel of North Halawa Stream has been highly altered throughout many sections of the midreach in order to accomodate construction of the H-3 freeway, but despite this there are also long sections that appear to retain a semblance of their original bed characteristics and hydrology. Near the mouth of the valley the stream passes by an underground pumping station built in the 1940's by the Board of Water Supply to tap the Koolau Aquifer; this is interpreted to be the dividing point between the mid and terminal reaches for the purposes of this study.

The channel distance from the pumping station downstream to the confluence with South Halawa Stream is approximately one mile, after which the two combined streams, known through this terminal reach simply as Halawa Stream, flow for an additional 2.5 kilometers to the seaward terminus at Pearl Harbor. The stream throughout this terminal reach is highly modified, in many cases having been channelized and realigned, and as such bears little resemblance to its original condition. It is generally devoid of native aquatic biota, with the possible exception of a few itinerant diadromous gobiod fishes such as *Awaos guamensis* which may migrate though during spates on their way to pools further upstream, in company with the introduced Tahitian Prawn (*Macrobrachium lar*).

Methods

Aquatic insects are defined herein as those species spending some significant portion of their life cycle within the stream itself or in the immediately adjacent wet riparian zone. The information of the aquatic insect biota of North Halawa stream presented herein is based on Malaise trap collections made between January 1991 and February 1994 at a site along the extreme upper midreach at 300 meters elevation. Additional stream insect collections were made using yellow pan traps, and general collections throughout the upper valley were undertaken by trained specialists using aerial nets. It is clear from the experience in North Halawa that neither Malaise traps, yellow pan traps, or general collecting alone are sufficient to provide a complete faunal profile of a particular site, and that whenever possible a combination of all possible capture methods should be employed. The use of drift nets, another common aquatic sampling method, was not feasible in North Halawa due to the naturally interrupted character of the midreach, where the channel was frequently dry, and the shallow, nearly laminar flow prevailing through the few perennial sections of the headwater reach.

Results

Thirty species of aquatic insects were collected during sampling in North Halawa Valley. These taxa are detailed in Table 7. Of the taxa collected 22 species, or 73 percent of the total, are taxa considered native to the Hawaiian Islands.

Table 7. Aquatic Insect Taxa Collected in North Halawa Valley
300 meters elevation

Taxon	Taxon Status
COLEOPTERA	
Dytiscidae	
Copelatus parvulus (Boisduval)	I
DIPTERA	
Ceratopogonidae	
Atricopogon jacobsoni (de Meijere)	I
Forcipomyia hardyi Wirth and Howarth	N
Forcipomyia kaneohe Wirth and Howarth	N
Chironomidae	
Cricotopus bicinctus (Meigen)	I
Culicidae	
Aedes albopictus (Skuse)	I
Dolichopodidae	
Campsicnemus gloriosus Van Duzee	N
Campsicnemus miritibialis Van Duzee	N
Ephydridae	
Scatella hawaiiensis (Grimshaw)	N
Psychodidae	
Clogmia albipunctata (Williston)	I
Psychoda sp. undet.	I
Tipulidae	
Limonia hawaiiensis (Grimshaw)	N
Limonia jacobus (Alexander)	N
Limonia perkinsi (Grimshaw)	N
Limonia stygipennis (Alexander)	N
HETEROPTERA	
Veliidae	
Microvelia vagans White	N
Saldidae	
Saldula exulans (White)	N
Saldula procellaris (Kirkaldy)	N
ODONATA	
Aeschnidae	
Anax junius Drury	N
Anax strenuus Hagen	N
Libellulidae[1]	
Nesogonia blackburni (McLachlan)	N
Pantala flavescens (Fabricius)	N

1. An additional introduced species in this family, *Orthemis ferruginea* (Fabricius), was reported by Howarth from the lower valley in 1983, but was not seen during the present surveys.

Table 7. (continued).

Taxon	Taxon Status
ODONATA (continued).	
Coenagrionidae	
Megalagrion hawaiiense (McLachlan)	N
Megalagrion koelense (Blackburn)	N
Megalagrion leptodemas Perkins	N
Megalagrion nigrohamatum nigrolineatum (Blackburn)	N
Megalagrion oahuense (Blackburn)	N
TRICHOPTERA	
Hydropsychidae	
Cheumatopsyche pettiti (Banks)	I
Hydroptilidae	
Oxyethira maya Deming	I
Number of taxa present	
Native	22
Introduced	8
Total	30
Percentage of native species	73%

Explanations of codes used in table:
Taxon type: N = native species, I = introduced species

Discussion

North Halawa Valley is a typical leeward Koolau Mountain drainage, being elongate in form, with a narrow mouth and an expanded headwall amphitheater. The latter characteristics result from the marked precipitation gradient that exists in the valley, with erosion being far more intensive in the upper reaches where the annual rainfall averages 380 cm per year, in comparison to the 100 cm per year falling at the valley mouth (Blumenstock & Price, 1967). A plot of rainfall over the period of this study (Figure 2) shows this precipitation to be highly variable on both a monthly and annual basis. During 1992 and 1993 the wetter months occurred between July and December, but this is an aberration in the context of long term climate records, and was caused by the influence of a strong and prolonged El Niño event. The rainfall total for September 1992 was also influenced by the passage of Hurricane Iniki, which skirted Oahu on September 11th of that year. A more typical pattern is one in which precipitation is concentrated in the winter months, a cycle that appears to have been re-established in 1994, when January and February had very high rainfall totals in comparison to the previous two years (Fig. 2).

Stream discharge is intimately linked to these periods of high precipitation, and sudden localized downpours can occasionally result in catastrophic flash floods, such as that which occurred on 18 November 1930, sending Halawa, Moanalua and Kalihi streams into spate and causing 11 deaths (United States Geological Survey, 1991). Conversely, during drier months there may be a lag between the actual rainfall and the discharge related to it, as water slowly percolates through the recharging aquifer and streambed hyporheos. The unpredictable and naturally interrupted character of North Halawa Stream is thus typical of many leeward Koolau drainages, and is a product of both the marked month-to-month variation in rainfall and the porous nature of the streambed materials.

Due to the form of the valley there are few tributaries along the midreach, while the headwater reach breaks into several major branches, most of which contain perennial flow in sections. As a result, the majority of the aquatic insect species at North Halawa are found in these headwater reaches, where surface water is predictably encountered. These upper tributaries have also acted as refugia for many species in more recent decades, particularly damselflies, since their remote locations and steep gradients have discouraged human settlement and thus limited disturbance. The mid and terminal reaches, by contrast, have seen a long history of human disturbance from Polynesian colonization onward.

In comparison to the well-watered valleys on the windward face of the Koolau Range, the dry leeward valleys have always presented a more seasonally fluctuating set of habitats for aquatic insects, and their biotas have a differing taxonomic composition as a result. An enlightening comparison can be made between North Halawa Stream, on the leeward side, and Kaluanui (Sacred Falls) Stream on the windward, both of these catchments having had intensive recent surveys of their aquatic insect faunas. The aquatic insect biota present in the headwaters of Kaluanui is detailed in Table 8, and may be directly contrasted to the information on the North Halawa headwaters presented in Table 7. One of the most evident differences is in the diversity of torrenticolous flies in the families Canacidae (*Procanace*), Chironomidae (*Telmatogeton*), and Ephydridae (*Scatella*), which are well represented at Kaluanui but absent in North Halawa. This guild of flies lives in splash zones on wet boulders, and requires perennial, high volume flow, a situation common in most windward drainages, but rare in leeward streams.

It should be noted that during the present century the flow of many leeward streams has been augmented by the construction of wells and tunnels, which have tapped the waters of the Koolau Aquifer, or in some cases (such as Waiahole Ditch) even diverted waters from windward drainages under the Koolau Crest. These various water developments have greatly increased the base flow of many leeward streams, altering their ecology and to some degree mitigating the obvious hydrological dichotomy that once prevailed between the drainages of the windward and leeward slopes. Several such water tunnels are present at various points along the headwaters and upper midreach of North Halawa Stream, but do not presently appear to be altering the flow regime in this system.

Despite being a leeward drainage with relatively low discharge, North Halawa Stream supports a diverse aquatic insect biota, particularly in regard to its assemblage of native Odonata. The five species of native *Megalagrion* damselflies occurring in the valley represent the most diverse assemblage still known to occupy any single site on Oahu. Of particular note is the presence of *M. leptodemas*, the North Halawa colony being only one of two breeding populations of this species still known to exist. The *Megalagrion* species at Halawa show an interesting habitat partitioning in regard to their breeding sites, with *M. leptodemas* breeding in small rockhole pools and waterfall plunge pools, *M. nigrohamatum nigrolineatum* in shallow seepage fed pools with substrates of leaf litter in the streambed or along adjacent overflow channels, *M. hawaiiense* on rheocrenes and in other damp and seeping areas, *M. koelense* in the water filled phytotelmata of ieie plants (*Freycinetia arborea*), and *M. oahuense* in moist leaf litter under banks of uluhe fern (*Dicranopteris linearis*) (for additional comments on the ecology of individual taxa see the following section). The presence of this diverse damselfly assemblage is indicative of the generally good ecological condition of the upper valley stream community, and provides a strong argument for protection of the headwater reaches from excessive human intrusion once the highway is completed.

Recent surveys in the leeward Koolau Mountains indicate that the diversity of native Odonata seen in the headwaters of North Halawa Valley may be unusually high in comparison to other remote Koolau headwaters. A 1991 survey of the extreme upper headwaters of Helemano Stream, a relatively undisturbed area reached via the Poamoho Trail, found no evidence of *Megalagrion* damselflies, although five species had been taken in the area as recently as 1979. Similarly, a 1993 helicopter assisted survey of the upper midreaches of Kipapa Stream, a very complex and remote drainage in the central section of the leeward Koolau Mountains, failed to produce evidence of *Megalagrion* populations (Englund, 1993), despite the presence of suitable habitat. The results of these surveys further emphasize the importance of the remaining damselfly populations in North Halawa, which appears to be an important refuge for several increasingly rare species.

Comments on Selected Aquatic Insect Taxa

Odonata

Megalagrion leptodemas - This is a small, slender species, predominantly bright red in coloration with scattered black markings, that breeds in a few small permanent rockhole pools in the upper reaches of North Halawa Valley. *M. leptodemas* was apparently never common, having been recorded from only a few Koolau localities (Helemano, Poamoho, Makiki, Palolo, Kahamainui) since its discovery in 1899, with additional unconfirmed records from Haleauau. Many of these areas have now been heavily impacted by urban, military and agricultural development, and the population in North Halawa is one of only two presently known to remain, the other being in Maakua Gulch, above Haula. Williams (1936) provided an extensive discussion of the biology of this species, with illustrations of the immature stages.

Megalagrion nigrohamatum nigrolineatum - This species may be easily recognized by its relatively small size, slender body, and the coloration of the eyes, which are dark reddish above but bright blue or lime green below. The subspecies *nigrolineatum* is endemic to Oahu. Along North Halawa Stream this species was found in the uppermost headwaters, with adults flying near small pools in the streambed or along adjacent overflow channels. The preferred breeding sites seem to be shallow pools with a substrate of leaf litter. The North Halawa population of this species is one of four presently known to remain on Oahu.

Megalagrion hawaiiense - Although perhaps the most common *Megalagrion* species on Molokai, Maui and Hawaii Islands, *Megalagrion hawaiiense* is now quite rare on Oahu, and is probably the least common of the stream-associated damselflies in North Halawa. Adults of this species may distinguished from other damselflies occurring in the valley by their pale blue coloration overlain with black markings. This blue color form of *M. hawaiiense* is restricted to the southeastern Koolau Mountains, and the North Halawa population is one of only three colonies still known to exist. The remaining Oahu populations in the northwestern Koolaus and the Waianae Mountains are orange and black instead, and thus similar to the morphs occurring on other islands. Adults of *M. hawaiiense* are generally found in the vicinity of rheocrenes, at sites where water seeps over vertical or sloping rock surfaces, and females were observed ovipositing in such situations at a rockhole downstream from the Malaise trap site. The immatures generally prefer these rheocrenes over actual stream pools, which are instead occupied by the immatures of *M. leptodemas* and *M. nigrohamatum nigrolineatum*. The biology of *M. hawaiiense* on Oahu was described in detail by Williams (1936).

Megalagrion oahuense - This is an elongate, dull reddish damselfly that is occasionally encountered in the forest understory along upper reaches of the valley. The larvae are unusual among Zygoptera in that they breed in moist leaf litter under banks of uluhe ferns (*Dicranopteris linearis*), an odd ecology that was elucidated by Williams (1936). As a consequence of its breeding habits, *M. oahuense* is more typically encountered along ridgetops, such as nearby Aiea Ridge, where uluhe is most abundant, rather than in North Halawa Valley itself, although several males have been taken near the Malaise trap site, always in the wetter winter months.

Megalagrion koelense - Adults of this species are predominantly black, with limited yellow markings on the thorax, and are also relatively large and elongate. The immatures breed in the leaf axils of ieie (*Freycinetia arborea*), and are usually found at elevations above 400 m where the frequent mists and rain keep these specialized habitats constantly moist. Captures in North Halawa have been sporadic, with one individual taken along the wall of the upper amphitheater, well above the valley floor, and another in the forest understory near the Malaise trap. *Megalagrion koelense*, like *M. oahuense*, seems to be primarily a species of high ridgetops that only rarely descends to the valley floor, and adults have only been taken during the winter months. Further information on the biology of this species may be found in Williams (1936).

Nesogonia blackburni - This is a small forest dragonfly, easily recognized by its black coloration with scattered bright red patches. Adults are quite territorial, and will base themselves on particular exposed sunny rocks in the streambed, from which they fly short beats up and down the surrounding stream channel. The population in North Halawa Valley appears to be relatively small, but individual insects seem to have moderate longevity, since the same territory will be predictably guarded for many weeks running by what is presumably the same dragonfly.

Anax strenuus - This is a large, swift dragonfly that is frequently seen patrolling along the streambed in the upper valley. The immatures breed in stream pools, and are the largest native subaquatic predators in North Halawa, capable of consuming frogs and small fish. The adults are also fiercely predaceous, and actively hunt a wide range of flying insects, including the smaller damselflies in the genus *Megalagrion*. Much additional information on the biology of this species may be found in Williams (1936).

Diptera

Campsicnemus miritibialis - This is a moderately large, active, water skating fly, adults of which are found as scattered individuals on flowing pools or in the tailraces of small riffles. Due to its preference for flowing water, this species is most abundantly encountered along North Halawa Stream during the rainier periods of the year. Williams (1939) provided notes on the biology of this species.

Campsicnemus gloriosus - This is a small, yellowish, water skating species, adults of which are usually found on standing pools in the North Halawa headwaters. This species occasionally attains very high adult densities when the waters in such pools begin to stagnate during dry periods of the year.

Limonia stygipennis - This dark colored crane fly is the largest native tipulid in Hawaii. Adults are found in dark, moist cavities amid boulder jams, from which they issue forth with great rapidity if disturbed.

Limonia jacobus - This small brown native crane fly is common along streams throughout the high Hawaiian islands. At North Halawa adults were found flying above moist, shaded, rocky sections of the streambed in the headwater reach, often in company with *L. stygipennis*. Additional observations on the biology of this species may be found in Williams (1943).

Coleoptera

Copelatus parvulus - This small introduced water beetle is found in isolated permanent pools along the headwater reaches, and appears to be particularly abundant during dry periods when such pools afford the only permanent aquatic refugia in the valley. The biology of this species was discussed in detail by Williams (1936).

Heteroptera

Microvelia vagans - This tiny water skating bug is a common endemic species widely distributed on the all high Hawaiian islands. In North Halawa Valley it is found around the margins of calm pools, often in water pockets amid the cobbles lining the stream margins, from the headwaters through the midreach.

Saldula exulans - This endemic shore bug is widely distributed on all the high Hawaiian islands. At North Halawa this species is common on wet rocks in and near the streambed, in both dry and flowing sections. If pursued, individuals display an interesting habit, anomalous within the Saldidae, of jumping into the water and swimming to an adjacent rock.

Saldula procellaris - This is a smaller and less brightly marked species than *S. exulans*, and is more localized in its distribution in North Halawa Valley, being found on damp rock faces adjacent to waterfalls in the upper headwater reach.

Table 8. **Aquatic Insect Taxa Collected in Kaluanui Stream**. 670 meters elevation.

Kaluanui is typical of upper elevation drainages on the windward side of the Koolau Mountains. Note the marked difference in aquatic insect faunal composition as compared to that seen in the headwaters of North Halawa Stream on the leeward slope (Table 7).

Insect Taxon	Taxon Status
DIPTERA	
Canaceidae	
Procanace bifurcata Hardy and Delfinado	N
Procanace wirthi Hardy and Delfinado	N
Ceratopogonidae	
Forcipomyia sp. undet.	N
Chironomidae	
Telmatogeton fluviatilis Wirth	N
Telmatogeton abnormis (Terry)	N
Telmatogeton williamsi Wirth	N
Calopsectra hawaiiensis Hardy	N
Dolichopodidae	
Campsicnemus miritibialis Van Duzee	N
Ephydridae	
Scatella cilipes (Wirth)	N
Scatella clavipes (Wirth)	N
Scatella hawaiiensis Grimshaw	N
Tipulidae	
Limonia advena (Alexander)	I
Limonia jacobus (Alexander)	N
Limonia stygipennis (Alexander)	N
HETEROPTERA	
Veliidae	
Microvelia vagans White	N
Saldidae	
Saldula exulans (White)	N
LEPIDOPTERA	
Cosmopterigidae	
Hyposmocoma nr. *montivolans* (Butler)	N
ODONATA	
Aeschnidae	
Anax strenuus Hagen	N
Libellulidae	
Pantala flavescens (Fabricius)	N
Coenagrionidae	
Megalagrion nigrohamatum nigrolineatum (Blackburn)	N
Megalagrion oceanicum McLachlan	N

Table 8. (continued).

Insect Taxon	**Taxon Status**
TRICHOPTERA	
Hydropsychidae	
Cheumatopsyche pettiti (Banks)	I
Hydroptilidae	
Hydroptila arctia Ross	I
Number of taxa present	
Native	20
Introduced	3
Total	23
Percentage of native species	87%

Explanations of codes used in table:
Taxon type: N = native species, I = introduced species

CHAPTER 11
THE BIRDS OF NORTH HALAWA VALLEY

DAVID J. PRESTON, ROBERT PYLE†, & FRANCIS G. HOWARTH

Introduction

North Halawa Valley was largely inaccessible to scientists and naturalists until 1987, and records of birds present in the valley were limited to observations made during occasional visits on foot to the valley or along the neighboring ridges. The first comprehensive bird survey of the area was made by Shallenberger in 1976—1977. His survey recorded 20 species from North Halawa Valley (Shallenberger 1977). Following construction of the access road in 1987, travel to the back of the valley became easier, and the number of records increased.

From November 1991 to February 1994, one of us (Preston) recorded birds seen during visits to maintain an insect trap at the upper end of the valley. These observations were made approximately weekly throughout the valley. This report details the results of the survey augmented with records from previous surveys. Additional records are provided by Bishop Museum archaeologists.

Site Description

North Halawa Valley is located on the leeward side of the Koolau Mountains. The valley is approximately 8 km long rising to an elevation of about 396 m. The vegetation is a mixture of *Andropogon*-*Schinus* at the lower altitudes, guava-*Syzygium* at the mid-altitudes, changing to native Koa-Ohia-*Hibiscus* at the upper elevations. The valley floor rising southwest to northeast, is bounded by Aiea Ridge to the north and the Halawa Ridge to the south. Vegetation is remarkably partitioned throughout the valley such that definite vegetation types can be clearly observed. Much of the central valley floor is dominated by *Hibiscus*, or hau, making access to large areas of the valley very difficult. At higher altitudes the forest canopy is more open and diverse affording better opportunity for bird sightings.

Methods

This study began with a review of the historic avifaunal records for North Halawa Valley and the surrounding areas. The Bishop Museum bird sighting database yielded records from 1976 through 1991. Records from 1991 through 1994 are from observations by the senior author with assistance from various visiting specialists. A record of the species, site where seen, vegetation at the particular site and any noteworthy observations were made. Birds were spotted using 10× binoculars and a 15×–60× spotting scope.

Results

A total of 32 species of birds were recorded from North Halawa Valley from 1976 to 1994. These taxa are listed in Table 9. Of the 32 taxa recorded only 6 are native, one of which is on the Federal Endangered Species List. The more notable records are annotated in Table 9.

Table 9. Checklist of the Birds of North Halawa Valley and Adjacent Areas 1994

Taxon	NHV 1976-1977	NHV 1991-1994	SHV 1976	Hhts	ART	MV	HRT	Status (in Hawaii)
PROCELLARIIDAE								
Wedge-tailed Shearwater *Puffinus pacificus*		X						Bi
ARDEIDAE								
Cattle Egret *Bubulcus ibis*		X						An
Black-crowned Night-Heron *Nycticorax nycticorax*	X	X						Ri
CHARADRIIDAE								
Pacific Golden Plover *Pluvialis dominica*	X	X					X	Vc
COLUMBIDAE								
Spotted Dove *Streptopelia chinensis*	X	X	X	X	X	X	X	Al
Zebra Dove *Geopelia striata*	X	X	X	X	X	X	X	Al
TYTONIDAE								
Barn Owl *Tyto alba*				X	X			An
STRIGIDAE								
Pueo *Asio flammeus sandwichensis*	X							Re
APODIDAE								
Grey Swiftlet *Aerodramus vanikorensis*	X	X					X	An
PYCNONOTIDAE								
Red-vented Bulbul *Pycnonotus cafer*	X	X	X					An
Red-whiskered Bulbul *Pycnonotus jocosus*		X						An
MUSCICAPIDAE								
Japanese Bush-Warbler *Cettia diphone*	X	X			X		X	Al
Oahu ‘Elepaio *Chasiempis sandwichensis ibidus*	X	X	X	X	X	X	X	Re
White-rumped Shama *Copsychus malabaricus*	X	X	X	X	X	X	X	Al
Hwamei (Melodious Laughing Thrush) *Garrulax canorus*	X	X		X	X	X	X	Al
Red-billed Leiothrix *Leiothrix lutea*	X	X			X		X	Al
MIMIDAE								
Northern Mockingbird *Mimus polyglottos*		(?)					X	Al

Table 9. Checklist of the Birds of North Halawa Valley and Adjacent Areas 1994

Taxon	NHV 1976-1977	NHV 1991-1994	SHV 1976	Hhts	ART	MV	HRT	Status (in Hawaii)
STURNIDAE								
Common Myna *Acridotheres tristis*	X	X	X	X	X	X	X	Al
ZOSTEROPIDAE								
Japanese White-eye *Zosterops japonicus*	X	X	X	X	X	X	X	Al
EMBERIZIDAE								
Northern Cardinal *Cardinalis cardinalis*	X	X	X	X	X	X	X	Al
Red-crested Cardinal *Paroaria coronata*		X						Al
Yellow-faced Grassquit *Tiaris olivacea*					X		X	An
Saffron Finch *Sicalis flaveola*		X						An
FRINGILLIDAE								
House Finch (Linnet) *Carpodacus mexicanus*	X	X	X	X	X	X	X	Al
Common ‘Amakihi *Hemignathus virens*	X	X	X	X	X	X	X	Re
‘Alauahio (Oahu Creeper) *Paroreomyza maculata*	X				X	X		ReE
‘I‘iwi *Vestiaria coccinea*	(?)							Re
‘Apapane *Himatione sanguinea*		X	X		X		X	Re
PASSERIDAE								
House Sparrow *Passer domesticus*		X	X			X		Al
PLOCEIDAE								
Red Bishop (escaped) *Euplectes orix*	X							A
ESTRILDIDAE								
Common Waxbill *Estrilda astrild*		X						Al
Nutmeg Mannikin *Lonchura punctulata*	X	X	X	X	X	X		Al

Status (from Pyle, 1992): A = Alien introduced species; resident; normally does not leave the islands; Al = Alien; long established and breeding since before 1940; An = Alien; new introduction since 1950; apparently established; Bi = Breeder; Hawaiian form also breeds elsewhere; Re = Resident; endemic; ReE = Resident; endemic; endangered; Ri = Resident; indigenous species; Hawaiian form is not endemic; Vc= Visitor; common migrant to Hawaii. **Locality**: NHV = North Halawa Valley; SHV = South Halawa Valley;ART = Aiea Ridge Trail; HRT = Halawa Ridge Trail; Hhts = Halawa Hights (residential area); MV = Moanalua Valley;

Notable Bird Species Recorded from North Halawa Valley

Procellariidae
Puffinus pacificus - A single Wedge-Tailed Shearwater apparently strayed into the valley on 28 November 1992. The bird had no apparent injury and after recording its band number it was released.

Ardeidae
Nycticorax nycticorax - The Black-crowned Night-Heron was recorded by Shallenberger in North Halawa Valley during his 1977 survey. This rather large bird was also observed by D.J. Preston on February of 1992 in the channeled area of North Halawa Stream near the sub-division.

Charadriidae
Pluvialis dominica - The Pacific Golden Plover was observed by Shallenberger in 1976 and 1977 and by D.J. Preston in the lower portion of the valley in the vicinity of the cement plant from 1991–1993. A winter visitor, this bird is quite common in open fields and parking lots in the area from August through April.

Columbidae
Geopelia striata and *Streptopelia chinensis* - The Zebra Dove and the Spotted Dove are very common throughout the valley. Sightings were made in 1976–1977, 1980–1991, and 1991–1994.

Apodidae
Aerodramus vanikorensis - This small dark-grayish swiftlet was observed by Shallenberger and others in 1976, 1977 and by D.J. Preston and F.G. Howarth in December, 1993 in a western tributary near the top of the valley. Earlier sightings of swiftlets hawking insects were made at or near the Eucalyptus grove during the 1976 and 1977 surveys by Shallenberger and again in 1983 by F.G. Howarth viewing the same area from the Halawa Ridge Trail.

In December of 1993 several birds were observed in and near a manmade water tunnel at the base of a water fall. At least 4 individuals were seen exiting the tunnel as the senior author approached the falls. Upon entering the tunnel several nests were spotted attached to the cave walls at 30.5 to 167 cm above the muddy floor near the end of the tunnel nearly 61 m from the entrance. Fresh saliva was noticed on 4 of the nests indicating recent activity.

Pycnonotidae
Pycnonotus cafer - The Red-vented Bulbul frequents all areas of North Halawa Valley. It is most common in the midreaches of the valley. It can be heard trying to mimic the shama on occasion.

Pycnonotus jocosus - The Red-whiskered Bulbul seems restricted to the Eucalyptus grove area near the middle of North Halawa Valley. On occasion this species will venture up to the tunnel area at about the 1000 ft. elevation in search of guavas and insects, but not in large numbers, preferring to stay at lower elevations.

Muscicapidae
Cettia diphone - The Japanese Bush-Warbler is more often heard than seen in North Halawa Valley. This is the case of observations made between 1991 and 1994. Actual visual records were not made, instead their call was enough to confirm their presence.

Chasiempis sandwichensis ibidis - The Oahu ‘Elepaio is one of the most endearing of our native birds. It’s inquisitive nature and a noticeable lack of fear of humans make this a fascinating bird to watch. One is able to get very close to the bird to make a positive identification. This species appears to be common only in upper reaches of the valley. The Oahu population is now very rare and the race is an official candidate for Federal Endangered Species listing. North Halawa valley is one of the few places where individuals have been seen consistently in the last 3–5 years.

Copsychus malabaricus - The White-rumped Shama is one of the most common species in the valley. It has been seen and heard regularly during weekly visits to the valley since November 1991.

Garrulax canorus - The Hwamei was rarely seen but often heard at the higher end of North Halawa Valley. It is more common along the Aiea Ridge Trail and sometimes seen in South Halawa Valley. This alien species became established in Hawaii in 1900.

Leiothrix lutea - The Red-billed Leiothrix has long been an important pet species in Hawaii and around the world. The species was introduced and became established in Hawaii in 1918 and is found in small numbers on most islands. Since becoming established, numbers dropped drastically on Kauai and Oahu, but the species is again increasing its numbers on Oahu. At least 6 pairs have been observed from very low in the valley at a patch of lilikoi (passion fruit) up to site 3 at 304.8 m elevation near an insect trap (see Entomology report), which is located just above the H-3 portals in North Halawa Stream.

Mimidae

Mimus polyglottos - The Northern Mockingbird has not been reported from North Halawa Valley, however it has been seen on Halawa Ridge Trail. Several workers in the valley claim to have heard this bird but there have been no confirmed sightings.

Sturnidae

Acridotheres tristis - The Common Myna, introduced and established in the Hawaiian Islands in 1865, is now abundant on all main islands, and also has a small population on Midway. It is common throughout the valley but more abundant in lower, more disturbed areas.

Zosteropidae

Zosterops japonicus - The Japanese White-eye, probably the most abundant bird in the valley, is common at all elevations. Insectivory and fruit-eating is very common during the guava fruiting season as well as the lilikoi (Passion fruit) season.

Emberizidae

Cardinalis cardinalis - The red Northern Cardinal is an attractive but noisy bird. It is more conspicuous during its mating season between December through February. This species seems to prefer the lower portions of the valley as seed grasses can be exploited there. Numerous records exist for this widespread species in Halawa Valley.

Tiaris olivacea - The Yellow-faced Grassquit was not observed during our 1991—1994 survey. Records exist only from Shallenberger’s 1977 survey. This is not a common species. Shallenberger observed this bird at about the 2000 ft. elevation along the Aiea Ridge Trail.

Sicalis flaveola - The Saffron Finch was observed by Bruce Eilerts in the Crosspointe subdivision near the Aloha Stadium in 1991. It is not yet known from North Halawa Valley.

Fringillidae

Carpodacus mexicanus - The House Finch is very common in the valley and adjacent areas of North Halawa. Numerous records exist from North Halawa Valley from 1976—1994.

Hemignathus virens - The Oahu Amakihi is another very common inhabitant of North Halawa Valley. It's high whizzing call can be readily distinguished from the other birds in the valley. Able to blend well with the foliage, this species is not always easy to see at first. This species is the most common endemic bird in the valley.

Himatione sanguinea - The Apapane is fairly common in native ohia lehua rain forests at higher elevations on Oahu and is frequently seen or heard in the upper reaches of the valley above 300 m (1000 feet) elevation.

Paroreomyza maculata - The Oahu Creeper has not been authoritatively sighted in Halawa Valley since 1978. This species is officially listed as endangered on both the State and Federal Endangered Species Lists. It has been rarely sighted in recent decades. The 1978 Halawa record is one of the last known observations of this very rare species.

Vestiaria coccinea - The I‘iwi certainly lived in Halawa Valley in the past, but has become rare on Oahu in recent decades. Only one recent sighting of the I‘iwi in North Halawa Valley is known, that being a questionable sighting at about the 300 m (1000 foot) elevation in April 1981.

Passeridae

Passer domesticus - The house sparrow was not recorded in North Halawa Valley until 1982. It was recorded again in 1991, 1992, 1993 and 1994. This species is very common in the area of the cement plant of the H-3 highway project just above the animal quarantine station, but does not seem to venture much higher into the valley.

Ploceidae

Euplectes orix - An isolated record of the Red Bishop in 1976 was probably an escaped cage bird. It is not known to be established anywhere in Hawaii and has not been observed since.

Estrilidae

Estrilda astrild - The Common Waxbill inhabits the lower grassland areas of North Halawa Valley. These birds gather in flocks of 5–20 or more birds and feed on the tops of tall grasses.

Lonchura punctulata - The Nutmeg Mannikin. Observed in 1977 and again in 1991 but not recorded since.

CHAPTER 12
THE NON-BIRD VERTEBRATE FAUNA OF NORTH HALAWA VALLEY

DAVID J. PRESTON

Introduction

Natural history surveys in North Halawa Valley have been few and far between, and not until the early 1990s was there any attempt to catalog the non-bird vertebrates of this valley. This report lists all the vertebrates (except the birds) observed in the valley from November 1990 to October 1994.

Site Description

North Halawa Valley is located on the leeward side of the Koolau Mountains and is nearly 8 km long, rising to an elevation of about 400 m. In the lower reaches of the valley the vegetation is made up of mostly weedy herbs and shrubs, with *Schinus* being dominant. The mid-reaches of the valley are dominated by *Psidium* (guava) and *Hibiscus tiliaceus* (hau). At the upper end of the valley vegetation is a composite of ‘õhi‘a forest, kukui forest, koa forest, and *Psidium* forest, with ‘ōhi‘a being dominant. For a more complete description of the valley see chapters 1 and 2.

Methods

Records of the non-bird vertebrates are based on observations and collections made in conjunction with weekly visits to the valley to service an insect trap at the upper end. Additional observations were made by Bishop Museum staff archaeologists and visiting research biologists. While it was not practical to collect any of the mammals, visual records were made. Voucher specimens of most of the reptiles and amphibians were collected and deposited at the Bishop Museum. Records for cattle, goats and axis deer are based on historical or anecdotal information.

Results

A total of 20 species of non-bird vertebrates were either collected or observed during three years of sampling in North Halawa Valley. Additional records were added based on historical information. These taxa are listed in Table 10. Except for the native bat, *Lasiurus cinereus semotus,* all of the species observed and or collected are considered to be alien to the Hawaiian Islands. A brief discussion of the notable records is given below.

Table 10. Terrestrial and Aquatic Non-bird Vertebrate Fauna of North Halawa Valley

Taxa	Status	Observed	Occurs elsewhere but not seen in North	Specimen Collected	BPBM Catalog no.
AMPHIBIA					
Anura					
Ranidae					
Rana catesbeiana	Pur	X			
Rana rugosa	Pur			X	12210-12211
Bufonidae					
Bufo marinus	Pur	X			
REPTILIA					
Squamata					
Iguanidae					
Anolis carolinensis porcatus	A	X			
Gekkonidae					
Gehyra mutilata	A		X		
Hemidactylus frenatus	A		X		
Hemidactylus garnoti	A		X		
Hemiphyllodactylus typus typus	A		X		
Lepidodactylus lugubris	A			X	12212–12214
Scincidae					
Lampropholis delicata	A			X	12215
Lipinia noctua noctua	A		X		
Typhlopidae					
Ramphotyphlops braminus	A		X		
FISHES					
GAMBUSINOS					
Poeciliidae					
Gambusia sp.	Pur			X	35797
Lebistes reticulatus	Pur		X		
Xiphphorus helleri	Pur			X	35798
MAMMALIA					
Chiroptera					
Vespertilionidae					
Lasiurus cinereus semotus	E	(*)			
Rodentia					
Muridae					
Rattus sp. (spp.)	A			(bones)	
Mus musculus domesticus	A	X			
Carnivora					
Canidae					
Canis lupus	Pur	X			

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Table 10. Terrestrial and Aquatic Non-bird Vertebrate Fauna of North Halawa Valley

Taxa	Status	Observed	Occurs elsewhere but not seen in North	Specimen Collected	BPBM Catalog no.
Viverridae					
Herpestes javanicus	Pur	X			
Felidae					
Felis silvestris	Pur	X			
Artiodactyla					
Suidae					
Sus scrofa scrofa	Pur	X			
Cervidae				(bones)	
Axis axis	Pur	(*)			
Bovidae					
Bos tarus	Pur	(*)		(bones)	
Capra hircus hircus	Pur	(*)			

Status codes: E = endemic, A = alien, Pur = purposely introduced.
Record codes: X = positive, (*) = historic or anecdotal records, not seen during study.

Notable Non-bird Vertebrates from North Halawa Valley

Amphibians

Two species of frog and one toad occur in North Halawa. The Japanese wrinkled frog was introduced in 1896 to control insects (McKeown, 1978, p. 18), and is the most common amphibian found in the valley. It is very common at higher elevations and near the entomologist's trap site located at 400 m. The bullfrog, which was purposely introduced from California in 1867 and again in 1879 as a food source (McKeown 1978, p.16), is not very common and was seen on only one occasion. It seems to be restricted to the lower reaches of North Halawa Stream. The cane toad which was purposely introduced in 1932 from Puerto Rico (McKeown 1978, p. 20) to control pest insects is frequently encountered as road kills at lower sections in the valley. Specimens of the Japanese wrinkled frog were collected, but only visual records were made for the bullfrog and the cane toad.

Reptiles

Three species of lizard and one snake were observed in North Halawa Valley. Three specimens of *Lepidodactylus lugubris* and one *Lampropholis delicata* were captured. Visual records for the green anole and the blind snake were made but no specimens were collected. All are introductions. These predators pose a threat to native insects and related arthropods. Other lizards may inhabit the valley but were not observed. Lizards known from similar valleys but not seen in Halawa are listed in Table l0.

Fishes

There were three species of fish observed in North Halawa. The common guppy, the mosquito fish *Gambusia*, and the green swordtail are present. The mosquito fish seems to be the most abundant and restricted to the lower reaches of North Halawa Stream. The green swordtail is also quite common at lower elevations. The guppy although in lower numbers is still common. No gobiioids were observed in the valley.

Bats

The native bat *Lasiurus cinereus semotus* was not observed during our survey of the valley. This species has not been authoritatively sighted on Oahu for nearly 100 years although reports from hikers seeing bats continue to persist. It is likely these reports are sightings of the very large Black witch moth that feeds on monkeypod in the larval stage and is quite common in the valley.

Mongoose

The mongoose is the most common mammalian predator found in the valley. It is present at all elevations and very abundant in the lower reaches of North Halawa Valley. The mongoose was purposely introduced to Oahu from either populations on Hawaii island or subsequent introductions from the West Indies. They were originally brought to Hawaii to help reduce the rat populations (Tomich 1986, p. 95).

Rodents

At least one species of rat and one species of field mouse are known to occur in North Halawa Valley. Both were observed by various construction workers and Bishop Museum staff scientists on numerous occasions during the last three years. The rats seem to be more common in the midreaches in association with rocky outcroppings and palm trees. The field mouse is quite common at lower elevations among weedy shrubs and in grassy areas.

Feral Dogs and Cats

On several occasions a single dog and several cats were observed at the lower end of the valley. These animals are undoubtedly strays that are taking advantage of the leftovers from construction workers. A few sightings of cats were made in the middle and upper reaches of the valley. Many of Hawaii's natural historians have documented bird predation by feral cats over the years. There is no reason to doubt that cats also prey on the birds of North Halawa Valley. Further study needs to be done to confirm this.

Feral Pigs

The first pig brought to Hawaii is believed to have been a smallish, Asian species introduced by the Polynesians, and was an important prehistoric food source (Luomala, 1960). The Polynesian pig no longer exists here in its original form, with the pig as we know it today being a cross between the Polynesian pig and European hogs, which were brought to Hawaii on Cook's first voyage to the Islands in 1778 (Tomich, 1986). This form is now established on all the main islands and is common at all elevations. Several times during 1992 entomologists recorded pig damage to their insect trap placed just above the H-3 tunnels. During weekly visits to the valley fresh pig tracks and rooting damage were observed at the middle and upper elevations. Construction workers have observed pigs near a cement plant which is located at the lower end of the valley. In December of 1993 a large carcass was observed in a drainage just below the H-3 portals. A second carcass of a very young pig was observed near the Malaise trap site. Skeletal remains of the second pig were collected and brought back to the Bishop Museum. Disturbance by pigs to the remaining native flora is very evident. Pig activity has diminished slightly in the lower reaches of the valley due to the highway construction activities, which seem to have pushed the pigs higher up into the back areas where the vegetation is more pristine and as a result at higher risk. Hunting pressures have been curtailed since the initiation of construction allowing populations to grow.

Other Ungulates

Cattle, goats, and axis deer were not observed during this study, however historical records of cattle and goats, and the possibility of axis deer entering the valley from Moanalua Valley deserve mention here. Axis deer were introduced to Molokai in 1868 (Tomich 1986). From the original stock on Molokai several deer were brought to and released on Oahu in 1920.

Populations were established in Moanalua Valley and the nearby Salt lake area. Although no reliable records exist for axis deer entering North Halawa Valley, reports of sightings by several longtime residents near the valley support claims that axis deer did inhabit the valley at one time. Cattle and goats are also known to have inhabited nearly every valley on Oahu at one time or another, thus it would not have been unusual for cattle and goats to have entered Halawa.

Impact of Vertebrates on the Current Environment

Halawa Valley's native biota are at constant risk from alien species. Loss of native species occurs either by predation or loss of habitat due to the destruction of the forest.

Cattle probably had the biggest impact on the native environment of North Halawa Valley. Large portions of lower sections of the valley had likely been cleared of native vegetation to allow for pasture, and rock walls in the middle portion of the valley suggest cattle barriers. Major changes in surface runoff patterns must have occurred due to erosion caused by foraging and damage to vegetation that would otherwise retain the soil. Documented evidence places cattle in the valley from 1830 to the start of sugar growing in 1898. Feral cattle must have persisted for some time after ranching ceased. Cattle do not inhabit North Halawa Valley today.

Other ungulates are believed to have inhabited the valley, but no documentation other than stories from longtime residents near the valley and accounts from older hunters recalling past adventures are available to support these claims. If goats and deer actually existed in the valley for even a short period, massive destruction to native forest would have occurred and many native insects and other animals, especially birds would have been heavily impacted and possibly driven out.

Hawaii has a long history of negative impact of alien predators on native animals, especially birds. Records of predation on native ground nesting birds by feral dogs, cats, and mongooses are well known. These predators are undoubtedly a major threat to the remaining native birds in the valley.

Amphibians and reptiles, all of which are predators, are probably responsible for some loss of lowland insects. Documentation of population declines of native damselflies coincides with the introduction of frogs and fishes. There is some evidence that where the Japanese wrinkled frog is abundant, native aquatic insect diversity is lower. Future studies will improve our knowledge of their true impact on native biota.

Although no native fish were found during this study, native gobiioids must have inhabited the valley at one time. It is well known that alien fish introductions throughout Hawaii have proven disastrous. Documentation of native species occurrence and abundance, relative to alien fish presence, has shown that as the number of alien fish species in a given stream increases, the number of native fish species decreases or is eliminated.

Vertebrate Faunal Change Over Time

As stated above, the Polynesian pig is of Asian ancestry. It is believed to have been a small species that adapted well to domestication (Buck, 1957). Prehistoric Hawaiians must have brought the pig into the valley and some of them evidently escaped into the wild. With the introduction of the European pig in 1785, and its subsequent escape and establishment on all the high islands of Hawaii, it was not long before the two varieties of pig produced what is now known as the Hawaiian feral pig. The result was a cross-bred pig of rather large stature, reaching weights of over 226.8 kg. As to be expected, this large animal is capable of great destruction to the native forest.

The Polynesian or poi dog was a rather small animal standing about 35.5 cm at the shoulder (Tomich, 1986). The poi dog was valued for food, as an item of barter, and for sacrifice, and was used in sorcery and folklore (Luomala, 1960). Here again, some of the first dogs must have escaped or were purposely allowed to mix with European introduced dogs producing an animal that was much larger. It was not until the introduction of ungulates that dogs would be able to establish thriving populations in the wild. There first needed to be an available food source. Goats would have provided the necessary food source for a wild dog population. Cattle may have also played a minor role in providing food for marauding packs of wild dogs. As no documentation exists to support any of these speculations, information gathered from similar valleys can be used to shed light on what might have gone on in North Halawa.

Native fish in Halawa Valley appear to be nonexistent. We expect that native gobiiods once inhabited the valley, however no current records exist. Channelization combined with negative impact from alien species, has probably wiped them out. At least three species of fish do occur in the valley, however all are alien.

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CHAPTER 13
GLOSSARY

Adiabatic Lapse Rate: An equation describing the rate at which air temperature decreases as elevation increases. In Hawaii this is calculated as a "moist rate," and is generally 5.5 °C/km (= ~3 °F/1000ft.).

Adventive: An inadvertently introduced non-native species.

Alien: A non-native species introduced to a region either purposefully or inadvertently through the actions of humans.

Alluvial: Relating to, or composed of, material deposited by running water.

Annual: Plant species living for one year.

Arborescent: Resembling a tree.

Colluvial: Relating to, or composed of, material deposited by gravity; for example rock detritus and soil accumulated at the base of a slope.

Diadromous: Relating to animals that migrate between fresh and salt waters.

Edaphic: Pertaining to, or influenced by, the soil.

El Niño: A warm ocean current that periodically develops off Peru, usually around the Christmas season, causing a warming of the ocean surface in the eastern tropical Pacific, and subsequent changes in atmospheric circulation. Due to its pronounced effect on the Southern Oscillation of the atmosphere, such a condition is also frequently referred to as an ENSO (El Niño/Southern Oscillation) event.

Endemic: Native to and restricted to a geographical region.

Exotic: See alien.

Headwater Reach: That portion of a Hawaiian stream lying at elevations above 800 m, and/or with a gradient exceeding 30%.

Herbaceous: Non-woody.

Hyporheos: Underground water flow beneath or lateral to a stream.

Indigenous: Native to but not restricted to a geographical region.

Malaise Trap: A large, tent-like trap made of net material, suspended in insect flyways, and used to capture flying insects.

Mesonotum: The dorsal surface of the middle segment of an insect thorax.

Mid Reach: The middle portion of a stream, displaying characteristics intermediate between Headwater and Terminal Reaches.

Native Species: A species naturally occurring in a region, i.e., having colonized the region without the aid of humans (See Endemic and Indigenous).

Phytotelmata: A moist habitat found at the base of large leaf axils.

Rheocrene: A moist habitat formed where a thin sheet of water flows over a steeply sloping bare rock face or cliff.

Riparien: Pertaining to the area along the bank of a river or stream.

Sill: A more or less horizontal sheetlike intrusion of magma lying parallel to stratified rock layers; i.e., a horizontal dike.

Spate: A sudden increase in stream flow following rain: a flash flood.

Terminal Reach: The lower portion of a Hawaiian stream, lying at an elevation less than 50 m, and with a gradient less than 5%.

Torrenticolous: Relating to an organism that normally lives in stream habitats exposed to strong currents.

Vascular plant: A plant having a specialized conducting system that includes xylem and phloem; i.e., the higher plants, including ferns, gymnosperms, and flowering plants, but excluding fungi, mosses, lichens, and algae.

CHAPTER 14
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