



**Kāneʻohe Bay, Oʻahu  
Stream Estuary Studies**

**Hawaii  
Biological  
Survey**

**Final Report**

**May 2003**

**FINAL REPORT**  
**KĀNE‘OHE BAY, O‘AHU STREAM ESTUARY STUDIES**

**Prepared for:**  
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## INTRODUCTION

Surveys of native and nonindigenous species by the Hawaii Biological Survey of the Bishop Museum were conducted along the stream estuary regions of Kāneʻohe Bay from May 2001 to April 2003, and were funded by a grant from the David and Lucile Packard Foundation with matching Dingell-Johnson funding provided by the Hawaii Department of Natural Resources, Division of Aquatic Resources. This project was conducted in two phases, with the first phase involving investigations of marine organisms in Kāneʻohe Bay (Coles et al. 2002), with an emphasis on the detection of nonindigenous marine organisms, with stream mouth estuarine areas examined during the present study. The current study investigated the lowest sections of stream estuaries, or areas where freshwater mixes with ocean water upon entering Kāneʻohe Bay, and emphasized the detection of nonindigenous freshwater and estuarine organisms. The study area extended from the Kawa Stream estuary on the easternmost portion of Kāneʻohe Bay to the Hakipuʻu Stream estuary on the western end of Kāneʻohe Bay. Because of the great importance of riparian vegetation in providing habitat and cover for aquatic organisms this study also examined aquatic vegetation in the estuarine reaches of the surveyed streams. This report provides an update of collected taxa that have been identified to the lowest possible taxonomic level. Field collections and specimen identifications were finalized in April 2003.

## STUDY AREA

Located on windward Oʻahu, ten major named stream systems empty into Kāneʻohe Bay, encompassing a watershed approximately 40 square miles in size (Takasaki et al. 1969). From south to north these streams include Kawa, Kāneʻohe, Keaʻahala, Heʻeia, Kahaluʻu, Waiheʻe, Kaʻalaea, Waiāhole, Waikāne, and Hakipuʻu. With the exception of Kawa Stream at the southern end of Kāneʻohe Bay, these streams originate as amphitheater-headed valleys along the steep crests of the central western Koʻolau mountain range. Kawa Stream originates from the low hills separating Kāneʻohe and Kailua Bays at a much lower elevation (ca. 300 ft) than the other Kāneʻohe Bay streams. Because of the close proximity of the Koʻolau mountain range to the ocean, channel lengths for Kāneʻohe Bay streams are abbreviated when compared to the longer leeward Oʻahu stream channels. These short lengths also lead to steeper stream gradients and relatively straight, non-sinuuous stream channels when compared to leeward Koʻolau mountain stream channels.

Hydrologic conditions of all Kāneʻohe Bay streams have been greatly altered by stream diversions and groundwater wells (Takasaki et al. 1969). This alteration has resulted in the loss of numerous springs flowing into these streams and decreased streamflow (Miyagi 1963; Devaney et al. 1976). For example, a diversion tunnel in upper Haiʻkū Valley (Heʻeia watershed) intercepts approximately 1 million gallons/day (mgd) of water that originally flowed for another 2.5 miles and ended in Kahaluʻu Stream (Takasaki et al. 1969). Prior to the partial restoration of water flow in Waiāhole Stream in 1994, stream and freshwater

discharge into Kāneʻohe Bay had been reduced from 83.2 mgd to 48.1 mgd, a decrease of greater than 40% (Devaney et al. 1976). Additionally, these reductions in stream flow throughout the Kāneʻohe Bay watershed have also had the effect of greatly changing original estuarine conditions by altering the system towards a more marine condition.

A general description and GPS coordinates of some stations (using old Hawaiian datum) are given below, and a full list of GPS coordinates will be provided upon completion of the final report.

#### Sample Station Descriptions

##### Station 1: Hakipuʻu Stream

At 2.3 mi in length, Hakipuʻu Stream is the northernmost stream emptying into Kāneʻohe Bay, and except for the area downstream of Kamehameha Highway, the entire watershed is undeveloped pasture and forest land. Hakipuʻu Stream is largely diverted, resulting in very little surface water flow entering into Kāneʻohe Bay. At the estuary sampling site, the vegetation (see Vegetation section) has mostly overgrown the stream channel with the substrate in the lower channel areas consisting mainly of mud and silt. The last silted, stagnant pool in the Hakipuʻu Stream was located in a heavily grazed pasture near Kāneʻohe Bay. Salinity in the flowing stream 20 m upstream from the ocean was measured at 7 ppt, while salinity where the stream met the ocean was 26 ppt. GPS Coordinates: 21°30'29.5"N, 157°51'15.5"W.

##### Station 2: Waikāne Stream

At 8.0 mi in length, including tributaries, Waikāne Stream is the longest and most undisturbed stream flowing into Kāneʻohe Bay, with virtually no agriculture or housing development in the watershed until downstream of Kamehameha Highway. The stream near Kamehameha Highway averages 1-2 ft deep, and was mainly comprised long shallow runs connected by shallow riffles. The Waikāne estuary was reduced in size and more shallow than the Waiāhole estuary. Stream flow at the Waikāne estuary is generally very low, and the interface between it and Kāneʻohe Bay has an almost imperceptible flow. The stream mouth at Kāneʻohe Bay was approximately 70 ft wide and only several inches deep in the most areas. The substrate in this area was mainly fine silt, sand, and gravel.

##### Station 3: Waiāhole Stream

Located on the windward side of Oʻahu, the Waiāhole watershed encompasses 2,376 acres (Miyagi 1963). Waiāhole Valley (including Waianu and Uwau tributaries) is bordered by the central Koʻolau range to the west and by Waikāne Valley to the north and Kaʻalaia Valley to the south. Currently, most of upper Waiāhole Valley is undeveloped forest land. The uppermost 1,169 acres of Waiāhole and Waianu Valleys was designated as the Waiāhole Forest Reserve in 1918 to conserve and produce water and the valley bottom then consisted of dense stands of *koa* (*Acacia koa*), *ʻōhiʻa lehua* (*Metrosideros polymorpha*), *kukui*

(*Aleurites mollucana*), vines, ferns, and other dense undergrowth (Devaney et al. 1976). Total channel length of the main Waiāhole Stream, Waianu, and Uwau tributaries is 6.2 mi (Norton et al. 1978). Before the development of the Waiāhole Ditch in 1913, Waiāhole Stream flow originated as a series of large rheocrene springs at the base of the Koʻolau cliffs at 750-1000 ft (Miyagi 1963), but these springs are currently dry (Filbert and Englund 1995). Water flow in Waiāhole Stream is regulated by the Waiāhole Ditch, and from 1916 to 1994 the stream was completely diverted. Flows have been partially restored since December 1994.

The Waiāhole Stream estuary begins near a dirt boat ramp located 0.25 mi downstream of the Kamehameha Highway Bridge. The last riffle on Waiāhole Stream, located approximately 75 yd downstream from this boat ramp, was encountered near and adjacent to Kāneʻohe Bay with estuarine conditions starting just below this riffle. The predominant substrate consisted of varying amounts of sand, organic matter, and small and large gravels.

#### Station 4: Kaʻalaea Stream

Kaʻalaea Stream flows through cultivated banana and other agricultural fields in the upper reaches, and residential areas containing wetland taro farms in the lower reaches. Kaʻalaea Stream has a small, reduced estuary with little noticeable stream flow at Kāneʻohe Bay. This site was located 50 yd downstream of Kamehameha Highway. Shoreline vegetation consisted of mangroves and salt grasses. The Kaʻalaea Stream watershed is a small, short catchment flowing for 2.4 mi into the central portion of Kāneʻohe Bay. The Kaʻalaea watershed is separated by a series sharp mountain ridges forming the boundary between the Waiāhole watershed to the north and Waiheʻe Stream to the south. This stream estuary has a very small and short mixing zone with salinities measured at 19 ppt at the edge of Kāneʻohe Bay and 0 ppt only a few yards upstream of Kāneʻohe Bay. Silt, sand, and gravel were the main substrate components. GPS Coordinates: 21°28'15.4"N, 157°50'42.4"W

#### Station 5: Waiheʻe Stream

Bounded by the Kaʻalaea and Kahaluʻu (ʻĀhuimanu) watersheds, Waiheʻe Stream empties into Kāneʻohe Bay at the large Kahaluʻu Stream system estuary. This estuary is the largest entering Kāneʻohe Bay and the mouths of both Waiheʻe and Kahaluʻu Streams combine to form the large area around the Kamehameha Highway Bridge. Waiheʻe Stream is one of the more undisturbed watersheds flowing into Kāneʻohe Bay and in its upper reaches the watershed is largely undeveloped. Large agricultural fields such as *kalo loʻi* are found in the mid-to-lower reaches, with lower Waiheʻe Stream still having most extensive areas of wetland taro. Waiheʻe Stream has a regulated and much reduced stream flow because of the construction of the Waiheʻe tunnel in 1955 (Devaney et al. 1976). The Waiheʻe tunnel differs from the water tunnels on the Kahaluʻu and Heʻeia Streams in that the stream diversion can be regulated (Devaney et al. 1976, Takasaki et al.

1969). Unlike the Kahaluʻu and Heʻeia Stream tunnels, the Waiheʻe tunnel diversion can be turned on or off, whereas the former two stream diversions are not adjustable and completely divert all stream flow. The Waiheʻe Stream estuary was sampled where the stream mouth enters the Kahaluʻu system estuary. The mudflat area sampled did not have riparian vegetation, while the stream banks were lined with dense stands of Job's tears (*Coix lachryma-jobi*). Sampling for aquatic biota was quite difficult in the Waiheʻe/Kahaluʻu estuary because of the great depth, poor water quality, and silty bottom of this area, and efforts will continue to sample this area. GPS Coordinates: 21°27'30.8"N, 157°50'29.6"W

#### Station 6: Kahaluʻu Stream

At 3.0 mi in length, Kahaluʻu Stream watershed is one of the most heavily urbanized streams discharging into Kāneʻohe Bay. The lower sections of this stream flow in a concrete-lined channel until emptying into the large Kahaluʻu/Waiheʻe Stream estuary. Stream flow was reduced in Kahaluʻu Stream by the construction of the Kahaluʻu Tunnel in 1946 resulting in the drying up of two springs at 610 ft elevation (Devaney et al. 1976). Other stream diversions have also reduced water flow in Kahaluʻu Stream. The Haiʻkū tunnel (on the Heʻeia Stream watershed) was built in 1940, and is 2.5 mi from Kahaluʻu Stream, and caused a reduction in Kahaluʻu Stream flow by 26% (Devaney et al. 1976). The tidal influence extends upstream into the concrete channel of the lower section of Kahaluʻu Stream, just below ʻAhaʻōlelo Bridge. We sampled the estuary in the concrete channel area, and also around the shoreline area downstream of the concrete Kahaluʻu/Āhuimanu Stream channel flume. Substrate below the concrete flume consists of fine silts with some rubble intermixed.

#### Station 7: Heʻeia Stream

At 6.8 mi in length, including tributaries, Heʻeia Stream watershed is heavily urbanized up to the boundaries of the U.S. Coast Guard Omega Site. The operation of Haiʻkū Tunnel has caused a 50% decrease in the flow of the one of the two main Heʻeia Stream tributaries (Devaney et al. 1976). The upper Heʻeia Stream has 3 major forks in the area of the U.S. Coast Guard Omega Site. The south and middle fork were dry during this survey. Lower Heʻeia Stream flows through Heʻeia State Park and until the recent removal of invasive mangroves (see Vegetation section) was nearly inaccessible because of thick mangrove growth. The lower estuarine reaches of this stream are low-flowing and substrate consists of mud and silt.

#### Station 8: Keaʻahala Stream

This estuary is located at a small boat harbor on the north side of Kāneʻohe Bay, surrounded by a housing and a condominium complex on both sides of the lower stream mouth. Although USGS topographic maps indicate this stream is intermittent, it actually contains a significant perennial flow of 2.2 mgd with most of the flow originating from Baskerville Springs (Takasaki et al. 1969). Salinities measured at the mouth of Kāneʻohe Bay were 2 ppt, reflecting this perennial flow. A unique feature of Keaʻahala Stream is a waterfall



feature found near its entrance into Kāneʻohe Bay. This approximate 15 ft basaltic waterfall is located downstream of Wailele Road, and estuarine influence begins within 40-50 yards of the falls. This easily accessible area contains a cobble and rock riffle that is tidally influenced, with a substrate of dead coral and reef rubble found closer to Kāneʻohe Bay. The channel and entrance area to the small boat harbor was deep and appears to have been dredged, and sampling in this area was limited to shallow shoreline areas. Water clarity was poor here, making visual observations difficult. GPS Coordinates: 21°25'15.5''N, 157°47'37.7''W

#### Station 9: Kāneʻohe Stream

Starting at the confluence of Kamoʻoaliʻi and Kapunahala tributaries, Kāneʻohe Stream flows for less than 1 mile (Takasaki et al. 1969) before entering Kāneʻohe Bay. This watershed is almost entirely developed in the mid-to-lower elevation areas, with the Hoʻomaluhia Reservoir area forming the upper boundary for most of the Kāneʻohe Stream basin. The estuarine reaches of Kāneʻohe Stream begin downstream of the Kāneʻohe Library/Police Station area, and we accessed this area by kayaking to the first riffle area and then walking up and downstream. A mixture of larger cobble and gravels were found in the lower reaches of Kāneʻohe Stream, unlike most of the other mainly silt and mud areas examined in this study. Downstream of the first riffle, Kāneʻohe Stream gradually became too deep to effectively sample.

#### Station 10: Kawa Stream

Kawa Stream is the southernmost stream flowing into Kāneʻohe Bay, and flows for approximately 2.5 miles from its spring-fed headwaters at 300 ft elevation (Filbert and Englund 1996). This watershed is almost completely developed, with land use consisting primarily of suburban housing. The lowest sections of the watershed include a golf course and old fish pond (adjacent to a sewage treatment plant) lining the stream estuary. Nearly the entire length of Kawa Stream has been straightened, and Timbol and Maciolek (1978) found 1.43 miles of concrete channelization. Base flow in Kawa Stream is normally low, and was measured at 0.2 mgd in 1995 (Filbert and Englund 1996). Substrate in the mangrove-lined estuary consists of mud and silt, with access to the estuary possible only by kayaks. Fish sampling is difficult in the lower regions of the estuary because of the thick silt, deep water, and poor water visibility. GPS Coordinates: 21°24'40.3''N, 157°47'32.2''W.

## METHODS

Biological assessments of Kāneʻohe Bay, Oʻahu stream estuaries began in March 2001 and ended in April 2003. Sampling took place during a periods of dry and mostly sunny weather, and streams were sampled at low basal flow. Kayaks were used to gain access to estuarine areas that were otherwise inaccessible by land. Composition of the riparian vegetation, stream substrate, and habitat condition for native aquatic organisms

were evaluated at each sampling station. Altitudes sampled were at or just above sea-level, with only the lowest portion of the stream mouth sampled. Stream names were taken from USGS topographic quads. Representative sampling stations were established in the lowest reaches of each Kāneʻohe Bay stream. Sampling locations were somewhat dependent upon the constraints of private property, water depth, sediment depth, and vegetation, but included a complete range of estuarine habitats.

#### Plant Sampling Methods

The botanical inventory was conducted by walk-through method. At each sampling site, notes were taken on the vegetation structure—the main canopy trees (if any), mid-layer trees and shrubs, and herb and groundcover species. General habitat descriptions were based on these notes, and taxa not common enough to be mentioned in these summaries were included in a comprehensive species list. Submerged sites (e.g., streams, ponds) were observed for floating or submerged vascular plants and algae. Mosses, liverworts, lichens, and fungi were excluded from the scope of the survey.

Because this was a survey of riparian and wetland sites, the inventory was largely restricted to plant communities directly influenced by saturated soil conditions, as well as those communities directly adjacent to them. In wetland sites every vascular plant and algae seen was recorded. Species in immediately adjacent communities were fully noted as well, but as a general rule, once known wetland indicator species were no longer seen, observations were stopped.

Specimens were generally collected only if positive identification could not be made in the field, or if the species represented a little-collected or new naturalized record for the island or state. Collected vouchers were processed and deposited in the Bishop Museum Herbarium Pacificum (BISH). Identifications were made with assistance from Derral Herbst and George Staples. Algae specimens were generally collected with their rock substrates. Jack Fisher assisted in processing and preliminary identification of the algal specimens.

#### Aquatic Insect Sampling

Aquatic insect sampling was conducted according to Polhemus (1995) and Englund and Preston (1998). Collections of both immature and adult specimens were made with aerial sweep nets, aquatic dip nets, seines, and benthic samples. Visual observations of aquatic insects were also conducted above the waterbody. Sampling of damselflies and dragonflies (Odonata) was emphasized, as several of these are currently candidate threatened or endangered species. All insect specimens were stored in 75% ethanol for curation and identification and voucher specimens are currently housed in the Bishop Museum collections.

### Fish and Crustacean Sampling

Seine netting was the main sampling technique used to assess introduced fish abundance. A fine-mesh, 15-ft seine was used to sample stream animals and assess species composition, and dip nets were also used to sample areas not accessible to seines. Salinity was also recorded at least once for each stream location sampled, and, unless otherwise stated, salinities were taken at the surface. Electroshocking was not attempted because recent Bishop Museum estuarine surveys on Oʻahu found salinity levels as low as 3-4 ppt rendered electrofishing completely ineffective (Englund et al. 2000). Snorkeling was not possible because of poor water clarity and quality in the Kāneʻohe Bay estuaries. In some areas above-water observations for fish and invertebrates were occasionally possible, although species identification was always assessed through capture of individuals.

Although some fish, crustacean, and mollusk species were identifiable in the field, many smaller specimens were immediately preserved in 75% ethanol and brought back to the Bishop Museum for further identification. Additionally, representative individuals of each fish species collected were preserved in 10% formalin as vouchers in the Bishop Museum Ichthyology collection. For this report, we used the following for scientific and common names: fishes (American Fisheries Society 1991), crustaceans (American Fisheries Society 1989), and for arthropods and their biogeographic status (Nishida 2002).

## RESULTS AND DISCUSSION – AQUATIC BIOTA

The objective of these surveys are to develop a baseline inventory of aquatic species present in Kāneʻohe Bay stream estuaries and to assess the status of the fauna from a conservation viewpoint. Nonindigenous aquatic species have been brought into Hawaiʻi both accidentally and intentionally and species of undetermined geographic origin are termed cryptogenic (Carlton 1996). Overall, nonindigenous aquatic animal species dominated the lowest sections of Kāneʻohe Bay stream mouths.

A total of 62 species of aquatic macrofauna were identified during this study (Table 1), and a complete list of species including their geographic origin can be found in Table 2. Twenty-three native aquatic species, two cryptogenic, and 37 introduced aquatic species were identified from stream estuarine regions of Kāneʻohe Bay (Table 1). For all stations combined, 60% of the aquatic taxa found during this study were introduced and 37% were native (either endemic or indigenous), and 3% were cryptogenic species. One species of aquatic fly and one fresh/brackish water sponge have not yet been identified to the species level, and will remain cryptogenic until further specific determinations can be made. Because the Kahaluʻu and Waiheʻe estuaries are immediately adjacent to each other and both form the large Kahaluʻu Pond area, it was not possible to distinguish between the two. Thus the results from these two estuaries are presented as combined data in the following species lists.

Table 1. Summary of native and nonindigenous status and total number (percent) of aquatic species found in all reaches combined in Kāneʻohe Bay streams, Oʻahu Island.

Geographic Status	All Aquatic Species	Reptiles & Amphibians	Fishes	Mollusks	Sponges	Aquatic Insects	Crustaceans
Introduced	37 (60%)	3 (100%)	11 (61%)	4 (80%)	-	19 (59%)	-
Native	23 (37%)	-	7 (39%)	1 (20%)	-	12 (38%)	3 (100%)
Cryptogenic	2 (3%)	-	-	-	1 (100%)	1 (4%)	-
Total	62	3	18	5	1	32	3

### Amphibians and Reptiles

Aquatic reptiles and amphibians are not native to the Hawaiian Islands but now form a highly visible part of the aquatic fauna. Being highly mobile animals, it was not unexpected to observe two species of frogs, *Rana catesbeiana* and *Bufo marinus*, in the lowest sections of several Kāneʻohe Bay streams. Additionally, a small (4 inch) introduced Chinese softshell turtle (*Pelodiscus sinensis*) was found in Kāneʻohe Stream in the first riffle area, just above the area of tidal influence. Kāneʻohe Stream and its tributary Kamoʻoaliʻi Stream are known to have a large population of Chinese softshell turtles, and were common in 2001 when Hawaii Biological Survey staff accompanied Hawaii Division of Aquatic Resources personnel electroshocking the upper portions of Kamoʻoaliʻi Stream for an unrelated study.

### Fish

Seven native and 11 nonindigenous species of fish have so far been found (Table 2), Kāneʻohe Stream having the greatest number of introductions. Many of the introduced fish are saline tolerant and can inhabit both estuaries and the lower to upper reaches of many Hawaiian streams. For example, most introduced tilapia (*Sarotherodon melanotheron*) and poeciliids are quite saline tolerant (Englund et al. 2000), and can be found in salinity concentrations of up to 40 ppt on Oʻahu. Full-blown fishery population estimates were beyond the scope of this study as they are time intensive and costly, and provide little information if only conducted at one point in time. However, general observations were made on the relative densities of the introduced and native fish fauna. Streams with the lowest flow rates and smallest estuaries such as Kawa Stream appear to have fewer native fish species. Additionally, although Kāneʻohe Stream has a substantial flow, it also has the greatest number of introduced fish species. Both native and introduced crustaceans are relatively uncommon in Kāneʻohe Stream, and it is possible that cichlid predators such as tilapia and blue mbuna (*Melanochromis johanni*) in this stream have reduced crustacean densities.

Kāneʻohe Bay Stream Estuaries Study

Table 2. Results of Hawaii Biological Survey, Bishop Museum surveys conducted for aquatic species in Kāneʻohe Bay stream estuaries, Oʻahu Island.

Taxon	Kawa Stream	Kāneʻohe Stream	Keaʻahala Stream	Heʻeia Stream	Kahaluʻu Estuary	Kaʻalaea Stream	Waiāhole Stream	Waikāne Stream	Hakipuʻu Stream	Status <sup>2</sup>
<b>Reptiles (turtles)</b>										
<i>Pelodiscus sinensis</i>		X								Int
<b>Amphibians</b>										
<i>Bufo marinus</i>	X									Int
<i>Rana catesbeiana</i>						X				Int
<b>Fish</b>										
<i>Awaous guamensis</i>		X	X				X	X		Ind
<i>Diodon hystrix</i>			X							Ind
<i>Eleotris sandwicensis</i>	X	X	X			X	X	X	X	Ind
<i>Kuhlia xenura</i>	X	X	X	X	X	X	X	X	X	End
<i>Mugil cephalus</i>	X	X	X	X	X	X	X			Ind
<i>Saurida nebulosa</i>								X	X	Ind
<i>Sphyræna barracuda</i>	X		X	X	X		X			Ind
<i>Stenogobius hawaiiensis</i>		X	X			X	X	X	X	End
<i>Mugilogobius cavifrons</i>									X	Int
<i>Gambusia affinis</i>	X	X	X	X	X		X		X	Int
<i>Ancistrus temmincki</i>		X								Int
<i>Hypostomus watwata</i>	X									Int
<i>Melanochromis johanni</i>		X								Int
<i>Poecilia mexicana</i> (complex)	X	X	X	X	X	X	X	X	X	Int
<i>Poecilia reticulata</i>								X	X	Int
<i>Tilapia (Sarotherodon) melanotheron</i>	X	X	X	X	X	X	X	X	X	Int
<i>Xiphophorus helleri</i>								X		Int
<i>Xiphophorus maculatus</i>								X	X	Int
<b>Mollusks</b>										
<i>Neritina vespertina</i>	X	X	X				X			End
<i>Corbicula fluminea</i>			X							Int
<i>Pomacea canaliculata</i>									X	Int
<i>Tarebia granifera</i>			X							Int
Thiaridae			X						X	Int
<b>Crustaceans</b>										
<i>Atyoida bisulcata</i>								X		End
<i>Macrobrachium grandimanus</i>	X	X	X			X		X	X	End
<i>Palaemon debilis</i>			X	X						Ind
<b>Aquatic Insects</b>										
<b>Anisoptera (Dragonflies)</b>										
Aeschnidae										
<i>Anax junius</i>									X	Ind
Libellulidae										
<i>Pantala flavescens</i>	X		X	X					X	Ind
<i>Crocothemis servilia</i>				X					X	Int
<i>Orthemis ferruginea</i>						X			X	Int

Kāneʻohe Bay Stream Estuaries Study

Table 2 (cont.). Results of Hawaii Biological Survey, Bishop Museum surveys conducted for aquatic species in Kāneʻohe Bay stream estuaries, Oʻahu Island.

Taxon	Kawa Stream	Kāneʻohe Stream	Keaʻahala Stream	Heʻeia Stream	Kahaluʻu Estuary	Kaʻalaea Stream	Waiāhole Stream	Waikāne Stream	Hakipuʻu Stream	Status <sup>2</sup>
<b>Zygotera (Damsel flies)</b>										
Coenagrionidae										
<i>Ischnura ramburii</i>	X	X	X		X	X				Int
<b>Heteroptera (True Bugs)</b>										
Mesoveliidae										
<i>Mesovelia mulsanti</i>		X								Int
<b>Diptera (Flies, gnats)</b>										
Canacidae										
<i>Canaceioides</i> sp.					X					Cry
<i>Canaceioides angulatus</i>							X			Int
<i>Procanace williamsi</i>			X				X	X		Int
Ceratopogonidae										
<i>Atrichopogon jacobsoni</i>		X								Int
<i>Dasyhelea digna</i>		X								End
Chironomidae										
<i>Cricotopus bicinctus</i>		X			X		X			Int
<i>Orthocladius</i> sp.							X	X		End
<i>Thalassomy setosipennis</i>			X							End
Chloropidae										
<i>Cadrema pallida</i>			X		X					Int
<i>Monochaetoscinella anonyma</i>		X								Int
Dolichopodidae										
<i>Achradocera arcuata</i>		X								Int
<i>Chrysotus longipalpus</i>		X								Int
<i>Dolichopus exsul</i>		X								Int
<i>Pelastonerus lugubris</i>		X								Int
<i>Syntormon flexible</i>			X				X	X		Int
<i>Thambemyia acrosticalis</i>							X	X		Int
<i>Thambemyia</i> sp.							X			Int
Empididae										
<i>Hemerodromia stellaris</i>		X								Int
Ephydriidae										
<i>Discocerina mera</i>					X					Int
<i>Donaceus nigronotatus</i>		X								Int
<i>Scatella hawaiiensis</i>		X								End
<i>Scatella sexnotata</i>							X			Ind
<i>Scatella stagnalis</i>		X	X				X			Int
Tethinidae										
<i>Dasyrhicnoessa insularis</i>		X			X		X	X		Ind
Tipulidae										
<i>Limonia advena</i>		X								Int

Kāneʻohe Bay Stream Estuaries Study

Table 2 (cont.). Results of Hawaii Biological Survey, Bishop Museum surveys conducted for aquatic species in Kāneʻohe Bay stream estuaries, Oʻahu Island.

Taxon	Kawa Stream	Kāneʻohe Stream	Keaʻahala Stream	Heʻeia Stream	Kahaluʻu <sup>1</sup> Estuary	Kaʻalaea Stream	Waiāhole Stream	Waikāne Stream	Hakipuʻu Stream	Status <sup>2</sup>
<b>Trichoptera (Caddisflies)</b>										
Hydropsychidae										
<i>Cheumatopsyche analis</i>	X	X	X				X	X	X	Int
<b>Porifera (Sponges)</b>										
Unidentified Porifera		X								Cry
Total: Intro. + Native + Crypto. Spp.	14	31	24	6	12	10	21	18	18	
Total Native Aquatic Species	7	8	11	3	5	5	10	9	7	
Percent Native Aquatic Species (%)	50	26	46	50	42	50	48	50	39	

<sup>1</sup>Includes both estuary areas from both Waiheʻe Kahaluʻu Streams, <sup>2</sup>End = Endemic, Ind = Indigenous, Int = Introduced, Cry = Cryptogenic

Aquatic Insects

Aquatic insects were by far the most species-rich group found and were also numerically the most abundant group found during these surveys. A total of 32 aquatic insect species representing 52% of the total aquatic species were collected in during the present study. Aquatic insects represented a major component of the biodiversity found during this study, and when data from all stations were combined 38% were native species, 59% were introductions, and 4% were cryptogenic (Table 1). Some areas that were highly saline such as Heʻeia Stream had a very low diversity of aquatic insects (Table 3), while other streams with a stronger freshwater influence and lesser amounts of mangrove such as Keaʻahala Stream had a greater species numbers.

Table 3. Numbers of native and introduced aquatic insect species found during surveys conducted in Kāneʻohe Bay stream estuaries, Oʻahu Island.

Stream Mouth	Number (%) Native spp.	Number (%) Introduced spp.	Number Cryptogenic (%) spp.	Total spp.
Kawa	1 (33%)	2 (67%)	-	3
Kāneʻohe	3 (18%)	14 (82%)	-	17
Keaʻahala	2 (25%)	6 (75%)	-	8
Heʻeia	1 (50%)	1 (50%)		2
Kahaluʻu <sup>1</sup>	1 (14%)	5 (71%)	1 (14%)	7
Kaʻalaea	0	2 (100%)	-	2
Waiāhole	3 (27%)	8 (73%)		11
Waikāne	2 (33%)	4 (67%)	-	6
Hakipuʻu	1 (33%)	2 (67%)	-	3
Average %	26%	72%	2%	

<sup>1</sup>Includes both estuary areas from both Waiheʻe Kahaluʻu Streams

Twelve native aquatic insect species were found during this study, representing 38% of the aquatic insect fauna collected during this study. Native species included the highly mobile and native *pinao* (dragonflies) *Anax junius* and *Pantala flavescens*, and several aquatic flies such as *Orthocladus* sp. and *Scatella hawaiiensis* and *Scatella sexnotata*. The species assemblage was representative of a disturbed lowland area and no rare species aquatic insects were found during this study.

#### Crustaceans

Only one native species were found during these surveys, likely because of the mostly estuarine influence of the areas sampled. The three species found included the estuarine *Palaemon debilis*, ‘Ōpae ‘ōeha‘a (*Macrobrachium grandimanus*) that are generally found in low elevation areas, and small post-larval ‘ōpae kuahiwi (*Atyoida bisulcata*) at the mouth of Waikāne Stream. The more mountain-dwelling ‘ōpae kuahiwi (*Atyoida bisulcata*) was also found in the headwaters of a number of Kāneʻohe Bay streams in 1995 (Filbert and Englund 1995). However, because we did not use larval or post-larval traps, we did not find this species in all the estuarine areas we sampled.

#### Mollusks

The native freshwater mollusk fauna of the Hawaiian Islands includes very few species, most in the families Lymnaeidae and Neritidae (Cowie et al. 1995). However, a greater number of alien species has been introduced to the islands (Cowie 1997, 1998) and these species now dominate the mollusk fauna of most freshwater ecosystems, especially those that have been modified for human use. A total of four snail species were identified during this survey. Of these species, three are introduced alien species and one is native. Apple snails (*Pomacea canaliculata*) are the pest species of greatest concern, and the distinctive pink egg cases were common in areas of Hakipu‘u Stream very near the ocean.

## AQUATIC VEGETATION SURVEYS

### Introduction

A vegetation survey of the lower sections of ten streams that drain into Kāneʻohe Bay was conducted between 10 May and 14 June 2001. The goals of the survey were to characterize and inventory the freshwater and estuarine plant communities at each site, in conjunction with concurrent surveys of the aquatic biota. The northernmost stream surveyed was Hakipu‘u, adjacent to Kualoa Point and Mōli‘i Pond; the southernmost stream was Kawa, by the Bay View Golf Park in Kāneʻohe. Dominant vegetation types ranged from estuarine swamps of American mangrove (*Rhizophora mangle*), freshwater swamps of *hau* (*Hibiscus tiliaceus*), to marshy coastal fringing grasslands of seashore paspalum (*Paspalum vaginatum*).



### Vegetation history

The original Polynesian settlers on Oʻahu must have immediately recognized the many virtues of the Kāneʻohe Bay basin for their taro (*Colocasia esculenta*)-based civilization—plentiful fresh water, broad coastal plains with deep, fertile soils, and equable climate. The large protected bay provided ideal conditions for fishpond farming. Moisture-laden northeast tradewinds confronted the steep, fluted pali of the Koʻolau Range backing the bay, providing plentiful upland water to nourish the lowlands. Streams from eight adjoining *ahupuaʻa* (mountain-to-sea land units) drain into the bay: Hakipuʻu, Waikāne, Waiāhole, Kaʻalaea, Waiheʻe, Kahaluʻu, Heʻeia, and Kāneʻohe. Much of the lowlands was intensively farmed for taro and associated crops. The region supported the largest population on Oʻahu in pre-European times, estimated at somewhere between 15,000 and 17,000 people (Devaney et al. 1976).

Handy and Handy (1972), pages 442-446, described some of these districts thusly: Hakipuʻu—“Old *loʻi* areas once covered the swampy flats *makai* . . . of the present Kamehameha Highway, and here as late as 1935 about a dozen *loʻi* were still cultivated along the Hakipuʻu stream . . .”. Waikāne—“. . . Waikāne was a major source of Koʻolau taro, especially in the broad area between the highway and the sea . . .”. Waiāhole, Kaʻalaea, Waiheʻe, Kahaluʻu, Heʻeia—“Each of these five districts has a broad coastal plain, which was converted by Hawaiians into an almost continuous expanse of *loʻi* irrigated with water from large streams flowing out of the deep valleys that cut back into the Koʻolau range. The hinterland must have produced great quantities of sweet potato, yam, banana, upland taro, *wauke*, *olona*, and *ʻawa*.” Kāneʻohe—Portlock (1789) described the area. “The bay all round has a very beautiful appearance, the low land and valleys being in high state of cultivation, and crowded with plantations of taro, sweet potatoes, sugarcane, etc., interspersed with a great number of coconut trees . . .”

The arrival of foreigners in the late 1700s was a harbinger of irreversible change for the Hawaiian subsistence lifestyle. Diseases that the Hawaiians had never been exposed to dealt them devastating blows, and an estimated population of 60,000 on Oʻahu in 1779 was whittled down to little more than half that by 1831 (Devaney et al. 1976). The Great Māhele of 1848 and the Kuleana Act of 1850 were landmark acts that converted the feudalistic land system into one that made it possible for commoners as well as foreigners to own parcels of land. Unfortunately, only 26% of eligible adult male commoners received *kuleana* lands to continue subsistence farming (Devaney et al. 1976). In the Kāneʻohe Bay area less than 1,000 acres in small parcels were awarded as *kuleana* lands to Hawaiian farmers, while over 18,000 acres were awarded to 25 chiefs, and other substantial parcels were declared Government or Crown lands. These results were repeated throughout the Kingdom, and as Devaney et al. (1976) state: “These conditions laid the foundation for the present land ownership situation in Hawaii: a few wealthy landowners own most of the lands in large

parcels, a large number of people own very little land (most of it in small parcels), and the great majority of Hawaiians are landless tenants.” The table was thus set for the beginning of modern plantation agriculture in Hawai‘i.

Because the landscape as we see it today has been so intensively altered by man, it is not possible to say with certainty what the vegetation of the lower parts of Kāneʻohe Bay might have looked like prior to the arrival of the Hawaiians. Comparing the site to present-day vegetation communities can have some predictive value. One such vegetation classification system, published in the *Manual of the Flowering Plants of Hawai‘i* (Wagner et al. 1999) describes 106 native and weedy Hawaiian communities based on a combination of elevation (coastal, lowland, upland, etc.), rainfall (dry, semi-wet, wet), and plant form (herbland, grassland, shrubland, forest), complete with a list of native and alien species typical of that vegetation type. Existing vegetation communities in the lower reaches of drainages into Kāneʻohe Bay can be placed in various of these categories [e.g., *Hau (Hibiscus)* Shrubland (p. 65), Mangrove (*Rhizophora/Bruguiera*) Forest (p. 66)]. Likewise, remnant native plant species can sometimes be used as cues (“indicator species”) to predict which of the native vegetation communities might once have inhabited the area. Based on the environmental settings and the presence of the native sedge (*Cyperus javanicus*), an *ʻAkaʻakai/Kaluha/Makaloa (Schoenoplectus/Bolboschoenus/Cyperus)* Sedgeland (p. 65) may once have existed in the Heʻeia area. Other possible native vegetation communities might have included *ʻUki* Sedgeland (p. 86), featuring *ʻuki (Cladium jamaicense)*, a large indigenous sedge; *Hala (Pandanus)* Forest (p. 63); and *Māmaki (Pipturus)* Riparian Shrubland (p. 89).

Palaeobotanical studies are one fascinating means of reconstructing the vegetation history of an area, both spatially and through time. Such work involves the identification of seeds, plant fragments, and wood from habitation sites, which can reveal economic plants used by the inhabitants; and identification of pollen in sediment cores, which can help reveal ancient vegetation patterns. Studies such as these conducted in other sites have often provided unexpected glimpses into an area’s past (for example, see Athens & Ward (1993) for their results in Kawainui Marsh, Oʻahu). The best pollen sampling locations are in permanently waterlogged sites, where the lack of oxygen slows decomposition of pollen grains, and a number of sites in Kāneʻohe Bay would seem to be ideal for such sampling.

#### Riparian Vegetation Study Area Descriptions

##### Hakipuʻu Stream mouth (4 June 2001)

The mouth of Hakipuʻu Stream was reached via kayak from Kualoa Regional State Park. The mouth was determined to be south of Mōliʻi Pond and just on the south side of a nearby oceanfront house with a small pier. The stream channel here is small (about 4 ft wide at the most) and consists of nothing more than a

dug-out trench with a mucky bottom. A resident reported that wetlands once occupied the lands inland from the ocean, and that the water did not flow to the ocean in a channel, but more in the manner of a sheet flow under the *hau* (*Hibiscus tiliaceus*) thicket that dominates the south side of the present drainage. The channel has low flow and the mouth is clogged with a thick layer of seashore paspalum (*Paspalum vaginatum*) interspersed with American mangrove (*Rhizophora mangle*) seedlings. In time the area may become dominated by *Rhizophora*. Other wetland plants noted here include barnyard grass (*Echinochloa crus-galli*), California grass (*Brachiaria mutica*), and the sedge *Cyperus polystachyos*. On the north side of the mouth, there is more *Paspalum/Rhizophora* mix in the foreshore area, backed by California grass and a mix of *hau*, American mangrove, *milo* (*Thespesia populnea*), and false *kamani* (*Terminalia catappa*). These are covered with the vines *maile pilau* (*Paederia foetida*) and the native beach pea (*Vigna marina*) with yellow pea-like flowers. *Maunaloa* (*Canavalia cathartica*) is also a common vine in the area with purple, pea-like flowers. The south bank is dominated by an impenetrable thicket of *hau* that extends upstream for 50 yards until a cleared pastureland is reached. Very little grows within the *hau* understory, but on the streambank can be seen false daisy (*Eclipta prostrata*), *maile hohono* (*Ageratum conyzoides*), primrose willow (*Ludwigia octovalvis*), barnyard grass, and Job's tears (*Coix lachryma-jobi*). The north bank 50 yards upstream slopes up a small bank to a landscaped adjoining property. These banks are dominated by wedelia (*Sphagneticola trilobata*), Job's tears, and *honohono* (*Commelina diffusa*). Once the pastureland is reached, areas of open water in the stream disappear, and the track appears as a vegetation-filled depression filled with grazed California grass, accompanied by marsh purslane (*Ludwigia palustris*) and *honohono*. The north bank here is dominated by California grass with the vine *Neonotonia wightii*. On the edge of the pastureland are unusual shrubs such as aramina (*Urena lobata*), a hibiscus relative with a small pink/purple flower and the weedy mint *Hyptis capitata*, which has been vouchered only from nearby Waiāhole Valley at Bishop Museum.

Waikāne Stream mouth and nearby wetlands (22 May 2001)

The mouth of Waikāne Stream is calm and wide and opens out into an estuarine mudflat that extends northward toward Kualoa. The mixing of waters gave a salinity reading of 5 ppt. The algal collections in this area included *Monostroma* sp. and *Enteromorpha* sp. The canopy vegetation along the streambank is primarily a dense mixture of American mangrove and *hau*. *Milo* forms dense stands on the south foreshore of the stream mouth. Seashore paspalum forms a prominent groundcover layer on banks protected from constant inundation. Almost nothing grows under the *hau*/mangrove canopy, save for mangrove seedlings. Under *milo* can be found coconut seedlings, wedelia, and mangrove seedlings.

In addition to the stream mouth proper, three wetland sites to the south were surveyed. These were smaller rivulets that apparently reach the ocean only during heavy rainstorms, but most of the time consist of standing stagnating water. One site is just on the north end of the large cleared parking area on the *makai*

side of the road. This stagnant waterway is about 50 ft long and 10 ft wide and is mostly covered with *hau* overstory, with some American mangrove and false *kamani*. A variety of grasses and sedges are found on the muddy bank: seashore paspalum, jungle-ricegrass (*Echinochloa colona*), and the indigenous sedges *Cyperus polystachyos* and 'ahu'awa (*C. javanicus*). The floating water fern *Spirodela punctata* was occasional in the water. Canopy vines include ivy gourd and moon flower.

A second drainage occurs about 10 yd north, with only a shallow pool of water in it. The banks were recently weed-whacked. *Hau* and *hala* (*Pandanus tectorius*) trees provide some shade. California grass (*Brachiaria mutica*), Guinea grass, and seedlings of Java plum and American mangrove were noted. The sandy seaward end supported vines of the indigenous beach morning-glory (*Ipomoea pes-caprae* ssp. *brasiliensis*). No water plants were noted in this stagnant drainage.

A third drainage was located in thick false *kamani* forest north of the canoe shed. The sandy shoreward is covered with a groundcover of wedelia and beach morning-glory. The understory away from the standing water consists of clumps of umbrella sedge (*Cyperus involucratus*), wedelia, American mangrove seedlings, and Guinea grass on drier soil. On the end open to sky at Kamehameha Highway, California grass dominates. At this end the stagnant water surface is covered with a layer of the invasive floating fern *Salvinia molesta*. A quick check of the drainage on the mauka side of the road revealed more *Salvinia* but not in a crowded state.

Waiāhole Stream mouth (21 May 2001)

The mouth of Waiāhole Stream is fairly broad (ca. 35 ft wide) and up to 2 ft deep in the central channel, and the stream waters are gentle. The bed is mucky with scattered cobbles. No submerged vascular plants were noted for a distance of about 50 yds upstream (stopped surveying before approaching a nearby residence upstream). The banks are covered on the north side with large rank elephant grass (*Pennisetum purpureum*), along with scattered *hau* (*Hibiscus tiliaceus*), *milo* (*Thespesia populnea*), California grass (*Brachiaria mutica*), and Java plum (*Syzygium cumini*) seedlings, and a thick groundcover layer of seashore paspalum (*Paspalum vaginatum*) mixed with wedelia (*Sphagneticola trilobata*). Behind this open-canopied layer, a thick American mangrove (*Rhizophora mangle*) forest forms a monodominant stand and continues north up the coast. The substrate beneath this forest is muddy, and the canopy is so thick that only a few *maile pilau* (*Paederia foetida*) vines and coconut (*Cocos nucifera*) seedlings were noted among the numerous mangrove seedlings and saplings. The oceanward (south) shore was a mixture of sand and mud, and the banks on this side featured taller tree species: *hau*, *milo*, tree heliotrope (*Tournefortia argentea*), false *kamani* (*Terminalia catappa*), and the native shrub *naupaka kahakai* (*Scaevola sericea*). Groundcover was dominated by seashore paspalum, with some native *pōhuehue* (*Ipomoea pes-caprae* ssp. *brasiliensis*) and *nanea* (*Vigna marina*) mixed in. Several algae were collected in the stream mouth channel, where the salinity was measured at 2–3

ppt. One was an unidentified blue-green alga, another an unidentified of *Enteromorpha* sp., and the third was unidentifiable. Further offshore (10 ppt) were *Enteromorpha* sp. and another unidentifiable alga .

On 22 May 2001 a short trip was taken on a dirt road *makai* of Kamehameha Highway but above the site of survey described in the above paragraph. The stream here was deep and still, ca. 20 ft across, with a mucky bottom. No water plants were noted. The overstory is tall and keeps the stream in dappled shade. It consists of thick *hau* primarily; further upstream Java plum, monkeypod (*Samanea saman*), and albizia (*Falcataria moluccana*) comprise the canopy. The stream banks are a mix of *Paederia*, Java plum seedlings, Job's-tears (*Coix lachryma-jobi*), Guinea grass (*Panicum maximum*), and the fern *Christella parasitica*. The vines ivy gourd (*Coccinia grandis*) and moon flower (*Ipomoea alba*) draped the trees.

#### Kaʻalaea Stream mouth (14 June 2001)

The stream was accessed via kayak launched from the boat ramp seaward and north of the Hygienic Store in Kahaluʻu. The mouth is 20–25 ft wide, the bottom consisting of small cobbles and mud. The banks on either side at the interface with the sea are dominated by a thick growth of seashore paspalum (*Paspalum vaginatum*), interspersed with American mangrove (*Rhizophora mangle*) seedlings. The south bank of the stream behind the seashore paspalum is dominated by a thicket of *Rhizophora* up to 25 ft tall. Some Oriental mangrove (*Bruguiera sexangula*) saplings are intermixed, along with *milo* (*Thespesia populnea*) and coconut (*Cocos nucifera*). The stream was explored about 50 yds upstream, where it was a 10 ft wide, shallow and cobbly. At this point, a rock wall adjacent to a home replaces the mangrove on the south bank. Occasional on this side under mangrove are scrambled egg tree (*Senna surratensis*), Indian fleabane (*Pluchea indica*), *koa haole* (*Leucaena leucocephala*), and fiddlewood (*Citharexylum caudatum*). The muddy north bank is adjacent to a house lot and is completely altered and maintained. Vegetation is restricted to a grass and herb cover dominated by seashore paspalum, along with occasional patches of the native herb *Bacopa monnieri*, false daisy (*Eclipta prostrata*), bristly foxtail (*Setaria verticillata*), Bermuda grass (*Cynodon dactylon*), and the native sedge (*Cyperus polystachyos*).

#### Waiheʻe Stream mouth (14 June 2001)

Waiheʻe Stream is a tributary of the larger Kahaluʻu Stream, which it enters mauka of Kamehameha Highway. The mouth was accessed via kayak. At the opening of the stream (10–12 ft wide), the entire southern portion is dominated by *hau* (*Hibiscus tiliaceus*) thicket. The north bank slopes up to a flatland bordered by barbed wire. They are dominated by wedelia (*Sphagneticola trilobata*) groundcover, with scattered Guinea grass (*Panicum maximum*) and sow thistle (*Sonchus oleraceus*). About 50 ft upstream, the channel is clogged with water hyacinth (*Eichhornia crassipes*) and California grass (*Brachiaria mutica*), and the survey was terminated at this point. Trees on the north bank at this juncture include gunpowder tree (*Trema orientalis*) and Java plum (*Syzygium cumini*).

Kahaluʻu Stream mouth (14 June 2001)

The mouth of Kahaluʻu Stream is about 100 ft across and channelized, and the vegetation consists of various herbs and grasses atop the large cemented basin and in the large cement channel parallel to Kamehameha Highway. Higher plants in the latter were restricted to scattered umbrella sedge (*Cyperus involucratus*) on the cement floor and isolated Chinese banyan (*Ficus microcarpa*) seedlings in cracks of the cement walls. The dirt banks of the larger channel just mauka of the Kahaluʻu Bridge were covered with a variety of grasses (bermuda grass, *Cynodon dactylon*; Johnson grass, *Sorghum halepense*; seashore paspalum (*Paspalum vaginatum*), herbs (beggar's tick, *Bidens alba* var. *radiata*; graceful spurge, (*Chamaesyce hypericifolia*); wedelia, (*Sphagneticola trilobata*); sow thistle, (*Sonchus oleraceus*); and some larger plants such as castor bean (*Ricinus communis*) and American mangrove (*Rhizophora mangle*) seedlings.

Heʻeia Stream mouth and adjacent wetlands (25 May 2001)

The mouth of Heʻeia Stream emerges from thick, 20 ft tall American mangrove (*Rhizophora mangle*) swampland on either bank, with a broad mudflat forming a large apron along the shoreline. Immediately bordering the stream to the south is the large Heʻeia Fishpond, which itself is completely ringed by American mangrove. The thick mangrove swampland on the fishpond side extends for 25 yds from the streambank to the fishpond margin. The understory is restricted to scattered individuals of Oriental mangrove (*Bruguiera sexangula*). On drier soil away from water, the understory includes *Bruguiera, milo* (*Thespesia populnea*), and scattered plants of yellow granadilla (*Passiflora laurifolia*), huehue haole (*P. suberosa*), the fern *lauaʻe* (*Phymatosorus grossus*), *koa haole* (*Leucaena leucocephala*), umbrella tree (*Schefflera actinophylla*), fiddlewood (*Citharexylum caudatum*), and Mickey Mouse plant (*Ochna thomasi*). Bunches of *Acanthopora spicifera* were noted attached to submerged mangrove stilt roots in the fishpond. A branched alga and a bubble alga (*Dictyosphaeria cavernosa*) was collected on the mudflats, and another was collected on rocks in the intertidal zone.

On the north bank of Heʻeia Stream, American mangrove forest extends for 25–30 yds on seasonally dried mudflats toward Kamehameha Highway. A steep bank separates the wetland from the road. The substrate is not as wet on this side, allowing for a larger mix of tree and shrub species, although *Rhizophora* is still the dominant species. Other tree species include *milo*, false *kamani* (*Terminalia catappa*), and American mangrove. Only a single sapling of another mangrove species, button mangrove (*Conocarpus erectus*), was noted. Sandy shoreline areas had many *milo* and American mangrove seedlings. In open areas, the ground layer included much seashore paspalum (*Paspalum vaginatum*), marsh fleabane (*Pluchea indica*), and pickleweed (*Batis maritima*). An extensive recent effort to clear out some of the *Rhizophora* in mudflat areas away from the stream allowed for some successional data to be taken. The *Rhizophora* was beginning to

resprout extensively, along with scattered *Bruguiera*, but in the meantime shrubs of Indian fleabane are common, along with pickleweed and seashore paspalum. Of note were many sprouts of a native sedge, ‘ahu‘awa (*Cyperus javanicus*), on bare saturated soils, and a small patch of ‘ākulikuli (*Sesuvium portulacastrum*). Hau (*Hibiscus tiliaceus*) was not noted until near the highway end, where a thicket is located. At this end are also very tall (60 ft) American mangrove. The stream adjacent to the cleared mudflats was about 7 ft wide, 2–3 ft deep, with a muddy bottom and sides, both banks still dominated by *Rhizophora*.

Kea‘ahala Stream below Wailele Bridge access (29 May 2001)

The stream was accessed from below Wailele Bridge, at the intersection of William Henry and Wailele roads. The stream is a concrete channel 20 ft wide that ends under the bridge, at which point the water rushes down a natural basalt dike formation to a channel below that is lined with houses on both sides. Some sections of this 15 ft wide channel are lined with rock walls, while others are kept maintained as low groundcovers.

At the bridge end, there is a thick canopy of Chinese banyan (*Ficus microphylla*), Java plum (*Syzygium cumini*), umbrella tree (*Schefflera actinophylla*), and koa haole (*Leucaena leucocephala*). The scandent weedy shrub *Hiptage benghalensis* is common, both as clambering into surrounding vegetation and as saplings and seedlings. Understory elements among wet rocks include umbrella sedge (*Cyperus involucratus*), wedelia (*Sphagneticola trilobata*), *Ruellia prostrata*, artillery plant (*Pilea microphylla*), Guinea grass (*Panicum maximum*), and maile hohono (*Ageratum conyzoides*). The stream bed just below the waterfall is bouldery with a gravelly bed. Downstream it becomes deeper and calmer, with occasional small boulders amidst deep muck. Just a few American mangrove (*Rhizophora mangle*) saplings were noted. Also downstream, the banks become more maintained; a long stretch of the north bank is seashore paspalum (*Paspalum vaginatum*) backed by wedelia. Coconut (*Cocos nucifera*) and milo (*Thespesia populnea*) trees line the bank. Further downstream (near the mouth) are some 60 ft tall ironwoods (*Casuarina equisetifolia*). No vascular water plants were noted. An unidentified species of *Cladophora* (Imada & Preston 2001-41), a bright green hairlike alga, was collected from a stone wall above water. A yellowish alga and dark brown alga were collected near a population of *hapawai* in 5 ppt water. A dominant green alga on submerged rocks was also collected further downstream in perhaps 8 ppt water.

On 12 June 2001, a return trip was made via kayak to the mouth of Kea‘ahala Stream. The channel here is about 30–40 ft wide. On the north side are townhouses and a boat harbor; on the left are townhouses. The banks are mostly of built-up rock walls and are mostly well-maintained vegetatively. Parts of the bank below the *Casuarina* are vegetated by milo, *Rhizophora*, tree heliotrope (*Tournefortia argentea*), false kamani (*Terminalia catappa*), and Indian fleabane (*Pluchea indica*). Wedelia is the dominant groundcover.

Kāneʻohe Stream adjacent to Kāneʻohe Library, downstream of Kamehameha Highway Bridge (10 May 2001)

The perennial stream adjacent to the library is about 25 ft. wide and 1 ft. deep at normal flow. The bed is composed of rubble and mud. The banks slope upward to a height of about 10 ft. and are composed of mostly bare soil on the sloping portions, with tall trees on the leveled-off upslope areas. The stream is largely open to the sky directly above. The stream is shallow and fast-running until the channel becomes narrower and deeper about 100 yds. downstream, where hau becomes the dominant vegetation type. Submergent vegetation is very common in the shallower channel and disappears downstream. Thick beds of *Vallisneria spiralis* mixed with *Egeria densa* are rooted in much of the shallower channel, and are sometimes joined by *honohono* (*Commelina diffusa*). In some places a much smaller groundcover-like version of *Vallisneria spiralis* grows sympatrically with the longer-leaved form. Occasionally seen growing in the saturated streambed margins are java plum seedlings, *Ludwigia palustris*, *L. octovalvis*, *Bacopa monnieri*, the sedges *Cyperus difformis*, *C. polystachyos*, and *Eleocharis geniculata*, and the grasses *Echinochloa colona* and *E. crus-galli*. The tree layer on the higher slopes away from the water are dominated by 30–40 ft. tall java plum, with a mixture of *Schefflera actinophylla*, *Leucaena leucocephala*, avocado, *Spathodea campanulata*. In places the trees are clothed with a variety of vining species: *Ipomoea alba*, *Paederia foetida*, *Coccinia grandis*, *Canavalia cathartica*, and *Ipomoea indica*. The shrub layer is poorly developed, and the herb layer within the wet streambank zone is dominated by *Pilea microphylla*. In the downstream zone where hau (*Hibiscus tiliaceus*) becomes the dominant tree cover, almost nothing grows underneath its tangle of branches. In fresh water, an unidentifiable brownish, gelatinous blue-green alga was scraped off the cement waterway, and green submerged algae were collected off of cobbly streambed rocks, yielding an unidentified *Cladophora* and possibly *C. vagabunda*.

A return trip to Kāneʻohe Stream was made on 5 June, this time approaching in kayak via the wide mouth of the stream. The opening of the stream is a man-made channel perhaps 80 ft across. The channel stays this way for perhaps 200 yards upstream. The banks along this stretch are kept mowed and consist primarily of low grasses and herbs. Residences line the north bank, while the south side is cleared, with a gravel road running the length of it down to the coast. No effort was made to do a plant list in this stretch. Past this section the vegetation becomes more rank and varied, a mix of typical alien riparian species. Of note in the vicinity of footbridge crossing the stream are floating patches of water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*). The more common species seen along the banks included wedelia (*Sphagneticola trilobata*) and California grass (*Brachiaria mutica*). A walk-through survey was done at an upstream location with high banks and houses on either side. Here the stream looks natural, with a boulder and cobble bed like that seen at the Kāneʻohe Library location. The vegetation is all alien. The patchy overstory includes hau (*Hibiscus tiliaceus*) thicket, 60 ft tall Java plum (*Syzygium cumini*), and umbrella



tree (*Schefflera actinophylla*). Planted coconut and banana trees are part of the mix. The submerged vegetation here included *Egeria densa*, *Vallisneria spiralis*, *honohono* (*Commelina diffusa*), jungle-rice grass (*Echinochloa colona*), and barnyard grass (*E. crus-galli*), just as they appeared in the upstream location. Many of the banks here are barren and support low herb weeds, such as artillery plant (*Pilea microphylla*), *maile hohono* (*Ageratum conyzoides*), Spanish needle (*Bidens pilosa*), graceful spurge (*Chamaesyce hypericifolia*), and *kaliko* (*Euphorbia heterophylla*).

Kawa Stream upstream from mouth (5 June 2001)

An approach was made via kayak to the mouth of the stream from Kāneʻohe Beach Park. The channel here is about 10–15 ft wide. Along most of the length of the stream, the banks are steep (up to 7 ft high) and topped by a golf course development on either side. The first part of the channel is dominated by a mix of American mangrove (*Rhizophora mangle*), Christmas berry (*Schinus terebinthifolius*), Indian fleabane (*Pluchea indica*), and *milo* (*Thespesia populnea*) in various combinations. Some areas are completely dominated by *Rhizophora*. In other places, the rank elephant grass (*Pennisetum purpureum*) or Guinea grass (*Panicum maximum*) are common. *Wedelia* (*Sphagneticola trilobata*) is ubiquitous, and the vines *maile pilau* (*Paederia foetida*), *maunaloa* (*Canavalia cathartica*), and ivy gourd (*Coccinia grandis*) are occasional. Approaching a cement ramp in the stream under a golf cart bridge, the streambed looks more natural, with large cobbles, and much narrower and choked with vegetation. Common species here include Job's tears (*Coix lachryma-jobi*) and umbrella sedge (*Cyperus involucratus*) in the streambed, elephant grass further upslope, with moon flower (*Ipomoea alba*) and *maunaloa* twining everywhere. One section of the stream here has a thick *hau* (*Hibiscus tiliaceus*) canopy. Other tree species here include Chinese banyan (*Ficus microcarpa*), umbrella tree, and a large *noni* (*Morinda citrifolia*) surrounded by banana trees (*Musa xparadisica*). *Egeria densa* was seen floating downstream, but no rooted populations were noted up to the concrete ramp; no other obligate wetland species were noted.

#### Riparian Vegetation Results and Discussion

A total of 144 taxa were noted during the survey. Of these, none were endemic; 12 indigenous; 127 naturalized (including 9 Polynesian-introduced); and 5 cultivated. Thus, only 8% (12 of 144) of all plant taxa seen were native, not surprising when the high level of man-made stream alteration and coastal development in the Kāneʻohe Bay basin are taken into account. (Note: *Endemic* plants are defined here as those that arrived long ago and, cut off from their mother populations, have since evolved to become uniquely Hawaiian; *indigenous* plants also arrived here by natural means long ago, but are usually readily dispersible by ocean or seabirds (the case with many coastal plants) and are also naturally occurring in other parts of the world; *naturalized* plants have been introduced in historic times, either intentionally or accidentally, and are now reproducing on their own in the wild; *Polynesian introductions* include plants believed to have been brought by the original settlers and are now naturalized).

### Description of Indigenous and Polynesian Introduced Riparian Plant Species

The indigenous and Polynesian-introduced taxa noted during the survey are enumerated and briefly commented on below.

#### Indigenous species

***Bacopa monnieri*** (L.) Wettst., 'ae'ae (Ni'ihau), figwort family (Scrophulariaceae). This creeping native herb with small, flat, fleshy leaves and white to lilac, 5-petaled flowers, is actually used frequently as a cultivated groundcover in Hawai'i. Widespread in the tropics and subtropics, in Hawai'i it can be seen naturally near the coast in wet areas such as marshes and mudflats. *Bacopa monnieri* was only occasionally seen as patches of groundcover along wet streambanks.

***Cyperus javanicus*** Houtt., 'ahu'awa, sedge family (Cyperaceae).

***Cyperus polystachyos*** Rottb., sedge family (Cyperaceae), native to tropical and subtropical regions worldwide, is a small sedge common throughout the islands, often seen in open grassy, disturbed areas from coastal sites up to the wet forest zone (Wagner et al. 1999). The species was seen in more than half the sites on wet streambanks.

***Hibiscus tiliaceus*** L., *hau*, hibiscus family (Malvaceae). A sprawling tree with an impenetrable network of branches, round, heart-shaped leaves, and typical hibiscus flowers with 5 petals that change from yellow (often with a dark red base) to orange to red during the day. *Hau* is native to tropical and subtropical coastal regions worldwide. In Hawai'i it frequently grows in dense thickets along stream courses and other lowland freshwater habitats; in Kāneʻohe Bay it is common watercourse element noted at seven of the stream sites, often forming dense thickets with a criss-crossed tangle of stems in the understory, but little else. It is thought by botanists that *hau* may have arrived in Hawai'i on its own (and is thus indigenous), but the plant was so useful that the original settlers probably also brought it with them. Uses include fiber for cordage; the light wood for booms and floats of canoe outriggers, fishing net floats, and creation of fire by friction in combination with the harder *olomea* (*Perrottetia sandwicensis*) wood; and the flowers and bark for medicinal purposes.

***Ipomoea indica*** (Burm.) Merr., *koali* 'awa, morning-glory family (Convolvulaceae). A pantropical, blue- or purple-flowered morning-glory vine common in Hawai'i in dry lowland, often disturbed sites. Called *koali* 'awa, *koali* 'awahia, or *koali pehu* in Hawaiian, the roots and leaves were used medicinally to treat wounds, sores, and broken bones, and the seeds were used as a cathartic (Wagner et al. 1999). The vine was noted twining only in a *hau* (*Hibiscus tiliaceus*) thicket on Kāneʻohe Stream.

***Ipomoea pes-caprae*** (L.) R. Br. subsp. ***brasiliensis*** (L.) Ooststr., *pōhuehue*, beach morning-glory, morning-glory family (Convolvulaceae). This pantropical vine has thick green stems; shiny green leaves up to 4 in. long, 3 in. wide, usually folded upward at midrib; and funnel-shaped flowers, pink to lavender with a purple throat and up to 3 in. long. In Hawaiʻi *pōhuehue* is a common beach plant just above the high-tide line; in Kāneʻohe Bay it was noted on sandy substrates fronting the ocean at Waiāhole and Waikāne streams. Hawaiians ate the roots and stems as a starvation food, but they are cathartic and dangerous if eaten in quantity. The seeds are also cathartic. The vines were used to drive fish into nets, and were slapped on the ocean by surfers to request high surf. The vine was part of a lei worn around the necks of new mothers to induce milk flow. The plant was also believed to have magical powers.

***Pandanus tectorius*** S. Parkinson ex Z, *hala*, screwpine, screwpine family (Pandanaceae).

***Scaevola sericea*** Vahl, *naupaka kahakai*, beach *naupaka* (Goodeniaceae). This mounding shrub is one of the most common native species still to be found on sandy Hawaiian coastlines. Beach *naupaka* has succulent, shiny green leaves; white to pale yellow, 5-petaled flowers that appear as though torn in half; and white, succulent, corky fruit about 0.5 in long. Also known by the name *Scaevola taccada*. Native throughout the coasts of the Indo-Pacific basin and Indian Ocean, in Hawaiʻi it is a common coastal shrub above the high-tide mark; during this survey it was noted as a coastal element on sand fronting the ocean adjacent to Waiāhole Stream. A primary species anchoring coastal sand dunes, beach *naupaka* is now widely used in landscaping. Plant parts are used medicinally in Asia: the bitter leaves used for indigestion, a leaf poultice applied to headaches, the charred pith used in a remedy for diarrhea, with the roots being used to treat syphilis and dysentery. The leaves are cooked as greens.

***Sesuvium portulacastrum*** (L.) L., *ʻākulikuli*, sea purslane, ice plant family (Aizoaceae).

***Solanum americanum*** Mill., glossy nightshade, *pōpolo*, tomato family (Solanaceae), is widely distributed in tropical and warm temperate areas and is often found in sites disturbed by man. A small shrub with small, glossy black berries, *pōpolo* can often be found locally in disturbed, open sites in the islands from sea level to subalpine woodlands. It is considered possibly indigenous to Hawaiʻi because seeds of this species were discovered at the Mauna Kea adze quarry complex, which was abandoned prior to Captain Cook's arrival in Hawaiʻi. *Pōpolo* was noted infrequently on wet soils near streams. The plant was used locally for sore throats and ailments of the digestive tract (Wagner et al. 1999).

***Thespesia populnea*** (L.) Sol. ex Corrêa, *milo*, portia tree, hibiscus family (Malvaceae).

***Vigna marina*** (Burm.) Merr., *nanea*, beach pea, bean family (Fabaceae).

### **Polynesian introductions**

***Aleurites moluccana*** (L.) Willd., *kukui*, candlenut tree, spurge family (Euphorbiaceae). This tree is conspicuous from a distance because of its light grayish green, maple-like foliage. The fruits are rounded, about 2 in. across, green to brown, and contain 1 or 2 black, hard-shelled seeds. It is native to Malesia and widespread in the tropics; in Hawaiʻi it is a common tree in semi-wet valleys and on slopes. It was noted streamside during the survey only at Kāneʻohe Stream. *Kukui* was declared the state tree by the 1959 Hawaiʻi State Legislature for its many uses and beauty. The wood was used for canoes and fishnet floats; the oily seeds strung on coconut midveins as candles or eaten after roasting in a condiment called *ʻinamona*; oil from the seed burned in stone lamps, mixed with soot and used as paint, and used medicinally; the white latex used medicinally, as glue, and used to waterproof *kapa*; the nuts used to make *lei*; and the green fruit husk and root bark used to produce a black dye, the latter used to stain canoes. The raw seeds are highly purgative.

***Artocarpus altilis*** (S. Parkinson ex Z) Fosb., *ʻulu*, breadfruit, fig family (Moraceae).

***Cocos nucifera*** L., *niu*, coconut, palm family (Arecaceae).

***Colocasia esculenta*** (L.) Schott, *kalo*, taro, aroid family (Araceae).

***Cordyline fruticosa*** (L.) A. Chev., *kī*, ti, agave family (Agavaceae).

***Ludwigia octovalvis*** (Jacq.) P.H. Raven, primrose willow, *kāmole*, evening primrose family (Onagraceae).

***Morinda citrifolia*** L., *noni*, Indian mulberry, coffee family (Rubiaceae). This small has leaves thick, glossy, ovate, 8–15 in. long, with prominent venation; flowers white, 5-petaled, borne in globose heads, followed by an enlargement of the head into a breadfruit-like multiple fruit 2–4 in. long, warty, hard and green at first, eventually becoming whitish yellow, ripening as a soft, foetid pulp. Native from southeastern Asia to Australia; in Hawaiʻi often seen in dry to semi-wet disturbed forests and moist gulches; a single large tree was growing streamside in Kawa Stream. *Noni* had many uses in old Hawaiʻi. A red dye was obtained from the bark and a yellow dye from the roots; the ripe fruit was used as a poultice and as a famine food either raw or cooked; the leaves, bark, and fruit used in medicines; an extracted foetid oil from the fruit used as a hair insecticide; and fruit juice used in a remedy for tuberculosis (*aumiki ʻawa*). There is much current commercial use of *noni* claiming various purported medicinal virtues.

***Musa xparadisiaca*** L., *maiʻa*, banana, banana family (Musaceae).

***Oxalis corniculata*** L., yellow wood sorrel, *ʻihi ʻai*, wood sorrel family (Oxalidaceae). A small, clover-like herb with leaves composed of 3 inverted heart-shaped leaflets; small, 5-petaled, yellow flowers; and erect, columnar green capsules that explode when pressure is applied, scattering abundant sticky seeds. A wide-ranging species of unknown origin; in Hawaiʻi it was collected by David Nelson (botanist on Capt. Cook's voyage in 1779), and may have arrived naturally attached as seeds on migratory birds. It is now a ubiquitous weed in open disturbed sites from the coast up to subalpine regions, but it was rarely seen as a wetland element during this survey. Reportedly used medicinally in Hawaiʻi. Elsewhere in Asia it is widely used to treat a variety of medical problems, including scurvy, dysentery, poisonous insect wounds, fever, and stomachache. Contains oxalic acid, which is poisonous in large doses.

#### **Alien species of note**

***Rhizophora mangle*** L., American mangrove, red mangrove, mangrove family (Rhizophoraceae). This mangrove, native to Florida, the West Indies, and South America, was introduced into Hawaiʻi by American Sugar Company in 1902 on the southwestern shore of Molokaʻi to keep soil from washing out to sea during heavy rains (Allen 1998). Other mangrove genera have subsequently been introduced into Hawaiʻi (e.g., *Bruguiera*, *Conocarpus*), but none have come close to achieving the same kind of dominance. Today, American mangrove forms monospecific, sometimes extensive groves in coastal marshy habitats. The successful proliferation of *Rhizophora* on coasts throughout the island chain owes to its efficiently dispersed fruits and its occupation of a unique niche apparently previously uninhabited in Hawaiian natural history, that of a woody tree species in the intertidal zone.

While scattered mangrove trees were noted on the windward coast of Oʻahu as early as 1921 (Devaney et al 1976), it was believed that they resulted from fruits transported 60+ miles from Molokaʻi, where the only known mature trees were found. In 1922, 14,000 seedlings of four mangrove species were planted in coastal marshlands along Oʻahu shores, resulting in the firm establishment of *Rhizophora mangle* (and, to a much lesser degree, *Bruguiera sexangula*). In a subsequent study of the vegetation of southeastern Oʻahu, Egler (1947) theorized that the total lack of evidence of any native vascular plant community in the tidal flat zone suggested that such assemblages had never developed. He surmised that plant life in these intertidal zones during prehistoric and early historic times may have consisted primarily of *Ruppia maritima*, a submerged indigenous, grasslike herb, and various algae. Once pickleweed (*Batis maritima*) was introduced in the mid-1850s, it claimed these habitats to form pure *Batis* meadows. Egler observed that *Rhizophora* was subsequently overtaking *Batis* at these sites, and he predicted that all suitable habitat would soon become American mangrove forests. Such predictions have proven accurate, as *Rhizophora* is now widespread along

the southern coast of Molokaʻi; the windward and south-central (e.g., Pearl Harbor) coasts of Oʻahu; and in scattered areas on Kauaʻi, Lānaʻi, Maui, and Hawaiʻi.

An interesting debate has developed in recent years over the virtues and drawbacks of mangroves in Hawaiʻi. Allen (1998) reviewed the history of mangroves in Hawaiʻi, noting as Egler (1947) did that they have not generally displaced native vascular plant communities. Instead, they have populated newly created coastal habitats formed from sediment deposits caused by soil runoff due to various human-caused activities (e.g., clearing of land for large-scale agriculture or urban development), as well as abandoned fishponds and disturbed coastal sites with alien herbaceous vegetation (e.g., *Batis maritima*, *Paspalum vaginatum*). Mangroves appear to provide some of the ecological benefits here that place them in high regard elsewhere in the tropics—retention of sediments washed down in streams, with accompanying improvement in offshore water quality, export of organic matter, and shoreline protection (Allen 1998). On the other hand, they have usurped coastal wetland habitat of four endangered Hawaiian waterbird taxa (and provided shelter for waterbird predators), overgrown archaeological Hawaiian fishpond sites and anchialine habitats, and clogged waterways. Mueller-Dombois and Fosberg (1998) believed that recent efforts to remove mangrove might be “ill-advised” because of its positive functions in the coastal ecosystem, unless there were clear objectives to restore native ecosystems, rebuild ancient fishponds, or reclaim endangered waterbird habitat.

*Rhizophora mangle* was by far the dominant woody species encountered during this survey. This salt-tolerant species occupies extensive stretches of coastline in Kāneʻohe Bay, especially around Heʻeia extending north and south. Thickets of mangrove allow virtually no understory except for numerous mangrove seedlings; the most commonly associated tree species was *milo* (*Thespesia populnea*). The *Rhizophora* thins out further inland with decreasing salinity, where *hau* (*Hibiscus tiliaceus*) or at Heʻeia Oriental mangrove (*Bruguiera sexangula*) take over. In some areas, such as the foreshore area of Hakipuʻu Stream, it seems only a matter of time before the drainage is clogged with mangrove.

***Bruguiera sexangula*** (L.) Lam., Oriental mangrove, *kukunaokalā*, mangrove family (Rhizophoraceae). First planted on Oʻahu in 1922 by the Hawaiian Sugar Planters' Association, this Philippine species is currently known to exist in only four Oʻahu streams—Heʻeia and Kaʻalaea in the Kāneʻohe Bay basin, and two north shore locations in Anahulu River (Waialua) and Paukauila Stream (Haleʻiwa) (Allen et al. 2000). Only at Heʻeia does a sizable naturalized population occur, and it dominates in the upper part of Heʻeia Swamp, where the salinity is almost that of fresh water, replacing the salt-tolerant *Rhizophora mangle* that forms monospecific stands downstream. Populations of *Bruguiera* at both Heʻeia and Kaʻalaea were noted during the survey, but they were thinly dispersed among the dominant *Rhizophora*. The survey at Heʻeia did not extend inland far enough to include the transition to *Bruguiera* swamp.

The name *Bruguiera gymnorrhiza* (L.) Lam. was applied to this species for many years (e.g., Neal 1965; Wagner et al. 1990), until Allen et al. (2000) presented evidence that diagnostic characters more closely matched those of *B. sexangula* (which, it turns out, was the original identification of the species when it was first planted on Oʻahu). *Bruguiera sexangula* is less salt-tolerant than *B. gymnorrhiza*, which would better explain why it is not nearly as common as *Rhizophora* as a coastal species, and why it replaces the latter in fresher waters.

***Salvinia molesta*** D. S. Mitch., Kariba weed, salvinia family (Salviniaceae). This invasive floating water fern was first noted in Hawaiʻi as an escape from water garden cultivation in April 1999 in Kaʻelepulu Pond (Enchanted Lake) and at Lake Wilson (Wahiawā). Native to southeastern Brazil, this species has been declared a Federal Noxious Weed primarily because of its incredible growth rate—it is cited as capable of doubling its volume every 2 to 3 days, under ideal conditions. Kariba weed is sterile but reproduces efficiently by vegetative means. It can readily form thick, impenetrable mats on open water that clog waterways, block all sunlight from reaching the bottom, and reduce available oxygen. The plants can be recognized by the characteristic hairs on the leaf surface, which are white, stalked, and resemble eggbeaters under magnification. One population was noted in a tributary drainage of Waikāne Stream located in thick false *kamani* forest south of the main stream. In an open area of this small tributary near Kamehameha Highway the stagnant water surface was covered with a thick layer of mature *Salvinia molesta* that covered an area of 5 ft by 10 ft. A quick check of the drainage on the mauka side of the road revealed more *Salvinia*, but not in a crowded state. Another recent collection (September 1999) was made in adjacent Waiāhole Valley in a rivulet inside the locked gates at the end of the north branch of Waiāhole Valley Road.

***Hiptage benghalensis*** (L.) Kurz, hiptage, malpighia family (Malpighiaceae). This woody vine is cultivated for its showy, fragrant, 5-petaled flowers, each petal fringed, the flag petal lemon yellow, the other four white to light pink. The helicopter-bladelike fruit has three wings, making it readily dispersible by wind. Native from Sri Lanka through Southeast Asia and the Philippines (Staples & Herbst in press), hiptage has been reported to be a serious pest in Mauritius, where it forms canopies on trees and eventually strangles them. In Hawaiʻi, naturalized populations have been noted on Kauaʻi, and on Oʻahu in Mānoa Valley and Keaʻahala Stream. The Keaʻahala population is mature and fruiting heavily, and seedlings are popping up in the understory and surrounding slopes. The thick vines are overtopping the surrounding canopy trees, primarily Java plum (*Syzygium cumini*) and Chinese banyan (*Ficus microphylla*). While apparently not yet widespread and not a threat to native forest communities in its urban location, this population should be watched closely for further spread.

Wetland Ratings

**Indicator category** (from Reed 1988)

- OBL **Obligate wetland:** species that occur almost always (est. probability >99%) under natural conditions in wetlands
- FACW **Facultative wetland:** species usually occurring in wetlands (est. probability 67–99%), but occasionally found in nonwetlands
- FAC **Facultative:** species equally likely to occur in wetlands or nonwetlands (est. probability 34–66%)
- FACU **Facultative upland:** species usually occurring in nonwetlands (est. probability 67–99%), but occasionally found in wetlands (est. probability 1–33%)
- NI **No indicator:** species for which insufficient information was available to determine indicator status
- \* **Asterisk:** indicates tentative assignments based on limited information
- **Negative:** indicates a frequency toward the lower end of the category (less frequently found in wetlands)
- + **Positive:** indicates a frequency toward the higher end of the category (more frequently found in wetlands)

Note: The Indicator categories do not refer to the degree of wetness. For example, obligate wetland species can occur in permanently flooded areas, or they may occur in areas that are only seasonally flooded. Facultative upland species can include weedy species that are adapted to environmentally stressful or disturbed sites (including wetlands), or species in which an ecotype always occurs in wetlands. Both the weedy species and the ecotype can occur in seasonally or semipermanently flooded wetlands.

**Obligate wetland**

*Bacopa monnieri* (L.) Wettst.

*Batis maritima* L.

*Bruguiera sexangula* (Lour.) Poir.

*Colocasia esculenta* (L.) Schott

*Cyperus difformis* L.

*Egeria densa* Planch.

*Eichhornia crassipes* (Mart.) Solms

*Eleocharis geniculata* (L.) Roem. & Schult.

*Spirodela punctata* (Meyer) Thompson

*Ludwigia octovalvis* (Jacq.) P. H. Raven

*Ludwigia palustris* (L.) Elliott



*Pistia stratiotes* L.

*Rhizophora mangle* L.

*Salvinia molesta* D. S. Mitch.

*Vallisneria spiralis* L.

#### **Facultative wetland**

*Brachiaria mutica* (Forssk.) Stapf

*Coix lachryma-jobi* L.

*Commelina diffusa* Burm. f.

*Conocarpus erectus* L.

*Cyperus haspan* L.

*Cyperus involucratus* Roxb.

*Cyperus javanicus* Houtt.

*Echinochloa colona* (L.) Link

*Echinochloa crus-galli* (L.) P. Beauv.

*Eclipta prostrata* (L.) L.

*Hibiscus tiliaceus* L.

*Paspalum vaginatum* Sw.

#### **Endangered Species**

A query of the Bishop Museum herbarium database for the areas surveyed in Kāneʻohe Bay uncovered no collections of plants currently (as of July 2001) on the U.S. Fish & Wildlife Service endangered and threatened plant list, and no federally listed taxa were noted on the survey. A separate database query was done to determine all of the native vascular “at-risk” taxa that might conceivably be found in the estuarine, riparian, and wetland habitats surveyed. A recent publication (Wagner, Bruegmann, Herbst & Lau 1999) assigns at-risk ratings to a total of 638 Hawaiian vascular taxa, ranging from Extinct to Endangered, Rare, or Vulnerable. Extraction of all taxa that were also given wetland ratings of OBL, FACW, or FAC in Reed (1988) resulted in a list of 89 at-risk wetland species. The vast majority were from upland bog or wet forest situations (e.g., many lobeliads in the genera *Clermontia*, *Cyanea*, and *Lobelia*). Three species, however, emerged as possibilities for the types of lowland habitats surveyed in Kāneʻohe Bay: two sedges, *Cyperus odoratus* L. and *C. trachyanthos* Hook. & Arn. (both facultative wetland species), and a fern, *Marsilea villosa* Kaulf. (obligate wetland). The latter two are federally listed endangered species, and *Cyperus odoratus* (formerly known as *Torulinium odoratum* (L.) S. S. Hooper ssp. *auriculatum* (Nees & Meyen) T. Koyama) is a species of concern. While all have been collected on Oʻahu, none have ever been collected on the windward side. Nevertheless, a more complete survey of the wetland areas in Kāneʻohe Bay might consider the potential presence of these taxa.

Much further inland, in wet gulches nestled under the Koʻolau Mountains, endangered taxa include at least three species of *Cyrtandra* (*C. kaulantha*, *C. rivularis*, *C. subumbellata*) in the African-violet family (Gesneriaceae), as well as *Lysimachia filifolia* C. Forbes in the primrose family (Primulaceae). However, none of these were found during the present study.

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Appendix A: Kāneʻohe Bay Stream Survey Plant

Species List

The following is a list of vascular plant species noted during walk-through surveys of ten estuarine and stream sites in Kāneʻohe Bay between 10 May and 14 June 2001. A total of 144 taxa are included.

Plants are divided into 4 main groups: ferns and fern allies, gymnosperms, dicots, and monocots. Within these groups, plants are arranged alphabetically by family, genus, and species. Each entry includes scientific name with author citation, biogeographic status, common name (if available), and presence or absence at each of 6 stations. Taxonomy, status, and common names are in accordance with Wagner et al. (1999) or Staples and Herbst (in press). A number of specimens were collected and deposited in the Bishop Museum Herbarium Pacificum; some unknown species were collected and compared with herbarium collections to secure correct identifications. Drs. Derral R. Herbst and George Staples (both of Bishop Museum) and Dr. Alison Sherwood (University of Hawaii at Mānoa) are thanked for assistance with identifications. An explanation of abbreviations used in the list follows.

Plant Biogeographic Status

end Endemic: native, occurring only in the Hawaiian Archipelago; species that have evolved into something uniquely Hawaiian after arriving naturally from elsewhere.

ind Indigenous: native, occurring naturally in the archipelago but also outside of Hawaiʻi; many of

these species inhabit the coastal zone, where they can be readily dispersed by water or seabirds.

nat Naturalized: introduced to the archipelago directly or indirectly by humans since Western contact and reproducing and spreading vegetatively or from seed.

pol Polynesian introduction: introduced by original Polynesian settlers, either intentionally or unintentionally, and now naturalized.

ind? Questionably indigenous: probably indigenous, possibly naturalized.

nat? Questionably naturalized: probably naturalized, possibly indigenous.

pol? Questionably a Polynesian introduction; possibly introduced in historic times.

Plant survey sites

- 1 Hakipuʻu Stream
- 2 Waikāne Stream
- 3 Waiāhole Stream
- 4 Kaʻalaea Stream
- 5 Waiheʻe Stream
- 6 Kahaluʻu Stream
- 7 Heʻeia Stream
- 8 Keaʻahala Stream
- 9 Kāneʻohe Stream
- 10 Kawa Stream

**Ferns & Fern Allies**

Family/Scientific name	Status	Common name		1	2	3	4	5	6	7	8	9	10
Dryopteridaceae													
<i>Cyrtomium falcatum</i> (L. f.) Presl	nat	holly fern										x	
Polypodiaceae													
<i>Phymatosorus grossus</i> (Langsd. & Fisch.) Brownlie	nat	<i>lauaʻe</i> , maile-scented fern								x	x	x	
Pteridaceae													
<i>Pityrogramma calomelanos</i> (L.) Link	nat	silverfern											x
<i>Pteris vittata</i> L.	nat	ladder brake, cliff brake, Chinese brake					x						x
Salviniaceae													
<i>Salvinia molesta</i> D. S. Mitch.	nat	Kariba weed, giant salvinia			x								
Thelypteridaceae													
<i>Christella parasitica</i> (L.) Leveille	nat			x		x						x	x

**Gymnosperms**

Family/Scientific name	Status	Common name		1	2	3	4	5	6	7	8	9	10
Podocarpaceae													
<i>Podocarpus</i> sp.	cult												x

**Dicots**

Family/Scientific name	Status	Common name		1	2	3	4	5	6	7	8	9	10
Acanthaceae													
<i>Asystasia gangetica</i> (L.) T. Anderson	nat	Chinese violet, coromandel								x			x
<i>Ruellia prostrata</i> Poir.	nat		FAC								x		
Aizoaceae													
<i>Sesuvium portulacastrum</i> (L.) L.	ind	<i>ʻākulikuli</i> , sea purslane	FAC							x			
Amaranthaceae													
<i>Amaranthus viridis</i> L.	nat	slender amaranth	FAC	x			x				x		x
Anacardiaceae													
<i>Schinus terebinthifolius</i> Raddi	nat	Christmas berry, <i>wilelaiki</i>	FACU -							x		x	x
Araliaceae													
<i>Schefflera actinophylla</i> (Endl.) Harms	nat	octopus tree, umbrella tree		x			x			x	x	x	x
Asteraceae													
<i>Ageratina riparia</i> (Regel) R. M. King & H. Rob.	nat	Hāmākua pāmakani, spreading mist flower	FACU								x		
<i>Ageratum conyzoides</i> L.	nat	<i>maile hohono</i>	FAC*	x			x				x	x	x
<i>Bidens alba</i> (L.) DC. var. <i>radiata</i> (Sch. Bip.) Ballard ex Melchert	nat	Spanish needle, beggartick							x				
<i>Bidens pilosa</i> L.	nat	Spanish needle, beggartick										x	
<i>Crassocephalum crepidioides</i> (Benth.) S. Moore	nat		FAC	x									

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<i>Eclipta prostrata</i> (L.) L.	nat	false daisy	FAC W	x	x		x			x	x		x
<i>Emilia fosbergii</i> Nicolson	nat	<i>pualele</i> (Ni'ihau)					x						x
<i>Emilia sonchifolia</i> (L.) DC. var. <i>sonchifolia</i>	nat	Flora's paintbrush		x									
<i>Galinsoga parviflora</i> Cav.	nat												x
<i>Pluchea carolinensis</i> (Jacq.) G. Don	nat	sourbush, marsh fleabane	FAC*	x		x		x		x			x
<i>Pluchea indica</i> (L.) Less.	nat	Indian fleabane, Indian pluchea	FAC				x			x	x		x
<i>Pluchea x fosbergii</i> Cooperr. & Galang	nat	marsh fleabane	FAC										x
<i>Sonchus oleraceus</i> L.	nat	sow thistle, <i>pualele</i>					x	x		x			x
<i>Sphagneticola trilobata</i> (L.) Pruski	nat	wedelia	FACU	x	x	x	x	x	x		x	x	x
<i>Youngia japonica</i> (L.) DC.	nat	Oriental hawksbeard										x	x
Balsaminaceae													
<i>Impatiens wallerana</i> Hook. f.	nat	busy Lizzy, patient Lucy											x
Bataceae													
<i>Batis maritima</i> L.	nat	pickleweed, 'ākulikuli <i>kai</i>	OBL							x			
Begoniaceae													
<i>Begonia hirtella</i> Link	nat												x
Bignoniaceae													
<i>Spathodea campanulata</i> P. Beauv.	nat	African tulip tree, fountain tree											x
Boraginaceae													
<i>Tournefortia argentea</i> L. f.	nat	tree heliotrope			x	x						x	
Brassicaceae													
<i>Cardamine flexuosa</i> With.	nat	bittercress	FAC	x									x
Buddleiaceae													
<i>Buddleia asiatica</i> Lour.	nat	<i>huelo</i> 'īlio, dog tail, butterfly bush											x
Casuarinaceae													
<i>Casuarina equisetifolia</i> L.	nat	common ironwood, <i>paina</i>	FACU			x						x	
Clusiaceae													
<i>Clusia rosea</i> Jacq.	nat	autograph tree, copey, Scotch attorney										x	x
Combretaceae													
<i>Conocarpus erectus</i> L.	nat	sea mulberry, buttonwood, button mangrove	FAC W							x			
<i>Terminalia catappa</i> L.	nat	tropical almond, Indian almond, false <i>kamani</i>		x	x	x				x	x		
Convolvulaceae													
<i>Ipomoea alba</i> L.	nat	moon flower, <i>koali pehu</i>	FACU		x	x							x
<i>Ipomoea indica</i> (Burm.) Merr.	ind	<i>koali</i> 'awa	FACU										x
<i>Ipomoea obscura</i> (L.) Ker Gawl.	nat	morning glory			x		x						x
<i>Ipomoea pes-caprae</i> (L.) R. Br. ssp. <i>brasiliensis</i> (L.) Ooststr.	ind	<i>pōhuehue</i> , beach morning glory	FAC		x	x							
<i>Ipomoea triloba</i> L.	nat	little bell					x						
<i>Merremia aegyptia</i> (L.) Urb.	nat?	hairy merremia											x
<i>Merremia tuberosa</i> (L.)	nat	wood rose, <i>pilikai</i>											x



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Rendle																			
Cucurbitaceae																			
<i>Coccinia grandis</i> (L.) Voigt	nat	ivy gourd, scarlet-fruited gourd			x	x						x	x	x	x				
<i>Momordica charantia</i> L.	nat	balsam pear, bitter melon	FAC*				x					x				x			
Euphorbiaceae																			
<i>Aleurites moluccana</i> (L.) Willd.	pol	kukui, candlenut																	x
<i>Chamaesyce hirta</i> (L.) Millsp.	nat	hairy spurge, garden spurge																	x
<i>Chamaesyce hypericifolia</i> (L.) Millsp.	nat	graceful spurge		x			x		x										x
<i>Chamaesyce hyssopifolia</i> (L.) Small	nat	spurge																	x
<i>Euphorbia heterophylla</i> L.	nat	kaliko, spurge																	x
<i>Manihot glaziovii</i> Müll. Arg.	nat	Ceará rubber tree																	x
<i>Phyllanthus debilis</i> Klein ex Willd.	nat	niruri	FAC	x			x		x	x									x
<i>Ricinus communis</i> L.	nat	castor bean								x									x x
Fabaceae																			
<i>Canavalia cathartica</i> Thouars	nat	maunaloa	FACU	x	x														x x x
<i>Chamaecrista nictitans</i> (L.) Moench var. <i>glabrata</i> (Vogel) H. S. Irwin & Barneby	nat	partridge pea, <i>laukī</i>																	x
<i>Desmanthus pernambucanus</i> (L.) Thell.	nat	slender mimosa, virgate mimosa																	x
<i>Desmodium sandwicense</i> E. Mey.	nat	Spanish clover, chili clover	FACU*																x
<i>Erythrina variegata</i> L.	cult	tiger's claw, Indian coral tree					x												
<i>Falcataria moluccana</i> (Miq.) Barneby & J. W. Grimes	nat						x												
<i>Leucaena leucocephala</i> (Lam.) de Wit	nat	koa haole			x		x		x	x	x	x	x	x	x	x	x	x	x
<i>Macroptilium lathyroides</i> (L.) Urb.	nat	wild bean, cow pea																	x
<i>Mimosa pudica</i> L. var. <i>unijuga</i> (Duchass. & Walp.) Griseb.	nat	sensitive plant, sleeping grass	FACU	x					x										x
<i>Neonotonia wightii</i> (Wight & Arn.) Lackey	nat			x															
<i>Samanea saman</i> (Jacq.) Merr.	nat	monkeypod, rain tree, 'ohai					x												x
<i>Senna surattensis</i> (Burm. f.) H. S. Irwin & Barneby	nat	kolomona, kalamona							x										
<i>Vigna marina</i> (Burm.) Merr.	ind	nanea, beach pea		x		x	x												
Goodeniaceae																			
<i>Scaevola sericea</i> Vahl	ind	naupaka kahakai					x												
Lamiaceae																			
<i>Hyptis capitata</i> Jacq.	nat			x															
<i>Hyptis pectinata</i> (L.) Poit.	nat	comb hyptis	NI																x
Lauraceae																			
<i>Persea americana</i> Mill.	nat	avocado, alligator pear																	x
Malpighiaceae																			
<i>Hiptage benghalensis</i> (L.)	nat	hiptage																	x

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Kurz																			
Malvaceae																			
<i>Hibiscus rosa-sinensis</i> L.	cult	red hibiscus, Chinese hibiscus					x												
<i>Hibiscus tiliaceus</i> L.	ind?	<i>hau</i>	FAC W	x	x	x	x	x								x	x		
<i>Malvaviscus penduliflorus</i> DC.	nat	Turk's cap, <i>aloalo pahūpahū</i>														x			
<i>Sida rhombifolia</i> L.	nat?		FACU	x															
<i>Thespesia populnea</i> (L.) Sol. ex Corrêa	ind?	<i>milo</i> , portia tree	FAC	x	x	x	x					x	x	x	x				
<i>Urena lobata</i> L.	nat	aramina		x															
Melastomataceae																			
<i>Clidemia hirta</i> (L.) D. Don var. <i>hirta</i>	nat	Koster's curse		x															
Moraceae																			
<i>Artocarpus altilis</i> (Parkins. ex Z) Fosb.	pol	' <i>ulu</i> , breadfruit																x	
<i>Ficus microcarpa</i> L. f.	nat	Chinese banyan, Malayan banyan					x			x			x	x	x				
Myrtaceae																			
<i>Eucalyptus</i> sp.	nat																	x	
<i>Eugenia uniflora</i> L.	nat	Surinam cherry, pitanga										x							
<i>Syzygium cumini</i> (L.) Skeels	nat	Java plum, jambolan plum	FACU	x	x	x		x					x	x	x				
Ochnaceae																			
<i>Ochna thomasi</i> Engl. & Gilg	nat												x						
Onagraceae																			
<i>Ludwigia octovalvis</i> (Jacq.) P. H. Raven	pol?	primrose willow, <i>kāmole</i>	OBL	x														x	x
<i>Ludwigia palustris</i> (L.) Elliott	nat	marsh purslane	OBL	x														x	x
Oxalidaceae																			
<i>Oxalis corniculata</i> L.	pol?	yellow wood sorrel, ' <i>ihi 'ai</i>																x	x
Passifloraceae																			
<i>Passiflora edulis</i> Sims	nat	passion fruit, purple granadilla, <i>liliko'i</i>																x	
<i>Passiflora laurifolia</i> L.	nat	yellow granadilla, yellow water lemon											x						
<i>Passiflora suberosa</i> L.	nat	<i>huehue haole</i>											x					x	
Phytolaccaceae																			
<i>Rivina humilis</i> L.	nat	coral berry, rouge plant																x	x
Portulacaceae																			
<i>Portulaca oleracea</i> L.	nat	pigweed																	x
Rhizophoraceae																			
<i>Bruguiera sexangula</i> (Lour.) Poir.	nat	Oriental mangrove, <i>kukunaokalā</i>	OBL				x						x						
<i>Rhizophora mangle</i> L.	nat	American mangrove, red mangrove	OBL	x	x	x	x					x	x	x					x
Rubiaceae																			
<i>Morinda citrifolia</i> L.	pol	<i>noni</i> , Indian mulberry																	x
<i>Paederia foetida</i> L.	nat	<i>maile pilau</i>		x		x		x				x	x	x	x				x
Sapotaceae																			
<i>Chrysophyllum oliviforme</i> L.	nat																		x

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Scrophulariaceae														
<i>Bacopa monnieri</i> (L.) Wettst.	ind	'ae'ae (Ni'ihau)	OBL		x		x					x	x	
Solanaceae														
<i>Solanum americanum</i> Mill.	ind?	glossy nightshade, <i>pōpolo</i>		x			x					x		
<i>Solanum lycopersicum</i> L. var. <i>cerasiforme</i> (Dunal) Spooner, G. J. Anderson & R. K. Jansen	nat	tomato, 'ōhi'a lomi										x		
Ulmaceae														
<i>Trema orientalis</i> (L.) Blume	nat	gunpowder tree, charcoal tree						x						
Urticaceae														
<i>Pilea microphylla</i> (L.) Liebm.	nat	artillery plant, rockweed											x	x x
Verbenaceae														
<i>Citharexylum caudatum</i> L.	nat	fiddlewood						x				x		

Monocots

Family/Scientific name	Status	Common name		1	2	3	4	5	6	7	8	9	10
Agavaceae													
<i>Cordyline fruticosa</i> (L.) A. Chev.	pol	<i>kī</i> , ti											x
Araceae													
<i>Colocasia esculenta</i> (L.) Schott	pol	<i>kalo</i> , taro	OBL		x							x	
<i>Epipremnum pinnatum</i> (L.) Engl.	nat	taro vine, pothos, golden pothos								x	x		x
<i>Pistia stratiotes</i> L.	nat	water lettuce	OBL										x
<i>Xanthosoma roseum</i> Schott	nat	'ape			x								x x
Arecaceae													
<i>Cocos nucifera</i> L.	pol	<i>niu</i> , coconut	FACU	x	x	x	x		x	x	x	x	x
Commelinaceae													
<i>Commelina diffusa</i> Burm. f.	nat	<i>honohono</i> , dayflower	FACW	x		x	x				x	x	x
Cyperaceae													
<i>Cyperus difformis</i> L.	nat		OBL										x
<i>Cyperus gracilis</i> R. Br.	nat	McCoy grass, <i>mau'u hunehune</i>	FAC							x			
<i>Cyperus haspan</i> L.	nat		FACW +	x									
<i>Cyperus involucratus</i> Roxb.	nat	umbrella sedge, 'ahu'awa <i>haole</i>	FACW	x	x	x	x		x	x	x	x	x
<i>Cyperus javanicus</i> Houtt.	ind	'ahu'awa, 'ehu'awa	FACW		x					x			
<i>Cyperus polystachyos</i> Rottb.	ind		FAC*	x	x	x	x				x	x	
<i>Eleocharis geniculata</i> (L.) Roem. & Schult.	nat	spikerush	OBL	x									x
<i>Kyllinga brevifolia</i> Rottb.	nat	<i>kili'o'opu</i>	FAC	x									
<i>Kyllinga nemoralis</i> (J. R. Forst. & G. Forst.) Dandy ex Hutch. & Dalziel	nat	<i>kili'o'opu</i>	FAC	x									
Heliconiaceae													
<i>Heliconia</i> sp.	cult											x	x
Hydrocharitaceae													
<i>Egeria densa</i> Planch.	nat		OBL										x x
<i>Vallisneria spiralis</i> L.	nat		OBL										x
Lemnaceae													

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<i>Spirodela punctata</i> (Meyer) Thompson	nat	duckweed	OBL		x												
Liliaceae																	
<i>Asparagus densiflorus</i> (Kunth) Jessop	nat											x					
<i>Crinum pedunculatum</i> R. Br.	cult	river lily, swamp lily											x				
Musaceae																	
<i>Musa x paradisiaca</i> L.	pol	mai'a, banana	FACU	x												x	x
Pandanaceae																	
<i>Pandanus tectorius</i> Parkinson ex Z	ind	hala, pū hala, screwpine	FAC	x	x												
Poaceae																	
<i>Brachiaria mutica</i> (Forssk.) Stapf	nat	California grass, Para grass	FACW	x	x	x	x	x								x	x
<i>Chloris barbata</i> (L.) Sw.	nat	swollen fingergrass, mau'u lei					x										
<i>Coix lachryma-jobi</i> L.	nat	Job's-tears, pū'ohe'ohe	FACW +	x	x	x	x								x		x
<i>Cynodon dactylon</i> (L.) Pers.	nat	Bermuda grass, mānienie					x			x							
<i>Echinochloa colona</i> (L.) Link	nat	jungle-rice	FACW		x		x									x	
<i>Echinochloa crus-galli</i> (L.) P. Beauv.	nat	barnyard grass	FACW	x			x									x	
<i>Eleusine indica</i> (L.) Gaertn.	nat	wiregrass, mānienie ali'i	FACU-				x					x				x	
<i>Panicum maximum</i> Jacq.	nat	Guinea grass	FACU		x	x		x							x	x	x
<i>Paspalum conjugatum</i> P. J. Bergius	nat	Hilo grass, sour paspalum	FAC+	x											x		
<i>Paspalum vaginatum</i> Sw.	nat	seashore paspalum	FACW +	x	x	x	x			x	x	x	x	x			
<i>Pennisetum purpureum</i> Schumach.	nat	elephant grass, Napier grass				x											x
<i>Setaria verticillata</i> (L.) P. Beauv.	nat	bristly foxtail, mau'u pilipili					x										x
<i>Sorghum halepense</i> (L.) Pers.	nat	Johnson grass								x							x
Pontederiaceae																	
<i>Eichhornia crassipes</i> (Mart.) Solms	nat	water hyacinth	OBL						x								x

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Appendix B: Vouchers taken (deposited at Bishop Museum)

COLLECTOR COLLNUMBER	GENUS SPECIES/FamilyID/LOCALITY/HABITAT/COLLDATE
C.Imada & D.Preston 2001-25	<i>Vallisneria spiralis</i> L. (Hydrocharitaceae)—Kāneʻohe Stream adjacent to Kāneʻohe Library. Forming dense patches rooted to the substrate in fast-running fresh water. Growing adjacent to a different form of <i>V. spiralis</i> , 10.v.2001
C.Imada & D.Preston 2001-26	<i>Vallisneria spiralis</i> L. (Hydrocharitaceae)—Kāneʻohe Stream adjacent to Kāneʻohe Library. Forming dense, flowing patches rooted to the substrate in fast-running fresh water. Growing adjacent to and intermingled with a different form of <i>V. spiralis</i> (Imada & Preston 2001-25), 10.v.2001
C.Imada & D.Preston 2001-27	<i>Egeria densa</i> Planch. (Hydrocharitaceae)—Kāneʻohe Stream adjacent to Kāneʻohe Library. Forming dense patches rooted to the substrate in fast-running fresh water. Growing with <i>Vallisneria spiralis</i> , 10.v.2001
C.Imada & D.Preston 2001-29	<i>Pennisetum purpureum</i> Schumach. (Poaceae)—Waiāhole Stream, on bank of stream about 100 ft from mouth. Tall, rank grass with thick, canelike stems forming dense stands. Fronted by <i>Brachiaria mutica</i> , backed by <i>Rhizophora mangle</i> forest, 21.v.2001
C.Imada & D.Preston 2001-30	<i>Paspalum vaginatum</i> Sw. (Poaceae)—Waiāhole Stream, on banks of stream at interface with the ocean. Forming thick mats along shoreline under saturated conditions, interspersed with some <i>Sphagneticola trilobata</i> and <i>Vigna marina</i> , 21.v.2001
C.Imada & D.Preston 2001-31	Unidentified Rhodophyta—Waiāhole Stream mouth. Attached to rocks at interface of stream and ocean, 10 ppt salinity, 21 May 2001
C.Imada & D.Preston 2001-33	<i>Rhizophora mangle</i> L. (Rhizophoraceae)—Waikāne Stream mouth. Dominant tree species on mudflats fronting the ocean, along with <i>Hibiscus tiliaceus</i> and <i>Thespesia populnea</i> , 22.v.2001
C.Imada & D.Preston 2001-34	<i>Spirodela punctata</i> (Meyer) Thompson (Lemnaceae)—Waikāne Stream, tributary drainage south of main drainage, on north edge of large clearing. Tiny floating plant in standing water with multiple roots. Waterway is dominated by <i>Hibiscus tiliaceus</i> , banks with <i>Sphagneticola trilobata</i> , <i>Echinochloa colona</i> , <i>Paspalum vaginatum</i> , <i>Cyperus javanicus</i> , <i>Bacopa monnieri</i> , 22.v.2001
C.Imada & D.Preston 2001-35	<i>Salvinia molesta</i> D.S.Mitch. (Salviniaceae)—Waikāne Stream, tributary drainage south of main drainage, not reaching the ocean. Dense cluster ca. 8 sq ft in standing water under heavy <i>Terminalia catappa</i> overstory, concentrated where canopy opens up adjacent to Kamehameha Hwy. Crowded plants with folded leaves, many sporocarps, 22.v.2001
C.Imada & D.Preston 2001-37	<i>Bruguiera sexangula</i> (Lour.) Poir. (Rhizophoraceae)—Heʻeia Stream, on mudflat between the stream and Heʻeia Fishpond. A small 7 ft. tall spreading tree, 25.v.2001
C.Imada & D.Preston 2001-39	<i>Acanthophora spicifera</i> (Vahl) Børgesen (Rhodomelaceae)—Heʻeia Stream, at interface between stream mouth and ocean. Attached to bottom in silty zone, 25 May 2001
C.Imada, R.Englund, D.Preston 2001-42	<i>Ludwigia palustris</i> (L.) Elliott (Onagraceae)—Kawa Stream, adjacent to Bayview Golf Course. An occasional creeping herb growing in standing water with <i>Coix lachryma-jobi</i> , <i>Ludwigia octovalvis</i> , <i>Commelina diffusa</i> , <i>Cyperus involucratus</i> , 5.vi.2001
C.Imada, R.Englund, D.Preston 2001-43	<i>Egeria densa</i> Planch. (Hydrocharitaceae)—Kāneʻohe Stream, in shallow, fast-running section of stream. Forming thick mats underwater along with <i>Vallisneria spiralis</i> , 5.vi.2001
C.Imada, R.Englund, D.Preston 2001-44	<i>Vallisneria spiralis</i> L. (Hydrocharitaceae)—Kāneʻohe Stream, in shallow, fast-running section of stream. Forming thick mats underwater along with <i>Egeria densa</i> and another form of <i>Vallisneria</i> , 5.vi.2001
C.Imada, R.Englund, D.Preston 2001-48	<i>Ruellia squarrosa</i> (Fenzl) Cuf. (Acanthaceae)—Kāneʻohe, Keaʻahala Stream, just below Wailele Bridge overpass. Common trailing herb on damp, rocky streamside banks under heavy canopy of <i>Ficus microphylla</i> , <i>Syzygium cumini</i> , <i>Schefflera actinophylla</i> . Growing with wedelia, <i>Hiptage benghalensis</i> , <i>Pilea microphylla</i> , 12.vi.2001

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C.Imada, R.Englund, D.Preston 2001-49	<i>Hiptage benghalensis</i> (L.) Kurz (Malpighiaceae)— Kāne‘ohe, Kea‘ahala Stream, just below Waialele Bridge overpass. Common liana with thick stems, growing up into and cascading over canopy of <i>Ficus microphylla</i> and <i>Syzygium cumini</i> . Produces abundant helicopter-like fruit. Many seedlings noted in understory, 12.vi.2001
C.Imada, R.Englund, D.Preston 2001-50	<i>Vigna marina</i> (Burm.) Merr. (Fabaceae)—On muddy, disturbed bank of Ka‘alaea Stream (located north of Kahalu‘u Stream) ca. 50 yds upstream from the mouth. Growing with <i>Paspalum vaginatum</i> , <i>Bacopa monnieri</i> , <i>Eclipta prostrata</i> , <i>Setaria verticillata</i> , <i>Cynodon dactylon</i> , <i>Cyperus polystachyos</i> . Vining herb with bright yellow pea-type flowers, 14.vi.2001