Rapid Biological Inventories of Streams in the Ala Wai Watershed, O‘ahu Island, Hawai‘i

Hawaii Biological Survey

Final Report **May 2004**

Rapid Biological Inventories of Streams in the Ala Wai Watershed, O‘ahu Island, Hawai‘i

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EXECUTIVE SUMMARY

As part of a rapid biological assessment of native and alien aquatic species, the Hawaii Biological Survey (HBS) of the Bishop Museum collected fish, aquatic insects and other stream invertebrates in streams draining the Ala Wai watershed. A total of thirty representative sampling stations for aquatic macrofauna were sampled concurrently with a riparian vegetation assessment by E. Guinther of Aecos, Inc., and a stream channel assessment by R. Bourke of Oceanit, Inc. The purpose of these surveys was to provide a rapid biological assessment of the aquatic biota found within the Ala Wai watershed and provide recommendations to assist in the restoration and rehabilitation of stream habitat within the watershed.

With a few notable exceptions, the aquatic macrofauna found within the Ala Wai watershed was comprised largely of invasive alien species. Except in the highest reaches of the Ala Wai watershed, aquatic habitats were found to be highly disturbed; this was a result of the effects of urbanization that includes stream diversions and miles of concrete channelization. The worst form of channelization found during these surveys was the flat-bottom concrete lined channels such as those found in lower Pālolo Stream, where stream temperatures were increased by 23° F because of channelization. No native aquatic species were found in concrete-lined stream channels. A complete loss of channel heterogeneity and riparian vegetation cover result in increased water temperatures that are lethal to native species.

To compare all sites, each site was ranked by the number of native aquatic species found at that site and the overall habitat quality. These rankings are not providing a value judgment as to which are the most valuable streams, or that any particular stream section has been ranked as good or bad. Rather, these qualitative ranking values reflect whether native aquatic species remain in each particular sample area of a highly urbanized and impacted watershed, in combination with the current condition of aquatic habitats at each assessed station. To provide a basis for the habitat rankings, two major criteria used to provide an overall rank at each sampling station. The number of native aquatic species found at each site, along with overall aquatic habitat quality were used to provide an overall rank between 1 (worst) and 10 (best). The numbers of native aquatic species, and their rarity or abundance at a particular station is not a subjective factor, but rather is a measurable value and has been incorporated into this ranking system. These habitat values are relative and are only comparable only between Ala Wai watershed streams and not to other areas such as other more pristine and unimpacted watersheds.

INTRODUCTION

As part of a rapid biological assessment of native and alien aquatic species, the Hawaii Biological Survey (HBS) of the Bishop Museum collected and identified fish, aquatic insects and other stream invertebrates in streams draining the Ala Wai watershed. A total of thirty representative sampling stations for aquatic macrofauna were sampled concurrently with a riparian vegetation assessment by E. Guinther of Aecos, Inc., and a stream channel assessment by R. Bourke of Oceanit, Inc. The purpose of these surveys was to provide a rapid biological assessment of the aquatic biota found within the Ala Wai watershed and provide recommendations to assist in the restoration and rehabilitation of stream habitat within the watershed. These surveys provided an inventory of the overall aquatic macrofauna present at each sampling station and also ensured museum specimens will be available for future researchers.

STUDY AREA

The Ala Wai watershed encompasses some of the most densely populated urban areas of Honolulu and is located in leeward, south-central O‘ahu. Streams in this watershed drain Pu‘u Konahuanui, which at 3105 ft is the highest peak in the Ko‘olau Mountain range. Mānoa and Pālolo Valleys contain the two major stream systems of the Ala Wai watershed, with Mānoa Stream containing a complex radial set of six larger named tributaries in its upper reaches. Makiki and Kanaha Valleys drain a much smaller area, with Kanaha Stream only flowing intermittently. A representative cross-section of stream reaches were examined starting with the highest generally accessible sections of each stream and proceeding downstream to their terminus with the ocean. Table 1 denotes stream station sampled, dates of sampling, and GPS points (WGS 84) taken at each station.

The following is a brief discussion of aquatic habitats found within each of the three major valleys.

Makiki Stream

Three areas of Kanaha Stream were assessed but this stream obviously flows only intermittently, and it is unknown whether the Kanaha tributaries to Makiki Stream ever actually flowed permanently prior to large-scale urbanization that occurred in this area in the early part of the 20th century. Makiki Stream and its associated tributaries maintain a permanent albeit low-flow. For example, Herring Springs found at upper Moleka Stream was completely diverted by several Board of Water Supply box culverts apparently until 1994. This area was historically an important collecting site in the 1890s and early 1900s by R.C.L. Perkins and other early collectors, prior to it being diverted, for several now extinct native O‘ahu damselfly species (Englund 1999). The upper reaches of Makiki Stream are quite low-flowing and but it is unclear how the historical diversions impact current stream flow because virtually all the upper tributary reaches of Makiki Stream were diverted at one time. Feral pig wallows around the areas of the upper Makiki tributaries (e.g., Moleka Springs, Kanealole Stream), and damage to the vegetation by pigs was a large contributor of sediment into the stream. Makiki Stream flowed largely as a natural channel downstream through Makiki Park, but at Station MA2 near

the large Board of Water Supply tanks the stream was largely channelized downstream from this point to the ocean. Channelization varies from a either a complete concrete flume (sometimes encased completely underground) to concrete or rock walls with a more natural stream bottom, such as found at Station MA3 near Jack-In-The Box on King Street. In 1978, 32% of the length of Makiki Stream was channelized (Norton et al. 1978). Emergent springs appear to augment stream flow and maintain relatively low stream temperatures favorable for native fish at Station MA3, which is not tidally influenced. Slightly further downstream, the stream flows through residential and business areas with less favorable channelized habitats.

Mānoa Stream

Streams in the upper Mānoa watershed begin as numerous clear, cold, bifurcated streamlets draining the southern slopes of Pu‘u Konahuanui. Aquatic habitats in the uppermost sampling stations of Mānoa Stream contained excellent aquatic habitats. Clear water high gradient riffles and cascades connected by shallow runs and some smaller pools flowed through an introduced forest for most of the upper (> 400 ft) tributaries sampled. Shading in some areas, such as at Lua‘alaea Stream (Station MN4) by introduced riparian vegetation was deemed to be excessive, and not likely the natural state of riparian shading with the original native riparian plants. Complete dewatering of streams was not observed in any of the stations sampled in the Mānoa watershed, and diversions from Mānoa Stream appeared to be a lesser problem than observed in the Makiki drainage. The effects of urbanization on the stream became increasingly apparent further downstream, although stream habitats were still mostly quite good until Mānoa Elementary school. Occasional stream channel hardening such as concrete walls was observed above Mānoa Elementary but the streambed mostly retained a fairly natural channel. Below Mānoa Valley District Park the stream channel became wide and shallow, and heavy construction around the park area was responsible for sediment input into the streambed. Further downstream, the channel flows through University of Hawai‘i where urban debris and trash such as shopping carts were strewn throughout the stream channel. Some areas of Mānoa Stream flowing through the campus maintained excellent habitat and were clean, such as areas around the ‘auwai intake for the Hawaiian Studies kalo lo‘i. Below this point the stream flows to its tidal estuary through a wide, shallow and open concrete or sometimes dredged channel with little riparian vegetation to provide shading or cover for aquatic fauna.

Pālolo Stream

Pālolo Stream begins at over 2000 ft. from the bog found within Ka‘au Crater, and its upper reaches have a more straight and narrow overall stream morphology than Mānoa Stream. More than in any of the other streams examined in this study, conditions within Pālolo Stream dramatically illustrated how urbanization negatively impacts aquatic habitats. For example, one of the main impacts of urbanization has been concrete channelization of the stream leading to a near complete loss of aquatic habitats such as riffles and pools. Long segments of lower Pālolo Stream were found to

be channelized, and in 1978 24% of the length of the Mānoa/Pālolo stream was channelized (Norton et al. 1978). Stream temperature is one of the most important factors limiting native aquatic biota, and channelization was observed to greatly raise temperatures. Temperatures upstream of the channelization were found on 29 April 2004 to be 70.5 °F at Station PO5, while the highest recorded temperature found during this study of 93.5 °F was recorded at Station PO4, near the St. Louis High School football field, downstream of a long channelized stretch of river. This 23 °F difference was found during midday (between 1200 and 1300 hrs), and the higher temperatures are almost certainly lethal to native aquatic biota as none were observed in the concrete channel section. Temperatures would be expected to far exceed 93.5 °F in the summer when stream flows would be lower and overall temperatures higher. Although temperatures were certainly lethal for native aquatic biota because of a lack of shade in the channelized areas, the channel morphology was also greatly disturbed because of a complete lack of natural stream substrate needed to form pools and riffles in lower Pālolo Stream.

Table 1. Streams sampled, sampling sites, GPS waypoints (WGS 84), and dates sampled, elevations are approximate in some cases.

Stream (Elevation)	GPS (WGS 84)	Dates Sampled	Remarks
Kanaha (KN1) 120 ft	N 21.31089° W 157.83939°	6 Oct 2003	Dry Streambed
Kanaha (KN2) 380 ft	N 21.31930° W 157.83311°	6 Oct 2003	Dry Streambed
Kanaha (KN3) 950 ft	No gps reception here	6 Oct 2003	Dry Streambed
Kanealole (KL1) 950-976 ft	N 21.32676° W 157.82172°	6 Oct 2003	Silty streamlet
Kanealole (KL2) 360 ft	N 21.31779° W 157.82693°	6 Oct 2003	
Unnamed spring (IN1) 950 ft	N 21.32640° W 157.82143°	6 Oct; 3 Nov 2003,	Only site lacking alien fish
Moleka Spring (MO1) 1000 ft	N 21.32333° W 157.81857°	6 Oct 2003	also known as Herring springs
Makiki (MA1) 141 ft	N 21.31210° W 157.83012°	8 Oct 2003	
Makiki (MA2) 149 ft	N 21.30912° W 157.83029°	8 Oct 2003	
Makiki (MA3) 6-7 ft	N 21.29713° W 157.83670°	8 Oct 2003	at Jack-In-The Box
Makiki (MA4) 0 ft	N 21.29253° W 157.83594°	8 Oct 2003	tidal
Makiki (MA5) 0 ft	N 21.28885° W 157.83449°	8 Oct 2003	tidal
Hausten (HA1) 0 ft	N 21.28680° W 157.82918°	10 Oct 2003	tidal
Hausten (HA2) 0 ft	N 21.29044° W 157.82478°	8 Oct 2003	channelized tidal ditch
Aihualama (MN1) 420 ft	N 21.33338° W 157.80103°	13 Oct 2003	
Waihī (MN2) 420 ft	N 21.33438° W 157.80046°	13 Oct 2003	very depauperate station
Waiakeakua (MN3) 420 ft	N 21.32938° W 157.79744°	13 Oct 2003	
Luaalaea (MN4) 257 ft	N 21.33128° W 157.79832°	13 Oct 2003	large numbers of ants
Mānoa (MN5) 240 ft	N 21.32318° W 157.80269°	13 Oct 2003	
Mānoa (MN6) 206 ft	N 21.31786° W 157.80443°	23 Oct 2003	good quality habitat
Mānoa (MN7) 170 ft	N 21.31250° W 157.80736°	23 Oct 2003	silt from construction at park
Mānoa (MN8) 150 ft	N 21.30883° W 157.80942°	23 Oct 2003	depauperate insect fauna
Mānoa (MN9) 130 ft	N 21.30572° W 157.81006°	23 Oct 2003	nice high gradient cascades
Mānoa (MN10) 115 ft	N 21.29672° W 157.81349°	23 Oct 2003	start of Hawaiian studies ‘auwai
Mānoa (MN11) 80 ft	N 21.29319° W 157.81274°	29 Apr 2004	
Mānoa/Pālolo (MP3) 0 ft	N 21.29072° W 157.81451°	10 Oct 2003	
Mānoa/Pālolo (MP2) 0-1 ft	N 21.28625° W 157.81898°	10 Oct 2003	at Kaimukī High School
Mānoa/Pālolo (MP1) 0 ft	N 21.28325° W 157.82613°	10 Oct 2003	
Pālolo (PO5) 466 ft	N 21.31033° W 157.78204°	29 Apr 2004	
Pālolo (PO4) 80 ft	N 21.28799° W 157.80605°	29 Apr 2004	
Pālolo (PO3) 360 ft	N 21.30615° W 157.78864°	10 Oct 2003	
Pālolo (PO2) 110 ft	N 21.28977° W 157.80331°	10 Oct 2003	Pālolo Avenue crossing

METHODS

Aquatic sampling was conducted according to a slightly modified version of Englund et al. (2003) and Englund and Arakaki (2003). It was necessary to develop an efficient technique that allowed rapid yet effective sampling of the aquatic biota. Because these surveys were part of a rapid biological assessment conducted with other team members studying vegetation and stream channel morphology, time sampling at each site was approximately 30-45 minutes. More extensive sampling would likely have yielded only a few additional species of aquatic biota. However, past experience and extensive familiarity with most of these sample sites [many sections of these streams were previously extensively sampled during the studies of Englund (1999) and Englund et al. (2000)] ensured that most species of aquatic biota were recorded, and virtually all native aquatic species were observed or collected. This was accomplished by collections of both immature and adult specimens of fish, aquatic insects, and other aquatic fauna with aerial sweep nets, aquatic dip nets, kick-sampling, and Surber (benthic) samplers. Kick sampling is usually adequate for biodiversity surveys, as the first 'kick' has been found (in continental regions) to disturb 60% of the fauna yielded by 10 additional kicks (Southwood and Henderson, 2000). Benthic (bottom) sampling centered around kick netting and involved vigorously disturbing the substrate upstream of a fine meshed aquatic net to displace any aquatic invertebrates inhabiting the stream substrate. The use of frequent kick-netting allowed for a greater sample size and resulted in increased effort for invertebrate collections. Benthic sampling also included collecting individual rocks and using a toothbrush or forceps to remove invertebrates from variously sized stream rocks.

Visual observations of fish in the usually clear sampling stations was used to determine fish species composition, and nets were used to verify fish species composition. Above and below water visual observations for aquatic invertebrates were also conducted during hiking between sampling stations. Sampling effort was focused on all suitable aquatic habitats such as splash zones around riffles and cascades, wet rock faces associated with springs and seeps, nearby wetland areas associated with the streams, and variously-sized stream substrates. All aquatic habitats were sampled around the assessed streams. Collected specimens were stored in 95% ethanol for curation and identification and voucher specimens are currently housed in Bishop Museum collections. Visual observations of aquatic insects were also conducted above and around the stream. Sampling of damselflies and dragonflies (Odonata) was emphasized, because six species are currently considered Candidate Species by the U.S. Fish & Wildlife Service. Species were determined by R.A. Englund, K. Arakaki, and N.L. Evenhuis.

RESULTS AND DISCUSSION

With a few notable exceptions, the aquatic macrofauna found within the Ala Wai watershed was comprised largely of invasive alien species. Except in the highest reaches of the Ala Wai watershed, aquatic habitats were found to be highly

disturbed; this was a result of the effects of urbanization that includes stream diversions and miles of concrete channelization. The last major inventory of channelized streams on O'ahu occurred in 1978 when it was found that 57% of the streams on this island were channelized, with over 83 miles of modified channels on O'ahu alone (Timbol and Maciolek 1978; Norton et al. 1978). The worst form of channelization found during these surveys was the flat-bottom concrete lined channels such as those found in lower Pālolo Stream, where stream temperatures were increased by 23° F because of channelization. Similar to the findings of Norton et al. (1978), no native aquatic species were found in concrete-lined stream channels. A complete loss of channel heterogeneity and riparian vegetation cover result in increased water temperatures (Norton et al. 1978) that are lethal to native species.

In the Hawaiian Islands there is often a direct correlation between increasing elevation and increasing numbers and densities of native aquatic species (Englund et al. 2003). This pattern was not evident in the Ala Wai watershed and is most likely a result of these streams flowing through a highly urbanized environment dominated by alien species. There was no significant ($p > 0.001$) relationship between increasing elevation and increasing percentages of native species (Figure 1).

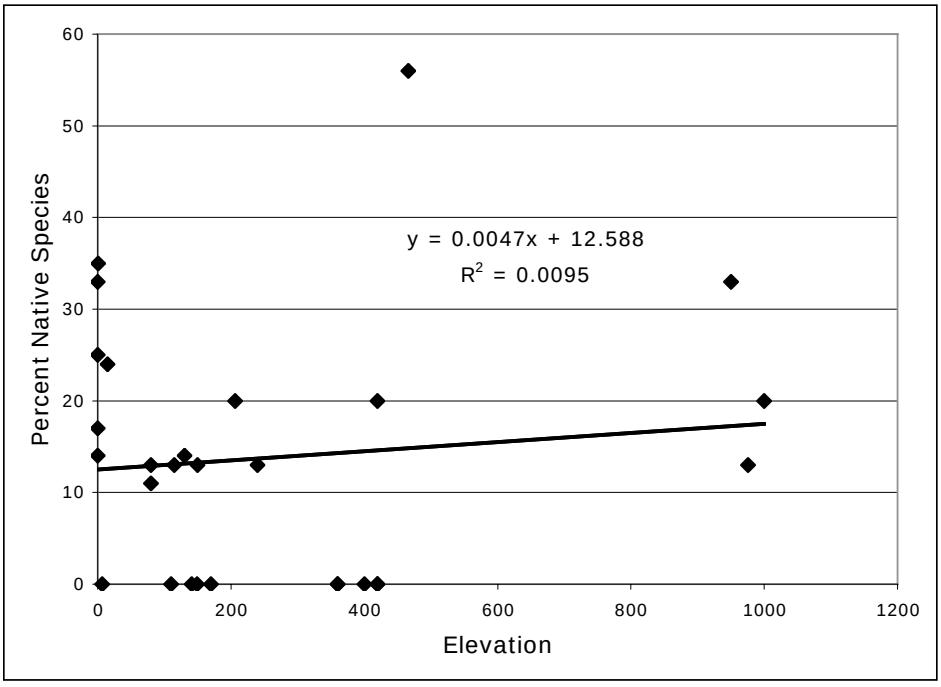

Figure 1. Non-significant ($p > 0.001$) relationship of percent native aquatic species by elevation obtained from all flowing streams in the Ala Wai watershed.

During the current study, remnant native species were found in two general areas; either in areas near the ocean or in a few high elevation areas, with very few native species being found in the mid-reaches of the watershed. There was one

notable upper elevation stream area lacking alien fish species at the unnamed spring and short section of stream (Station IN1) found between Kanealole and Moleka Springs in the upper (>950 ft) Makiki watershed. This was also the only section of stream found to lack the introduced grass shrimp (*Neocaridina denticulata sinensis*) and contain the native shrimp ʻōpae kalaʻole (*Atyoida bisulcata*). A 20 ft slanted waterfall at this stream appeared to be a barrier to introduced fish, which were observed at the bottom of the waterfalls. All other areas examined during this study were dominated by alien species (see Tables 2-4), but areas such as the Mānoa/Pālolo Stream junction by Kaimuki High School (Station MP2) and lower Makiki Stream (Station MA3) contained significant amounts of the native fish *A. guamensis* and *S. hawaiiensis*, along with the endemic hapawai (*Neritina vespertina*).

The undescribed endemic aquatic moth, *Hyposmocoma* sp. 1 was common in one section of Mānoa Stream (240 ft elevation, Station MN 4) and Pālolo Stream (466 ft, Station PO5), and is an indicator of habitat conditions. Although *Hyposmocoma* are more resistant to invasive aquatic species than many other insect species such as native damselflies (Englund 1999), they still require relatively good habitat conditions and their presence indicates these areas have high potential for restoring other native aquatic species. Hawaiian aquatic *Hyposmocoma* moths are found in clear, cold, and mostly unimpacted flowing streams at higher elevations (Englund et al. 2003), and are part of a large and almost exclusively terrestrial genus of up to 600 species (D. Rubinoff, pers. comm.) endemic to Hawaiʻi. *Hyposmocoma* in Hawaiian streams have adapted the unusual habit of grazing stream algae near or even under the waterline of stream rocks for their diet. Consequently, streams must have a relatively low sediment load that does not smother the particular species of aquatic algae required for their food.

Recommendations For Stream Habitat Improvement and Rehabilitation

- Where practical, restore flow and remove diversions in the upper reaches of streams, e.g., the Moleka (Herring) Springs area, and other springs tapped in the upstream sections of the Ala Wai watershed.
- Begin to control feral pig populations in the upper reaches of the Ala Wai watershed. Pig wallows were evident in the upper stream reaches and were particularly large in the upper Moleka (Herring Springs) site and elsewhere in the upper Makiki watershed. Feral pigs are obviously contributing greatly to increased sediment input into the watershed, and native aquatic species are harmed by this sediment input. Controlled hunts and other methods of pig reduction should be an overall part of the Ala Wai watershed management plan.
- Remove of invasive riparian plants (such as different species of grasses or ginger) from around the stream corridor and replanting with less invasive native species would open up the riparian zone for native aquatic species that are not adapted to heavily shaded areas. The importance of shade has to be recognized, but a monoculture of invasive plants is often too much shade for native aquatic biota.
- Whenever possible, restore the natural stream channel geomorphology. Habitat rehabilitation by necessity requires a relatively stable pool/riffle/run structure; the current concrete flume channel structure with no shade

provides lethal temperatures for native biota and is also likely a barrier for the migration of post-larval native freshwater organisms returning from the ocean.

- If at all feasible, remove current concrete channelization where possible, especially the bottom portion of the concrete-liner that is the most detrimental of all structures to stream biota.
- It is important to provide continuing education to the public on practical ways to reduce and minimize non-source input from urban areas into the Ala Wai watershed. This can be done in a variety of ways such as working with community groups and State agencies.

Diverted Herring Springs, Moleka Stream at Station MO1, R. Bourke, Oceanit for scale

Unnamed Springs (Station IN1) lacking alien fish in Upper Makiki watershed, Photo by R. Bourke, Oceanit

Makiki Stream at Station MA1

Makiki Stream disappearing at Station MA2

Table 2. Results of aquatic macrofauna collected for the Ala Wai Watershed, O'ahu surveys, Kanaha to Waihī Streams.

Taxon	Kanaha 120-950 ft (Kn1-Kn3)	Kanealole 976 ft (KL1)	Kanealole 360 ft (KL2)	Unnamed spring 950 ft (IN1)	Moleka 1000 ft (MO1)	Makiki 149 ft (MA1)	Makiki 141 ft (MA2)	Makiki 6-7 ft (MA3)	Makiki 0 ft (MA4)	Makiki 0 ft (MA5)	Hausten 0 ft (HA 1)	Hausten 0 ft (HA 2)	Aihualama 420 ft (MN1)	Waihī 420 ft (MN2)	Status[1]
Amphibians															
Rana rugosa		X	X	X	X										Int
Bufo marinus			X			X	X								Int
Fish															
Awaous guamensis								X							Ind
Eleotris sandwicensis															End
Stenogobius hawaiiensis								X							End
Mugil cephalus									X	X					Ind
Kuhlia sandvicensis											X	X			Ind
Sphyraena barracuda										X					Ind
Archocentrus nigrofasiciatus								X							Int
Oreochromis/Sarotherodon spp.								X	X	X	X	X			Int
Hypostomous c.f. *watwata*								X							Int
Ancistris c.f. *temmincki*								X					X		Int
Gambusia affinis											X	X			Int
Poecilia mexicana						X	X	X	X	X	X	X			Int
Poecilia reticulata		X	X		X	X	X	X					X	X	Int
Xiphophorus helleri			X		X	X	X	X							Int
Mollusks															
Melanoides tuberculata		X	X			X	X	X							Int
Tarebia granifera						X	X	X			X	X			Int
Ferrissia sharpi						X	X								Cry
Platyhelminthes (flatworms)															
Turbellaria															
Dugesia sp. 1		X	X	X		X	X								Int
Crustaceans															
Atyoida bisulcata				X											End
Macrobrachium grandimanus								X							Ind
Macrobrachium lar						X	X								Int
Neocaridina denticulata sinensis			X		X	X	X	X					X		Int
Procambarus clarkii													X	X	Int
Scylla serrata										X					Int
Chthamalus proteus									X	X	X	X			Int
Hyalella prob. *azteca*								X							Ind
Aquatic Insects															
Anisoptera (Dragonflies)															
Libellulidae															
Crocothemis servilia															Int
Orthemis ferruginea															Int

Table 2 (cont). Results of aquatic macrofauna collected for the Ala Wai Watershed, O'ahu surveys, Kanaha to Waihī Streams.

Taxon	Kanaha 120-950 ft (Kn1-Kn3)	Kanealole 976 ft (KL1)	Kanealole 360 ft (KL2)	Unnamed spring 950 ft (IN1)	Moleka 1000 ft (MO1)	Makiki 149 ft (MA1)	Makiki 141 ft (MA2)	Makiki 6-7 ft (MA3)	Makiki 0 ft (MA4)	Makiki 0 ft (MA5)	Hausten 0 ft (HA 1)	Hausten 0 ft (HA 2)	Aihualama 420 ft (MN1)	Waihī 420 ft (MN2)	Status[1]
Zygoptera (Damselflies)															
Coenagrionidae															
Ischnura posita						X	X								Int
Heteroptera (True Bugs)															
Veliidae															
Microvelia vagans		X			X										End
Coleoptera															
Parathroscinus cf. *murphyi*											X	X			Int
Diptera (Flies, gnats)															
Ceratopogonidae															
Forcipomyia sp.						X									Cry
Chironomidae															
Cricotopus bicinctus						X	X								Int
Dolichopodidae															
Condylostylus longicornis															Int
Chrysotus longipalpus		X				X									Int
Syntormon flexibile		X				X									Int
Genus sp.?														X	Cry
Ephydridae															
Scatella sp.		X													End
Tipulidae															
Limonia sp.														X	End
Limonia advena						X									Int
Trichoptera (Caddisflies)															
Hydropsychidae															
Cheumatopsyche analis			X			X	X						X	X	Int
Hydroptilidae															
Hydroptila icona								X							Int
Total Aquatic Species:	0	8	8	3	5	17	13	15	4	6	7	7	5	5	
Total Native Aquatic Species	0	1	0	1	1	0	0	2	1	2	1	1	0	1	
(%) Native Aquatic Species	0	13	0	33	20	0	0	13	25	33	14	14	0	20	

[1]End = Endemic, Ind = Indigenous, Int = Introduced, Cry = Cryptogenic, Pur = Purposefully Introduced

Table 3. Results of aquatic macrofauna collected for the Ala Wai Watershed, O'ahu surveys, Waiakeakua (Mānoa tributary) to Pālolo Stream at Station 4.

Taxon	Waiakeakua 420 ft (MN3)	Luaalaea 400 ft (MN4)	Mānoa 240 ft (MN5)	Mānoa 206 ft (MN6)	Mānoa 170 ft (MN7)	Mānoa 150 ft (MN8)	Mānoa 130 ft (MN9)	Mānoa 115 ft (MN10)	Mānoa 80 ft (MN11)	Mānoa/Pālolo 15 ft (MP3/PO1)	Mānoa/Pālolo 0-1 ft (MP2)	Ala Wai Canal 0 ft (MP1)	Pālolo 466 ft (PO5)	Pālolo 80 ft (PO4)	Status[1]
Turtles															
Pelodiscus sinensis				X											Int
Chrysemys scripta elegans					X										Int
Amphibians															
Rana rugosa															Int
Bufo marinus					X					X	X				Int
Fish															
Awaous guamensis						X	X			X	X				Ind
Eleotris sandwicensis										X	X				End
Stenogobius hawaiiensis										X	X				End
Mugil cephalus											X				Ind
Kuhlia sandvicensis										X	X				Ind
Sphyraena barracuda												X			Ind
Micropterus dolomieui			X	X	X	X	X	X	X	X					Int
Mugilogobius cavifrons											X				Int
Cyprinus carpio			X	X	X	X	X	X							Int
Archocentrus nigrofasiciatus					X	X	X	X		X	X			X	Int
Amphilophus citrinellum							X	X							Int
Hypsophrys nicaraguensis										X					Int
Oreochromis/Sarotherodon spp.										X	X	X		X	Int
Hypostomous cf. *Watwata*									X	X	X				Int
Ancistris c.f. *temmincki*	X		X		X	X	X	X	X	X					Int
Misgurnus anguillicaudatus				X	X										
Gambusia affinis										X	X	X			Int
Poecilia mexicana	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Int
Poecilia reticulata	X	X	X	X	X	X	X	X	X						Int
Xiphophorus helleri	X	X	X	X	X				X						Int
Mollusks															
Neritina vespertina											X				End
Corbicula fluminea					X	X	X	X	X	X	X				Int
Melanoides tuberculata			X	X	X	X	X	X	X	X	X				Int
Tarebia granifera			X	X	X	X	X	X		X	X				Int
Ferrissia sharpi															Cry
Platyhelminthes (flatworms)															
Turbellaria															
Dugesia sp. 1			X	X	X	X			X					X	Int
Crustaceans															
Atyoida bisulcata															End

Table 3 (cont.). Results of aquatic macrofauna collected for the Ala Wai Watershed, O'ahu surveys, Waiakeakua (Mānoa tributary) to Pālolo Stream at Station 4.

Taxon	Waiakeakua 420 ft (MN3)	Luaalaea 400 ft (MN4)	Mānoa 240 ft (MN5)	Mānoa 206 ft (MN6)	Mānoa 170 ft (MN7)	Mānoa 150 ft (MN8)	Mānoa 130 ft (MN9)	Mānoa 115 ft (MN10)	Mānoa 80 ft (MN11)	Mānoa/Pālolo 15 ft (MP3/PO1)	Mānoa/Pālolo 0-1 ft (MP2)	Ala Wai Canal 0 ft (MP1)	Pālolo 466 ft (PO5)	Pālolo 80 ft (PO4)	Status[1]
Macrobrachium grandimanus											X				Ind
Macrobrachium lar															Int
Neocaridina denticulata sinensis	X	X	X	X	X	X	X	X		X			X		Int
Procambarus clarkii	X	X	X	X	X	X									Int
Scylla serrata												X			Int
Chthamalus proteus												X			Int
Hyalella prob. *azteca*				X			X	X	X						Ind
Aquatic Insects															
Anisoptera (Dragonflies)															
Libellulidae															
Crocothemis servilia										X	X				Int
Orthemis ferruginea										X					Int
Pantala flavescens				X						X				X	Ind
Zygoptera (Damselflies)															
Coenagrionidae															
Enallagma civile														X	Int
Ischnura ramburii										X	X			X	Int
Ischnura posita				X											Int
Heteroptera (True Bugs)															
Saldidae															
Saldula exulans													X		End
Coleoptera															
Parathroscinus cf. *murphyi*											X				Int
Diptera (Flies, gnats)															
Canacidae															
Procanace williamsi											X				End
Ceratopogonidae															
Forcipomyia sp.?	X														Cry
Chironomidae															
Cricotopus bicinctus			X	X		X									Int
Dolichopodidae															
Condylostylus longicornis															Int
Chrysotus longipalpus								X							Int
Pelastoneurus lugubris									X						Int
Syntormon flexibile		X						X	X				X		Int
Thinophilus hardyi									X						Int
Genus sp.?			X	X		X									Cry
Ephydridae															
Scatella sp.						X									End

Table 3 (cont.). Results of aquatic macrofauna collected for the Ala Wai Watershed, O'ahu surveys, Waiakeakua (Mānoa tributary) to Pālolo Stream at Station 4.

Taxon	Waiakeakua 420 ft (MN3)	Luaalaea 400 ft (MN4)	Mānoa 240 ft (MN5)	Mānoa 206 ft (MN6)	Mānoa 170 ft (MN7)	Mānoa 150 ft (MN8)	Mānoa 130 ft (MN9)	Mānoa 115 ft (MN10)	Mānoa 80 ft (MN11)	Mānoa/Pālolo 15 ft (MP3/PO1)	Mānoa/Pālolo 0-1 ft (MP2)	Ala Wai Canal 0 ft (MP1)	Pālolo 466 ft (PO5)	Pālolo 80 ft (PO4)	Status[1]
Scatella cilipes			X	X				X					X		End
Scatella hawaiiensis									X				X		End
Scatella stagnalis									X		X			X	Int
Discocerina mera											X				Int
Tipulidae															
Limonia advena							X	X					X		Int
Limonia jacoba													X		End
Trichoptera (Caddisflies)															
Hydropsychidae															
Cheumatopsyche analis	X	X	X	X											Int
Hydroptilidae															
Hydroptila icona														X	Int
Lepidoptera (Aquatic Moths)															
Hyposmocoma sp. 1: Oahu form			X	X									X		End
Total Aquatic Species:	8	7	16	20	16	16	14	16	15	21	23	6	9	9	
Total Native Aquatic Species	0	0	2	4	0	2	2	2	2	5	8	1	5	1	
(%) Native Aquatic Species	0	0	13	20	0	13	14	13	13	24	35	17	56	11	

[1]End = Endemic, Ind = Indigenous, Int = Introduced, Cry = Cryptogenic, Pur = Purposefully Introduced

Makiki Stream at Station MA3. Two native fish species were found here (*A. guamensis and S. hawaiiensis*).

Table 4. Results of aquatic macrofauna collected for the Ala Wai Watershed, O'ahu surveys, Pālolo Stream, Stations 2 and 3.

Taxon	Pālolo 360 ft (PO3)	Pālolo 110 ft (PO2)	Status[1]
Amphibians			
Bufo marinus		X	Int
Fish			
Awaous guamensis			Ind
Eleotris sandwicensis			End
Stenogobius hawaiiensis			End
Mugil cephalus			Ind
Kuhlia sandvicensis			Ind
Archocentrus nigrofasiciatus			Ind
Oreochromis/Sarotherodon spp.			Ind
Hypostomous cf. *watwata*			Int
Ancistris c.f. *temmincki*	X		Int
Gambusia affinis			Int
Poecilia mexicana	X	X	Int
Poecilia reticulata	X		Int
Xiphophorus helleri	X		Int
Mollusks			
Tarebia granifera		X	Int
Crustaceans			
Neocaridina denticulata sinensis	X		Int
Procambarus clarkii	X		Int
Aquatic Insects			
Diptera (Flies, gnats)			
Chironomidae			
Cricotopus bicinctus	X		Int
Dolichopodidae			
Genus sp. 1	X		Cry
Ephydridae			
Scatella stagnalis	X		Int
Tipulidae			
Limonia advena	X		Int
Total Aquatic Species	10	3	
Total Native Aquatic Species	0	0	
(%) Native Aquatic Species	0	0	

[1]End = Endemic, Ind = Indigenous, Int = Introduced, Cry = Cryptogenic, Pur = Purposefully Introduced

QUALITATIVE SITE RANKING

To compare all sites, each site was ranked by the number of native aquatic species found at that site and the overall habitat quality. It should be emphasized that these rankings are not providing a value judgment as to which are the most valuable streams, or that any particular stream section has been ranked as good or bad. Rather, these qualitative ranking values reflect whether native aquatic species remain in each particular sample area of a highly urbanized and impacted watershed, in combination with the current condition of aquatic habitats at each assessed station.

Table 5. Qualitative ranking of streams in the Ala Wai Watershed based on habitat quality and native species numbers, densities and rarity.

Stream (Elevation)	GPS (WGS 84)	# Native Species (%)	Habitat Quality (1-10)	Overall Rank (1-10)
Kanaha (KN1) 120 ft	N 21.31089° W 157.83939°	0 (0%)	1 (intermittent stream)	1
Kanaha (KN2) 380 ft	N 21.31930° W 157.83311°	0 (0%)	1 (intermittent stream)	1
Kanaha (KN3) 950 ft	No gps reception here	0 (0%)	1 (intermittent stream)	1
Kanealole (KL1) 950-976 ft	N 21.32676° W 157.82172°	1 (13%)	6	6
Kanealole (KL2) 360 ft	N 21.31779° W 157.82693°	0 (0%)	5	5
Unnamed spring (IN1) 950 ft	N 21.32640° W 157.82143°	1 (33%)	9	10
Moleka Spring (MO1) 1000 ft	N 21.32333° W 157.81857°	1 (20%)	5	5
Makiki (MA1) 141 ft	N 21.31210° W 157.83012°	0 (0%)	6	5
Makiki (MA2) 149 ft	N 21.30912° W 157.83029°	0 (0%)	1*	1
Makiki (MA3) 6-7 ft	N 21.29713° W 157.83670°	2 (13%)	3	6
Makiki (MA4) 0 ft	N 21.29253° W 157.83594°	1 (25%)	1*	2
Makiki (MA5) 0 ft	N 21.28885° W 157.83449°	2 (33%)	1*	2
Hausten (HA1) 0 ft	N 21.28680° W 157.82918°	1 (14%)	4	3
Hausten (HA2) 0 ft	N 21.29044° W 157.82478°	1 (14%)	1	1
Aihualama (MN1) 420 ft	N 21.33338° W 157.80103°	0 (0%)	8	6
Waihī (MN2) 420 ft	N 21.33438° W 157.80046°	1 (20%)	8	7
Waiakeakua (MN3) 420 ft	N 21.32938° W 157.79744°	0 (0%)	8	6
Luaalaea (MN4) 257 ft	N 21.33128° W 157.79832°	0 (0%)	7	5
Mānoa (MN5) 240 ft	N 21.32318° W 157.80269°	2 (13%)	9	8
Mānoa (MN6) 206 ft	N 21.31786° W 157.80443°	4 (20%)	9	8
Mānoa (MN7) 170 ft	N 21.31250° W 157.80736°	0 (0%)	3	3
Mānoa (MN8) 150 ft	N 21.30883° W 157.80942°	2 (13%)	5	5
Mānoa (MN9) 130 ft	N 21.30572° W 157.81006°	2 (14%)	7	6
Mānoa (MN10) 115 ft	N 21.29672° W 157.81349°	2 (13%)	7	5
Mānoa (MN11) 80 ft	N 21.29319° W 157.81274°	2 (13%)	4	4
Mānoa/Pālolo (MP3/PO1) 0 ft	N 21.29072° W 157.81451°	5 (24%)	3*	6
Mānoa/Pālolo (MP2) 0-1 ft	N 21.28625° W 157.81898°	8 (35%)	4	7
Mānoa/Pālolo (MP1) 0 ft	N 21.28325° W 157.82613°	1 (17%)	2	3
Pālolo (PO5) 466 ft	N 21.31033° W 157.78204°	5 (56%)	9	8
Pālolo (PO4) 80 ft	N 21.28799° W 157.80605°	1 (11%)	2*	2
Pālolo (PO3) 360 ft	N 21.30615° W 157.78864°	0 (0%)	7	6
Pālolo (PO2) 110 ft	N 21.28977° W 157.80331°	0 (0%)	1*	1

*Concrete channelized section of stream

Habitat quality was based on the actual state of the stream habitat observed during these surveys; for example, construction near the streambed at Mānoa Valley District Park by Mānoa Elementary greatly reduced habitat quality values for this site, but following revegetation habitat quality will be greatly improved. To provide a somewhat transparent basis for the habitat rankings, Table 5 presents the two major criteria used to provide an overall rank at each sampling station. The number of native aquatic species found at each site, along with overall aquatic habitat quality were used to provide an overall rank between 1 (worst) and 10 (best). The numbers of native aquatic species, and their rarity or abundance at a particular station is not a subjective factor, but rather is a measurable value and has been incorporated into this ranking system. In Table 5, habitat values are relative and are only comparable between Ala Wai watershed streams and not to other areas such as other more pristine and unimpacted watersheds. For example, the habitat quality and the combined (overall) ranking for these highly disturbed streams would not be comparable to less impacted O'ahu or neighbor island streams, but this assessment could be modified to make it more comparable to other less impacted streams if so desired .

Because alien species such as armored catfish (*Ancistris/Hypostomous*) or tilapia actually modify and make habitats unfavorable for native species, aliens must be considered in any assessment of habitat for native species. Other important factors used to rank the streams for habitat quality included presence and densities of alien species, and important or less common native aquatic species. The relatively short section of high elevation unnamed spring (Station IN1) and flowing stream between Kanealole and Moleka Springs was the only sample area entirely lacking alien fish or crustacean species, and for this reason this station received the highest overall rank out of the thirty study areas, and this area may even be a possible candidate site for translocation of native damselflies or other native aquatic species. Although many sample areas contained no native species (primarily resulting from an abundance of invasives) or just one or two native species, they nonetheless still contain relatively intact aquatic habitats. These areas could once again support native species because they have relatively clean water, adequate (but not too much) shading, and/or good channel structure, and thus they received a higher habitat ranking then a channelized section of stream. If the alien species were removed, these sections of stream could once again provide suitable habitats for native aquatic species.

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