ASSESSMENT OF THE IMPACTS OF RAINBOW TROUT PREDATION ON NATIVE AQUATIC INVERTEBRATE SPECIES WITHIN KŌKE‘E STATE PARK STREAMS, KAUA‘I, HAWAI‘I

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Trout Unlimited

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July 2000

Bishop Museum Technical Report 18

Contribution No. 2000-009 to the Hawaii Biological Survey

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EXECUTIVE SUMMARY

The Hawaii Biological Survey of the Bishop Museum, in collaboration with the Smithsonian Institution, conducted a two-phase assessment of streams in the Kōke‘e State Park, Kaua‘i, Hawai‘i. The specific objectives of this study were to: 1) assess stream habitat, including available food resources and potential spawning areas, in Kōke‘e State Park streams in regard to suitability for a wild rainbow trout catch and release fishery; 2) evaluate whether rainbow trout reproduction currently occurs in any of the streams under study, and to ascertain the holdover status of previously stocked rainbow trout; 3) assess whether predation by rainbow trout negatively impacts the aquatic insect forage base in Kōke‘e State Park, particularly in regard to native aquatic insect and snail species; 4) evaluate seasonal variations in rainbow trout diet; and 5) describe the baseline distribution and abundance of endemic damselflies and other potentially sensitive native aquatic insects in Kōke‘e State Park streams. The study's efforts were concentrated along five specific streams: Wai‘alae, Koai‘e, Kauaikinanā, Kawaikōī, and Waiakoali.

Our surveys indicate that streams sampled within Kōke‘e State Park maintain diverse populations of native aquatic insects, both in streams containing rainbow trout, such as Wai‘alae, Koai‘e, and Kauaikinanā, and in streams lacking rainbow trout, such as Kawaikōī Stream above the Camp 10 Road. While it is now impossible to recreate conditions prior to the introduction of rainbow trout into the inland waters of Kaua‘i, our results indicate that the native aquatic insect assemblages seen in the streams under study compare favorably with other isolated and unimpacted streams in the Hawaiian archipelago.

All streams sampled were found to have large numbers (and high relative percentages) of native aquatic insect taxa. A low of 20 native aquatic insect species were collected in Wai‘alae Stream, while a high of 31 native taxa were found in Koai‘e Stream. The native species assemblage found at Koai‘e Stream represents the greatest number of native aquatic insect species recorded for any individual stream yet sampled in the Hawaiian archipelago, despite the presence of naturally reproducing rainbow trout in this system. An important finding of this study was that statistical tests indicated native aquatic insect diversity was not significantly influenced by the presence or absence of rainbow trout within a stream. Additionally, endangered damselflies or other sensitive native aquatic invertebrate species were not adversely impacted by rainbow trout as streams lacking trout (e.g., Hanalei, Kawaikōī, Lumaha‘i) exhibited similarly high levels of these native species as compared to streams containing trout.

One of the specific objectives of this study was a preliminary assessment of the extent and location of natural reproduction among rainbow trout in the Kōke‘e region. Natural reproduction of rainbow trout was found in Kauaikinanā, Koai‘e, Kōke‘e, and Wai‘alae Streams. Kōke‘e Stream was not sampled for trout diet or aquatic insects because heavy stands of ginger limited access to this stream. Rainbow trout did not maintain reproducing or hold-over populations in Waiakoali and Kawaikōī Streams.

Another major objective of this study was to quantify the forage base and resource utilization patterns of rainbow trout in upland Kaua‘i streams. Based on an analysis of contents from 80 individual trout stomachs, we concluded that rainbow trout in these systems are functioning primarily as opportunistic drift feeders, exploiting a steady stream of terrestrial insects and other arthropods entering into the streams from the adjacent forest. Although aquatic species accounted for 52.6% of rainbow trout diet (by number), native aquatic species amounted to only 7.5% of rainbow trout diet. The low percentage of native aquatic insects found in the trout diet reflects a low number of native aquatic insects in stream drift, a phenomenon that is likely related to the natural absence of the major orders of drifting stream insects in Hawai‘i, such as Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). By contrast, the aquatic insect fauna in the five streams surveyed consisted mainly of native species dwelling in splash zones, which appear less prone to drift. Our analysis of stomach contents indicates that rainbow trout are instead utilizing the available and abundant terrestrial insect drift, as well as introduced aquatic insects such as larval caddisflies for their primary food source.

The feeding mode of rainbow trout on Kaua‘i, skewed toward utilization of drifting terrestrial insects, was also noted by Needham and Welsh (1953) and is not unusual for trout. They found that rainbow trout diet in Kōke‘e Stream consisted of 34.7% (by number) terrestrial millipedes, which is similar to the 40% we found in Koai‘e and Kauaikinanā rainbow trout during the summer of 1997. The major difference in rainbow trout diet analysis between this study and the Needham and Welsh study was their 33.8% (by number of individuals) representation of native *Megalagrion* damselflies in Kōke‘e Stream rainbow trout. Our study, by contrast, found only 5 *Megalagrion* damselflies out of 1,596 identifiable prey items, accounting for 0.3% of rainbow trout diet, despite all endemic *Megalagrion* species being commonly found. Five of the 80 (6% frequency of occurrence) rainbow trout examined during this study contained immature *Megalagrion* in their guts, with most from Wai‘alae (n = 4) and one native damselfly from a trout collected in Koai‘e Stream. This compares to a 13% frequency of occurrence of *Megalagrion* found in the diet of the native freshwater gobiid *Lentipes concolor*. *Megalagrion* damselfly adults were abundant in the summer months in Kōke‘e State Park streams, while immatures were found in benthic samples year-round.

We also assessed whether rainbow trout could maintain catch and release populations for recreational fishing in Kōke‘e State Park streams without annual stocking. Some basic needs of a self-sustaining fish population are proper environmental conditions, such as water temperature and chemistry, an adequate forage base, and suitable spawning sites. Kawaikōī and Waiakoali Stream do not appear to meet the conditions for a self-sustaining trout fishery, and would likely need to be stocked on a regular basis. However, the forage base for rainbow trout in Kawaikōī Stream appears to be more than adequate for a stocked fishery, and anglers reported successful catches prior to the cessation of stocking in 1992. Kawaikōī Stream flows through a native *Metrosideros polymorpha* dominated forest with high densities of terrestrial insects and millipedes, so there appears to be no lack of forage for rainbow trout, given that they are acting primarily as drift feeders in this and other upland Kauaʻi stream systems.

Kauaikinanā, Koaiʻe, and Waiʻalae Streams within Kōkeʻe State Park maintain naturally reproducing trout populations that would allow for a self-sustaining, year-round catch and release trout fishery, if so desired. Naturally reproduced rainbow trout as large as 470 mm were collected in Koaiʻe Stream, and a 368 mm fish was collected in Kauaikinanā Stream. Natural reproduction was evident in these streams, with numerous 5–7 cm fish observed in Kauaikinanā Stream, and naturally reproduced 12–25 cm rainbow trout observed and collected in Koaiʻe Stream. Assuming that catch and release regulations could be enforced, we conclude that Kauaikinanā, Koaiʻe, and Waiʻalae Streams are suitable for year-round rainbow trout fishing without annual stocking. Kōkeʻe Stream could also provide year-round rainbow trout fishing because trout are abundant here, provided the introduced ginger plants completely covering the stream were removed or managed. Given the marginal existence of the Kōkeʻe trout populations, it seems likely that these limited naturally reproducing trout populations will decline over time in any event in response to normal variations in temperature and discharge rate typical of Hawaiian stream environments.

Fishery management options for Kōkeʻe State Park waters are not within the scope of this report but could include the complete removal of rainbow trout from Kauaʻi waters. We conclude that the removal of rainbow trout from Kōkeʻe State Park streams would be cost-ineffective and difficult, and could lead to the local extinction of endemic aquatic insects because fish poisons are also toxic to native aquatic insects. Rainbow trout appear to have low impacts on native aquatic fauna because the streams assessed during this study that contained naturally reproducing rainbow trout exhibited the highest biological diversity of native aquatic invertebrate species anywhere yet sampled in the Hawaiian Islands. Elimination of rainbow trout in Kōkeʻe State Park streams would therefore be unlikely to result in the restoration of a single native aquatic species not already present. Such management decisions are under the jurisdiction of the Hawaii Department of Land and Natural Resources, Division of Aquatic Resources.

INTRODUCTION

A. Kōke‘e State Park Stream Assessment Project

The Hawaii Biological Survey of the Bishop Museum, in collaboration with the Smithsonian Institution, conducted a two-phase assessment of streams in the Kōke‘e State Park, Kaua‘i, Hawai‘i to evaluate their suitability as habitat for a year-round catch and release rainbow trout (*Onchorhynchus mykiss*) fishery, and to gauge the impact of such trout on native and introduced stream invertebrates. Phase I was conducted during the dry (summer) season in August 1997, while Phase II was undertaken during the summer of 1998 and winter of 1999. The study's efforts were concentrated along five specific streams: Wai‘alae, Koai‘e, Kauaikinanā, Kawaikōī, and Waiakoali.

Salmonids were first stocked in Kaua‘i in 1894, with an unsuccessful attempt to establish brook trout (*Salvelinus fontinalis*) into the Waimea River (Needham and Welsh 1953). Rainbow trout were stocked in Kōke‘e area streams starting in 1920, and in 1935, brown trout (*Salmo trutta*) were stocked in Wainiha and other Kaua‘i streams, but these never became successfully established (Needham and Welsh 1953). In 1949, the last brown trout on Kaua‘i was observed dead inside the Wainiha Stream powerplant (Needham and Welsh 1953). Stocking of trout into Kōke‘e State Park streams was performed on an annual basis after World War II, but was discontinued in 1992 (Dennis Shinno, HDAR pers. comm.) because of concerns regarding the impacts of rainbow trout on populations of native damselflies (genus *Megalagrion*) and other native aquatic insect species.

In an attempt to supplement trout food production in Kōke‘e streams, mayflies were introduced from Waddell Creek in the Santa Cruz Mountains of California (Needham and Usinger 1960, 1961, 1962; Usinger 1972). Two mayfly species were selected, *Nixe rosea* (then called *Heptagenia rubroventris*) and *Epeorus lagunitas* (formerly *Iron lagunitas*), and over 200,000 mayfly eggs were planted into various habitats in Kōke‘e and Kawaikōī Streams. These herbivorous mayfly plantings completely failed, and adults of both species were never recovered from any Kaua‘i stream. The likely reason these introductions failed is because such North American temperate mayfly species require a winter diapause. Mayfly introductions would have had a much better chance of establishment if species from tropical regions such as New Guinea or northern Australia had been selected, as these areas have a climate similar to Hawai‘i. In Hawai‘i, the only known established mayfly species is *Caenis nigropunctata*, found in lowland, disturbed and silted streams on O‘ahu (Smith 2000). This tropical mayfly species is a native of Indonesia, the Philippines, and southern China (Dudgeon 1999). In addition, by 1965 several species of caddisfly, including the large *Cheumatopsyche pettiti*, had become established in Hawaiian streams (Denning and Beardsley 1967), providing additional food sources for introduced gamefish such as rainbow trout. The mode of introduction for the caddisflies and mayflies in Hawai‘i remains unknown, but probably involved the arrival of eggs in aquatic plants imported for the aquarium trade.

Although native damselflies appear to be sensitive to the presence of introduced fishes such as the Western mosquitofish (*Gambusia affinis*), green swordtails (*Xiphophorus helleri*) and shortfin mollies (*Poecilia mexicana*) in the family Poeciliidae (Polhemus and Asquith 1996, Englund 1999), the impact of rainbow trout predation on native damselfly populations was equivocal prior to this study. Recently, different authors have claimed that rainbow trout impact native damselfly populations on Kaua‘i (Kido et al. 1999) or that trout in Hawai‘i are an example of a failed invasion [and therefore have little impact] (Brown et al. 1999). One of the primary aims of this study was to assess the impacts of trout on damselfly populations in the context of the overall limnological setting occupied by both organisms, and assess the real impacts of rainbow trout on native aquatic invertebrate species.

To assess available rainbow trout forage, we surveyed the abundance and species composition of aquatic invertebrate populations in Wai‘alae, Koai‘e, Kauaikinanā, Kawaikōī, and Waiakoali streams within Kōke‘e State Park. This investigation also examined the influence of rainbow trout predation on potentially sensitive native stream-dwelling damselfly species and other native aquatic insects. To evaluate rainbow trout diet, stomach contents were collected from rainbow trout on all five streams, although trout were found in only a very short section of one stream (Kawaikōī).

The specific objectives of this study were to: 1) assess stream habitat, including available food resources and potential spawning areas, in Kōke‘e State Park streams in regard to suitability for a wild rainbow trout catch and release fishery; 2) evaluate whether rainbow trout reproduction currently occurs in any of the streams under study, and to ascertain the holdover status of previously stocked rainbow trout; 3) assess whether predation by rainbow trout negatively impacts the aquatic insect forage base in Kōke‘e State Park, particularly in regard to native aquatic insect and snail species; 4) evaluate seasonal variations in rainbow trout diet; and 5) describe the baseline distribution and abundance of endemic damselflies and other potentially sensitive native aquatic insects in Kōke‘e State Park streams.

Study Area: Kōke‘e State Park Streams, Physical Environment

A. Station Locations and Descriptions

The following section details specific sampling locations used in this study. Elevations are given in meters, with converted equivalents in feet to allow subsequent researchers to more accurately locate these sites on current United States Geological Survey (USGS) 7.5 min. topographic maps, which use English system measurements. Stream names were taken from USGS topographic quads. GPS coordinates are given using Old Hawaiian Datum, and only one set per stream area is given, although sampling occurred continuously up and downstream of areas where GPS coordinates were recorded.

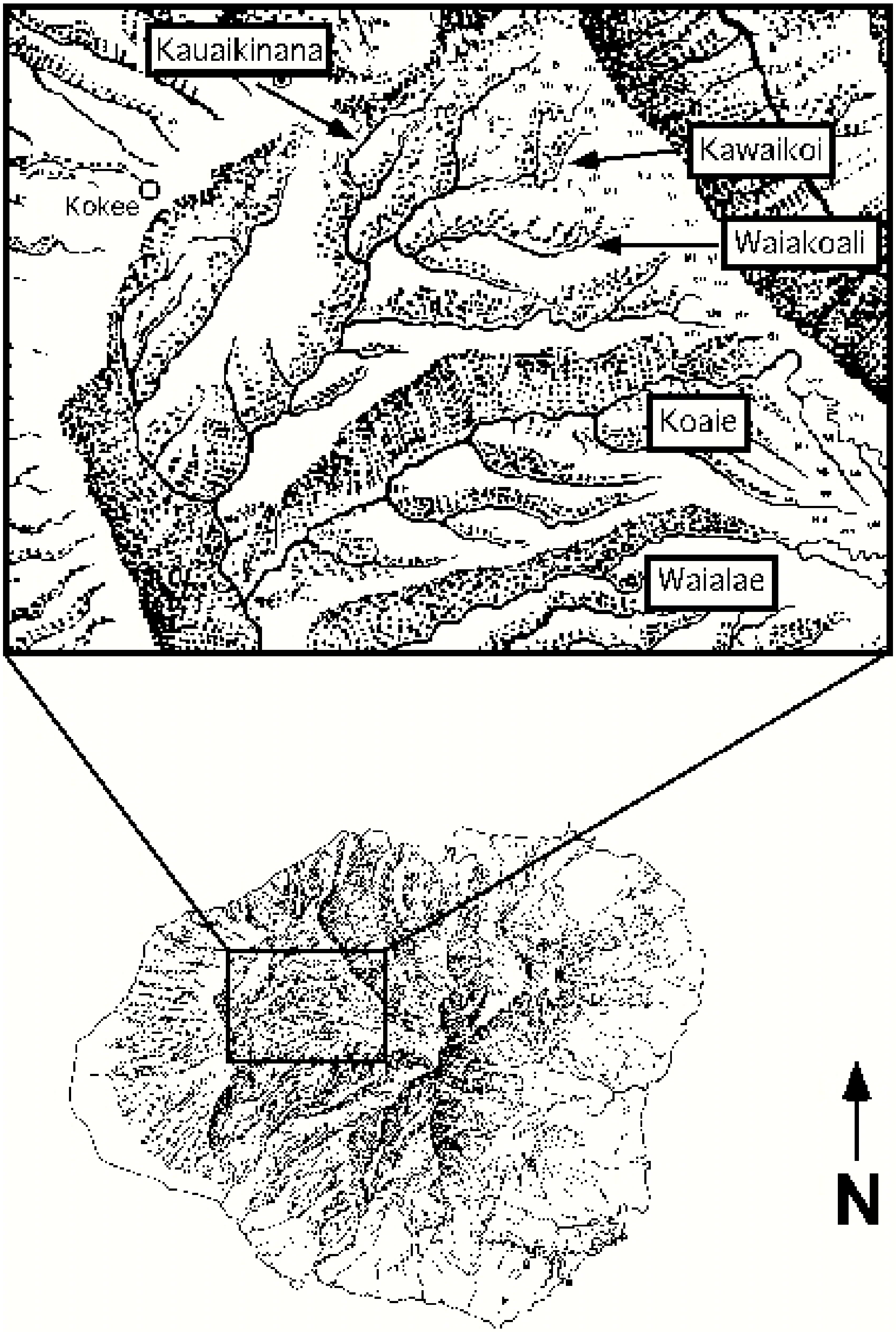
Encompassing most of the Alakaʻi Swamp, Kōkeʻe State Park is located in northwestern Kauaʻi. The park contains numerous streams draining from the flanks of Mt. Waiʻaleʻale, near the highest summit on Kauaʻi and putatively the wettest area on earth (Hazlett and Hyndman 1996). The Alakaʻi Plateau surrounding Mt. Waiʻaleʻale is heavily dissected by deep, erosion-formed canyons that cut into its relatively flat surface, and is thickly covered by predominantly native Hawaiian upland rain forest.

The five streams assessed in this study, Waiʻalae, Koaiʻe, Kauaikinanā, Kawaikōī and Waiakoali, are situated relatively close to each other in the western section of the Alakaʻi Plateau, and they range in elevation from approximately 1035–1160 m (3400–3800 ft) (Figure 1). Two stations were sampled for each stream (with the exception of Waiakoali Stream) under study. Kawaikōī and Koaiʻe streams appeared to have relatively similar base flows, while Kauaikinanā Stream was smaller and had a lower base flow. Waiʻalae Stream's baseflow is roughly equivalent in size to that of Koaiʻe Stream, while Waiakoali Stream maintains a lower baseflow compared to all other streams except Kauaikinanā, and is comprised largely of surface runoff. Overall, stream flow was low and stable throughout both phases of this study, allowing for uniform aquatic insect sampling protocols. This, in combination with the fact that all five streams lay at relatively similar elevations, meant the data from sampling stations on these streams were quite comparable.

B. Site Descriptions and GPS Coordinates

Station 1: HAWAIʻI, Kauaʻi, Waiʻalae Stream in vicinity of Waiʻalae Cabin, 1095 m (3600 ft), water temp. 15°C, 5–6 January 1999. 22°04.964'N, 159°35.170'W.

Figure 1. Sampling stations within Kōke‘e State Park Streams.



Station 2: HAWAI'I, Kaua'i, Koai'e Stream in vicinity of USGS gaging station, near Mōhihi- Wai'alae Trail crossing, 1125 m (3700 ft), water temp. 15°C, 7–8 January 1999. 22°06.778'N, 159°33.723'W.

Station 3: HAWAI'I, Kaua'i, Waiakoali Stream above Camp 10 Road, 1035 m (3400 ft), water temp. 13°C, 10–11 January 1999. 22°07.586'N, 159°37.225'W.

Station 4: HAWAI'I, Kaua'i, Kawaikōī Stream above Camp 10 Road, 1035 m (3400 ft), water temp. 15°C, 10–11 January 1999. 22°07.892'N, 159°37.280'W.

Station 5: HAWAI'I, Kaua'i, Kauaikinanā Stream at Camp 10 Road, 1035 m (3400 ft.), water temp. 14°C, 9–10 January 1999. 22°07.974'N, 159°37.840'W.

Wai'alae Stream

Wai'alae Stream is a tributary to the Waimea River, draining a large section of the Alaka'i Plateau in central Kaua'i, and having a total length of approximately 13 km. The stream's headwaters rise in the southern section of the Alaka'i Swamp near 1370 m elevation, and consist of two major branches, the Halehaha and the Halepaakai, which meet at approximately 1220 m elevation to form the main stem Wai'alae. The middle section of the stream below this confluence has a relatively gentle gradient, with many alternating riffles and pools. At approximately 915 m elevation this gentle midreach abruptly terminates in a series of high waterfalls that drop over 450 m into the Waimea canyon system. Below these falls the stream once again exhibits a moderate gradient for its final 4 km before reaching its confluence with the Waimea at 180 m elevation.

Because of its origin in the Alaka'i Swamp, the waters of Wai'alae Stream are very dark, being stained with tannins. This blackwater character is among the most pronounced of any stream on Kaua'i, except perhaps Kawaikōī, and in combination with the numerous boulders covered by pale lichens that line the stream's midreach serves to give the Wai'alae a striking and highly photogenic visual appearance. The catchment is also relatively undisturbed along its entire length, with no road access or water diversion structures. A single major trail, the Mōhihi- Wai'alae Trail, crosses the stream's midreach at 1100 m elevation, and at this point a rustic shelter, known as the Wai'alae Cabin, provides an overnight resting site for travelers on foot or horseback. This cabin and its adjoining helicopter landing zone was used as the base of operations for the current studies.

Vegetatively, the country surrounding Wai'alae Stream makes a transition from wet forest along the stream's headwaters, to mesic forest at Wai'alae Cabin, and then to dry forest and shrubland along the lower reaches in Waimea Canyon. The catchment suffered relatively light damage from Hurricane Iniki, and as a result few tree falls and debris masses were present along the stream channel. By contrast, damage from feral pigs is evident in many areas, particularly along the middle and upper reaches.

Wai‘alae Stream – 1159 m (3800 ft)

Sampling occurred above Wai‘alae Cabin upstream to the upper USGS stream gaging station on the mainstem of Wai‘alae Stream. Along with Koai‘e Stream, the riparian zone above Wai‘alae Cabin maintains some of the most pristine forests remaining in Hawai‘i. Stream flow upstream diminishes, but large and deep pools occur in a *Metrosideros polymorpha* and *Dicranopteris linearis* forest. Fine to medium-sized gravel in this reach provides suitable spawning substrate, as naturally reproduced trout were common in the area around and below Wai‘alae Cabin.

Wai‘alae Stream – 1037 m (3400 ft)

Sampling took place downstream from Wai‘alae Cabin nearly to Wai‘alae Falls. The stream flows through a rolling, open and grassy meadow area and maintains a generally low gradient except where 1–5 m high cascades form large pools. A long series of low-gradient riffles with gravel and cobble substrates were found in this reach. Small spring-fed streams also increased stream flow here, but the water quality instruments malfunctioned at this stream and thus we could not assess groundwater inputs.

Koai‘e Stream

Koai‘e Stream is a tributary to the Waimea River, draining from the middle section of the Alaka‘i Plateau in central Kaua‘i and having a length of approximately 13 km. The stream’s headwaters rise in the southern section of the Alaka‘i Swamp near 1400 m elevation, with the upper tributaries extending nearly to the Wainiha Pali. The swampy character of the headwater reaches imparts an amber color to the water because of dissolved tannins, although this blackwater character is far less pronounced than that seen in the basin of the Wai‘alae Stream immediately to the south.

Being deeply incised below the level of the surrounding plateau, the upper Koai‘e system also effectively cuts the Alaka‘i Swamp into northwestern and southeastern blocks, which drain via separate catchments. The current study surveyed two southeastern block catchments, the Wai‘alae and the Koai‘e, and three northwestern block catchments, the Kauaikinanā, Kawaikōī, and Waiakoali.

Aquatic insect surveys were made along the reaches of Koai‘e Stream lying both above and below the USGS gaging station, which is located at the crossing of the Mōhihi–Wai‘alae Trail near 1125 m elevation. Vegetation in this area was predominantly native and extremely diverse, with a closed canopy of *Metrosideros polymorpha*, a subcanopy of *Cheirodendron* sp., and an understory including such native elements as *Broussaisia arguta*, *Melicope* sp., *Smilax* sp., *Clermontia* sp., and *Coprosma* sp.

The sampling sites on Koaiʻe Stream were accessed from the end of Camp 10 Road by hiking along the Mōhihi–Waiʻalae trail to Koaiʻe Camp. This camp, lying at 1159 m elevation next to the metal shed at the USGS stream gaging station, was also being used as an endangered bird research station during Phase 1 of this study. Along the reach sampled, Koaiʻe Stream had many small, side tributaries entering from the surrounding Alakaʻi Plateau. These tributaries emptied from small, semi-circular amphitheaters with sheer, moss-lined rock walls. The abundant seep habitats lining Koaiʻe Stream stood in contrast to the situation at the other study sites, which lacked extensive habitats of this type at our sampling locations. Side pool and side channel areas were also common at Koaiʻe Stream, immediately below the falls at the USGS stream gage.

The riparian vegetation at Koaiʻe Stream was predominantly native; the streambed was lined mostly with *D. linearis* ferns and *M. polymorpha*, with relatively small amounts of intermixed raspberry being the most noticeable introduced species.

Koaiʻe Stream – 1159 m (3800 ft)

The first sampling area began with a long series of riffles upstream of the USGS gaging station. The stream in this area flowed through an incised canyon approximately 90 m deep, and was characterized by low to moderate gradient riffles interspersed with large, deep, still pools. Substrate composition in the shallower run and riffle areas consisted of an even mix of larger gravels, small and large cobbles, and numerous small and large boulders. Finer gravel substrates suitable for rainbow trout spawning were not abundant along this reach of Koaiʻe Stream. Upstream of the USGS station, the stream could be traversed for approximately 1 km until the base of a waterfall approximately 15 m high was encountered. This fall represented the upper limit of our sampling of Koaiʻe Stream.

Koaiʻe Stream – 1113 m (3650 ft)

The second sampling station was located below a large 20 m waterfall, which lay approximately 0.4 km downstream of the USGS gaging station. This area was accessed by hiking up the nearly vertical valley ridge on the north bank of Koaiʻe Stream, then descending the cliff to the stream bottom below the falls. The steep ridge is overgrown with stands of *D. linearis* 2–4 m high, and because of the difficult and dangerous nature of this terrain, we recommend that any future visits to this station be accomplished via helicopter. Stream gradient and habitat were similar to those observed at the sampling station on Koaiʻe Stream above the USGS gage. Several springs and rheocrenes (as defined by Polhemus et al. 1992) were observed entering the stream along this reach. Below this point, Koaiʻe Stream flowed for another approximately 0.8 km before passing over a second large, impassable waterfall estimated at 20 m in height that blocked further downstream passage. This area also had plentiful seep and rheocrene habitat, and many areas with gravel-sized substrate suitable for trout spawning.

Kauaikinanā Stream

Kauaikinanā Stream is an upper basin tributary to the Poʻomau Stream, a major tributary to the Waimea River. It heads on the northern Alakaʻi Plateau near Pihea peak at an elevation of approximately 1220 m and flows roughly southwest for 4 km to its confluence with Kawaikōī Stream at the head of the Poʻomau canyon system. Unlike many other streams in this section of the Alakaʻi Plateau, the headwaters of the Kauaikinanā do not lie in a region of extensive bogs, and as a result its waters are clear, without staining from tannins. The stream is crossed by the Camp 10 Road at an elevation of approximately 1035 m, and immediately below this point the stream's base flow is greatly increased by the addition of water diverted from the Kawaikōī system via the Kōkeʻe Ditch. This combined flow from Kawaikōī and Kauaikinanā is then collected by a diversion dam and intake structure, and sent onward into the lower portion of the Kōkeʻe Ditch system.

During the present study, aquatic insect surveys were made along the stream reach immediately above the road crossing. Vegetation in this area consisted of a mixture of introduced guava and native ohia, with a diverse understory of including certain native plants, such as *Pipturis* and *Coprosma*. We studied Kauaikinanā Stream downstream from Camp 10 Road to the diversion dam, and upstream approximately 0.8 km from Camp 10 road. Along both of these reaches Kauaikinanā is a small stream characterized by a relatively low baseflow. The stream flows though a small, narrow, sinuate canyon with walls covered by an *D. linearis* fern understory overtopped by many large *M. polymorpha* trees growing on the stream banks. Although native plants dominated the forest a few meters away from the stream banks, alien plants dominated the riparian zone. In particular, alien plants such as raspberry (*Rubus argutus*), common guava (*Psidium guajava*), Kahili ginger (*Hedychium gardnerianum*), and grasses were common along the more open stream bank areas.

Kauaikinanā Stream – 1037 m (3400 ft)

This station was located at the concrete diversion weir for the Mōhihi Ditch system. Upstream of the concrete diversion weir, stream base flow appeared to be doubled by the Mōhihi ditch for a short distance of about 50 m. At the concrete weir this flow disappears entirely into the Mōhihi tunnel system. Above the influence of the Mōhihi ditch, stream flow is quite low, with the stream generally 1–2 m in width, except for a few deep pools up to 10 m wide. Stream gradient in this area was moderate, with shallow (4–18 cm deep) riffles formed by small boulders. Suitably sized rainbow trout spawning substrate was observed in many of the small riffles. More silt was found in this station than in other areas investigated during this study. Below the Mōhihi Ditch emergent springs once again fill the Kauaikinanā Stream channel, in contrast to the stagnant conditions found below the weir at Waiakoali Stream, a watershed with little apparent spring input.

Kauaikinanā Stream – 1080 m (3540 ft)

This station was located upstream of Camp 10 Road. Water clarity increased upstream of the road crossing, with the stream gradient still moderate but slightly increasing, and the streambed becoming filled with large boulders. The stream canyon above Camp 10 Road becomes quite constricted in places, making the stream channel the smallest of the any assessed during this study. Seep habitat was not evident, even along reaches of the stream bordered sheer gorge walls. By contrast, there was ample side pool and side channel habitat. Further upstream the stream becomes more narrow and boulder strewn, making upstream progress difficult. Although small rainbow trout were still observed by R. Englund after hiking upstream for 3 hours, angling becomes more difficult as the raspberry, other vegetation and large boulders block the stream channel.

Kawaikōī Stream

Kawaikōī Stream is in the main upper basin tributary of Po‘omau Stream, a major fork of the Waimea River. At over 7 km in length, it is the largest and most complex catchment draining the northern section of the Alaka‘i Plateau. The stream’s headwaters begin in the Alaka‘i Swamp at an elevation of about 1260 m, and initially flow northward, before making a sharp bend to the west. From this point the stream follows a sinuate but roughly westward course to its junction with Kauaikinanā Stream at the head of the Po‘omau Canyon, picking up several large north bank tributaries along the way. The headwaters of these tributaries, and of the main stem Kawaikōī, all originate in the Alaka‘i Swamp, and their tannin-rich waters give the stream a pronounced blackwater character. The stream is crossed by the Camp 10 Road at an elevation near 1035 m, and approximately 0.5 km. downstream of this point is a diversion dam and intake structure, which diverts a portion of the stream’s base flow into the Kōke‘e Ditch system. During the present study rainbow trout were found in Kawaikōī Stream for only a short distance, starting at the diversion and extending upstream approximately 75 m to an impassable series of large cascades amid enormous boulders. Rainbow trout were not found above the Camp 10 Road crossing, where our aquatic macroinvertebrate assessments were conducted.

At our study site Kawaikōī Stream flows through a fairly open canyon covered by *D. linearis* ferns and *M. polymorpha* trees. Along this reach the stream is relatively large, being quite similar in discharge and size to Koai‘e Stream. Riparian vegetation at the road crossing consisted of introduced conifers and raspberry, giving way further upstream to a more native assemblage, with an open canopy of ohia and an understory of *Athyrium* ferns. We sampled Kawaikōī Stream at two stations above Camp 10 Road: the first location was adjacent to the USGS gaging station at 1043 m elevation, and the second was on a tributary approximately 1.6 km upstream from the USGS gaging station, reached via the Kawaikōī Trail. Both study sites along

Kawaikōī Stream had abundant isolated side pool and side channel habitats, but lacked seep or rheocrene habitats.

Kawaikōī Stream – 1042 m (3420 ft)

Station 3 was located in a moderate gradient area of Kawaikōī Stream, with short riffles interspersed between large, deep pools. Stream gradient was similar to Kauaikinanā Stream, but somewhat less steep than Koaiʻe Stream. The numerous large, clean boulders along this reach indicate that the streambed is regularly scoured by high flows. Water clarity was good here, although the stream contained large quantities of green filamentous algae. The stream undergoes tremendous spates in this area on a regular basis.

Kawaikōī Stream – 1091 m (3580 ft)

This station was located along a tributary in a narrow, incised gorge approximately 30 m deep. A dense riparian vegetation corridor was formed along the stream by Kahili ginger and raspberry. The main stem of Kawaikōī Stream becomes smaller above this tributary, being similar in size at this point to Kauaikinanā Stream. Stream habitat consisted of shallow (0.5–1 m) pools with many slow, clear side-pools. Several small springs also enter into this tributary. Abundant still water pool habitats were interspersed with many small 1–1.25 m high cascades.

Waiakoali Stream

Waiakoali Stream is an upper basin tributary to the Poʻomau Stream, one of the major forks of the Waimea River. It begins in the northern section of the Alakaʻi Plateau at an elevation near 1220 m, and flows more or less westward for about 5 km before reaching a confluence with Kawaikōī Stream near the head of the Poʻomau Canyon. Throughout most of its length the stream exhibits a moderate gradient, with alternating riffles and pools. Although it heads in the Alakaʻi Swamp, its waters are not as highly stained with tannins as those of the Kawaikōī Stream, which occupies the next major catchment to the north. The stream is crossed by the Camp 10 Road at an elevation near 1035 m, and immediately upstream of this crossing is a diversion dam and intake structure, which diverts much of the stream's base flow into the Kōkeʻe Ditch system. Below this point, Waiakoali Stream consists for much of the year of standing and nearly stagnant pools, which receive flushing only during spates.

Waiakoali Stream – 1037–1098 m (3400– 3600 ft)

During the present study, aquatic insect surveys were made along the stream reach immediately above the weir, from the head of the first long pool impounded behind the diversion dam upstream for approximately 0.5 km. Vegetation along this reach consisted of a thick forest of introduced guava, giving way on the upper slopes to a predominantly native forest assemblage, consisting of scattered *M. polymorpha* protruding from an understory of *D. linearis*. To ensure we captured fish that were not being fed by the feeding station at the Mōhihi Ditch, fish capture and insect sampling started above the first large pool formed by the Waiakoali diversion dam. Sampling occurred upstream to an area of the first major stream bifurcation, which is reached after several hours of traversing deep pools.

METHODS

A. General Methods

Fieldwork for Phase 1 was conducted in 1997, 1998, and 1999 during low flow periods in Kōke‘e State Park streams. Sampling was almost uniformly conducted under unusually clear weather conditions, with the exception of a few days of light rain during the winter of 1999. Representative sampling stations (see STUDY AREA) were established on each stream, and aquatic macrofauna (fish, crustaceans, mollusks, and amphibians) were assessed at each stream. Sampling areas were somewhat dependent upon the constraints of vegetation and local terrain, and were established both in streams containing rainbow trout with natural reproduction (Kauaikinanā, Koai‘e, Wai‘alae, Waiakoali), and a stream currently devoid of rainbow trout (Kawaikōī). Snorkeling and above-water observation were not used to estimate fish density because of poor underwater visibility.

Composition of the riparian vegetation and stream substrate were evaluated at each sampling station. Habitat condition for native aquatic organisms was evaluated both within sampling stations and throughout the stream reaches traversed. Altitude at each sampling station was determined by using a combination of USGS 7.5 min. topographic maps and a hand-held Casio altimeter. The altitude given at each sampling station (see STUDY AREA) was the starting altitude. Stream distances were measured with a planimeter on USGS 7.5 min. quads. Field water quality measurements were made in Kawaikōī and Kauaikinanā Streams, while pH and temperatures were collected in Koai‘e Stream during Phase I of the study (summer 1997). Stream temperatures were taken during the Phase 2 (Winter 1999).

Aquatic Insect Sampling

Aquatic insect sampling was conducted using the methodology of Polhemus (1995), Englund and Filbert (1997) and Englund et al. (1998). Collections of both immature and adult specimens were obtained using aerial sweep netting, dip nets and Surber (benthic) samplers. Visual observations of flying adult aquatic insects, particularly Odonata, were also conducted while hiking along the streams between sampling stations. Malaise traps, large tent-like nets that allow for the passive capture of aquatic insects, were also placed over each stream for a 24-hour period.

Sampling effort was focused on habitat suitable for native aquatic insects: splash zones around riffles and cascades, wet rock faces associated with springs and seeps, waterfalls, and rock overhangs. The sampling of damselflies and dragonflies (Odonata) was emphasized, because six species of native *Megalagrion* damselflies are currently held as candidate Threatened, Endangered, or Species of Concern on the Federal Register. In addtition, native Hawaiian damselflies give an indication of the relative ‘health’ of a stream system, because they do not typically occur in highly disturbed areas (Polhemus and Asquith 1996).

Randomly selected Surber samples were used to assess benthic aquatic insect densities in riffles, and were collected in all streams studied. All streams contained many moderate gradient riffles, (although Waiakoali contained lesser amounts of riffles) with similarly sized substrate (6–25 cm).

Qualitative drift samples were collected in Kauaikinanā, Kawaikōī, Waiakoali, and Koaiʻe Streams but not at Waiʻalae Stream. Drifting invertebrates were collected with cone shaped Wildco® drift nets 0.9 m long with an aperture area of 0.09 m^2 and a mesh size of 450 µm. The center of the net was placed in the middle of the stream and was set at approximately 60% of the water column depth (Filbert and Hawkins 1995). Each drift collection consisted of one 10-min sample collected at midday (1200 hrs) in each stream sampled. All drift collections were made within a one-week time period during winter 1999 sampling. Time and budgetary constraints did not allow for comprehensive diel drift sampling that would involve nighttime samples or replicated sampling. Rather, these preliminary samples were collected to assess drift species composition and provide inferences on the propensity of native aquatic insects to drift.

All insect specimens were stored in 75 percent ethanol and subsequently transported to the Smithsonian Institution and Bishop Museum for curation and identification. Voucher specimens are currently housed in the Bishop Museum and Smithsonian Institution collections.

Rainbow Trout Diet Analysis

With the assistance of volunteer anglers from Trout Unlimited, rainbow trout were captured by angling for this study. Fish were immediately killed after capture and stomachs were injected with and placed in 70% ethanol for later laboratory analysis. In the Bishop Museum laboratory, gut contents were removed from the portion of the gut between the anterior of the esophagus and pyloric sphincter (Kimball and Helm 1971).

Contents of each rainbow trout stomach were identified to the lowest possible taxonomic level, and in many cases to genus and species. Species level identification was not always possible for partially digested insects, or some orders such as Diptera (aquatic flies) where adult males are required for identification. The biogeographic status (i.e., native versus introduced) of individual taxa was evaluated using Nishida (1997). Total prey item numbers in each trout stomach were recorded, and if contents were broken into pieces, head capsules were then counted as an indication of individual prey item numbers. Terrestrial or aquatic status was determined for each identifiable prey item found in the rainbow trout stomachs. The percent composition of rainbow trout diet represented by any given prey item class was calculated by adding the total number of identifiable prey items and dividing by the number in each prey item category. The proportion of introduced and native aquatic prey items in rainbow trout stomachs was calculated for the aquatic species where such information regarding geographic origin could be ascertained. The processed stomach contents are stored in the collections of the Hawaii Biological Survey, Bishop Museum Department of Natural Sciences.

We did not determine ash-free dry weight of captured prey items for the following reasons: 1) this process would have destroyed voucher specimens that will be permanently stored in the Bishop Museum collection, and precluded any future study of such specimens should the constituent species be taxonomically revised; 2) we felt it would be misleading, as we often identified species from only certain body parts such as head capsules or leg segments, thus it would be necessary to approximate an average weight for each specimen; 3) this study was not concerned with bioenergetics, but rather with an assessment of impacts of predation, thus total numbers of prey items consumed was considered to be a more appropriate method of determining trout impacts on aquatic insect populations; and 4) some prey items can have an enormous difference in weight (both dry and/or wet weight), both between taxa or even within a taxon. For example, the weight of an early instar of the large native dragonfly *Anax strenuus* would differ considerably from that of the last instar. Similarly, comparing ash free dry weights or wet weights is misleading in that one native *Anax strenuus* dragonfly would outweigh hundreds of introduced chironomid midges such as *Cricotopus bicinctus*. Thus the consumption of one individual native dragonfly would be considered to have a greater impact than the consumption of hundreds of introduced midges.

B. Data Analysis Summary

Proportions Tests

Proportion tests were conducted to assess whether the presence of rainbow trout influenced the number of native aquatic insect species in Kaua‘i streams (Ramsey and Schaefer 1997). The null hypothesis of there being no significant difference in the proportion of native aquatic insect species between streams with and without trout was tested against the alternative hypothesis that the proportion of native species in streams without trout is higher that that in streams with trout. A two-sample test for equality of proportions with continuity correction tests was conducted using the S-Plus®2000 statistical program (MathSoft, Inc. 1999). Streams used in the proportion test included all assessed streams in Kōke‘e State Park, and two other relatively high elevation Kaua‘i Streams lacking rainbow trout; the Lumaha‘i (430 m elevation) and Hanalei (380 m elevation) Rivers.

Poisson Regression for Count Data

The Poisson probability distribution is useful for describing the population distribution of counts of occurrences of some event over time or space. The distribution has been used in a wide variety of situations, and is most appropriate for counts of rare events that occur at random points in space or time. The counts of spiders and carabid beetles captured in pitfall traps over a sampling period are examples of these types of data.

The probability of obtaining Y successes is given by the formula

$$\text{Probability}\{Y\} = \exp(-m)*m^Y/Y!, \text{ for any } Y = 0,1,2, \ldots$$

The features of the Poisson distribution allow regression models to account for increasing variance with increasing means response. In the Poisson distribution, the variance is equal to the mean. Poisson log-linear regression models specify that the logarithms of means of Poisson responses are linear in regression coefficients. Coefficients of the Poisson regression model can be estimated using a generalized linear model.

The generalized linear model with a Poisson response is:

$$\log(m) = b_0 + b_1 X_1 + b_2 X_2$$

Where m = the mean of the Poisson distribution, b_0 is the intercept coefficient, b_1 is the coefficient for the first explanatory variable, X_1, and b_2 is the coefficient for the next explanatory variable, X_2.

Many times analysis of Poisson distributed data is conducted with transformed data. The logarithm of the response often straightens out the relationship between the response and the explanatory variables. The variance remains non-constant and normal regression analysis often fails to arrive at a parsimonious model. The transformation that stabilizes the variance is the square root of the response, but interpretation is not satisfactory. The Poisson log-linear approach does not require a transformation and is the most suitable approach to modeling count data.

The maximum likelihood method is used to estimate the coefficients in Poisson log-linear regression. The parameters for the model are those that yield the highest probability of observing precisely what was observed. The method is calculation intensive and is used in most modern statistical software packages. A thorough discussion of Generalized Linear Regression and Maximum Likelihood Estimation of model parameters is contained in *Generalized Linear Models 2nd Edition* (McCullagh and Nelder 1991).

Unmeasured effects, clustering of events, or other factors sometimes produce more variation in the responses than is predicted by the Poisson model. Using Poisson log-linear regression when extra-Poisson variation is present yields roughly unbiased estimates of parameters, but standard errors are smaller than reality and tests of significance yield smaller p-values than are truly warranted by the data. A quasi-likelihood approach can be applied to extend the model when extra-Poisson variation is present. The quasi-likelihood approach accounts for the larger than expected variation and gives tests and resulting p-values adjusted for the extra-Poisson variation. The extra-Poisson variation is summarized in the dispersion parameter.

A Poisson regression model for count data was used to test if the main constituent of the benthic fauna collected in Surber samples, *Cheumatopsyche pettiti*, varied by stream. The null hypothesis of there being no significant difference in the number of *C. pettiti* per stream was tested against the alternative hypothesis that densities varied among streams.

RESULTS

Our surveys indicate that streams sampled within Kōke‘e State Park maintain diverse populations of native aquatic insects, both in streams containing rainbow trout, such as Wai‘alae, Koai‘e, and Kauaikinanā, and in streams lacking rainbow trout, such as Kawaikōī Stream above the Camp 10 Road. While it is now impossible to recreate conditions prior to the introduction of rainbow trout into the inland waters of Kaua‘i, our results indicate that the native aquatic insect assemblages seen in the streams under study compare favorably with other isolated and unimpacted streams in the Hawaiian archipelago (Polhemus 1995; Englund and Preston 1999).

A large number of aquatic and terrestrial taxa were identified during this study; these are summarized in Table 1. A complete taxon list is provided in Appendices A–D. Terrestrial species were only included when found in trout stomachs or collected during invertebrate drift sampling (Table 1); even so, they compose a large proportion (47.4%) of the taxa consumed by rainbow trout. Table 1 also provides an indication of the effectiveness of various sampling techniques for assessing aquatic macroinvertebrate species diversity in Kaua‘i, and by extension all Hawaiian streams. For example, a far more diverse assemblage of native aquatic insect species was collected using general and aerial techniques, and by analyzing trout stomachs, than was obtained from only benthic sampling. This clearly indicates that standard benthic sampling, although a traditional method commonly employed in continental settings, is of limited utility in assessing the native insect diversity of Hawaiian streams, and is of little use in assessing impacts to native aquatic species.

One of the most important findings of this study is that the aquatic fauna of Kōke‘e State Park streams is composed largely of native species, as shown in Figure 2. Although this study mainly looked at the presence or absence of native aquatic insect taxa, rather than the relative numbers of such taxa, quantitative observations were made on the relative abundances of certain groups of special concern, particularly Odonata. Adult native damselflies were exceptionally abundant during sampling in the warmer summer months, but were noticeably absent during winter (January) sampling. A review of collection data from specimens in the Bishop Museum indicates that this may in fact be a typical seasonal pattern in upland Kaua‘i. Immature damselflies, by contrast, were collected in winter months during benthic and general sampling, and one adult *Megalagrion vagabundum* was collected along Wai‘alae Stream in January. The native dragonfly *Anax strenuus* was less affected by seasonality, with adults and immatures being captured during both winter and summer months. *Anax strenuus* larvae were common and readily observed, even in streams with naturally reproducing trout populations such as Koai‘e Stream.

Except for Wai‘alae Stream where drift samples were not collected, terrestrial species were included in Figure 2 in order to show the proportions of native versus introduced species present in the stream drift. A summary of the aquatic and terrestrial taxa collected in rainbow trout stomachs is shown in Figure 3, and clearly indicates the importance of drifting terrestrial taxa to the rainbow trout diet. Figure 3 also shows the lack of feeding selectivity by rainbow trout in regard to any particular aquatic or terrestrial taxon in their diet.

Table 1. Total number of aquatic species collected during benthic, drift, and aerial (general) collections during this study.

Method	Total Aquatic Spp.	Native Aquatic	Total Terrestrial[1]	Native Terrestrial[1]	Total Species
General/Aerial	48	33	n/a	n/a	48
Drift	15	7	26	13	41
Net Swings	20	17	n/a	n/a	20
Benthic (Surber)	9	3	n/a	n/a	9
Trout Stomach	43	21	85	36	128
Total	135	81	111	49	246

[1]Terrestrial species not sampled during benthic (Surber) or general species collections.

A. Surber (Benthic) Sample Results

A total of 60 Surber samples were randomly collected from riffles in the five surveyed streams (see Appendix C). Sampling was limited to riffles (as defined by Armantrout 1998) for three reasons: 1) this provided consistency of sampled habitat within and between streams, 2) many non-riffle habitats, particularly pools, were too deep to sample using this method, and 3) habitats other than riffles contained far fewer individuals and types of aquatic taxa. Our results indicate that benthic sampling was completely ineffective in assessing aquatic insect species in upland Kaua‘i streams, even accounting for the undescribed immature stages of many taxa that tend to predominate in such samples. Only 5 aquatic insect species were collected via benthic sampling: *Cheumatopsyche pettiti* (caddisfly), *Cricotopus bicinctus* (midge), *Rhantus pacificus* (diving beetle), *Megalagrion heterogamias* (Kaua‘i mountain damselfly), and an unidentified tipulid, accounting for little more than 1% (by number) of taxa collected in benthic samples (Table 2). Of these, only two (*Rhantus pacificus* and *Megalagrion heterogamias*) are unequivocally known to be native species, while two demonstrably introduced taxa (*Cheumatopsyche pettiti* and *Cricotopus bicinctus*) comprised over 80% of the total collected benthic macrofauna (Table 2). Clearly, the infrequent capture of only two native aquatic insect species, *R. pacificus* and *M. heterogamias* (and potentially a native tipulid), through the use of standardized, randomly selected Surber samples inadequately characterizes the native aquatic invertebrate diversity present in these Kaua‘i streams, as can be seen by comparing this meager taxon representation to the total diversity of native aquatic insects actually present at these study sites (see Table 1).

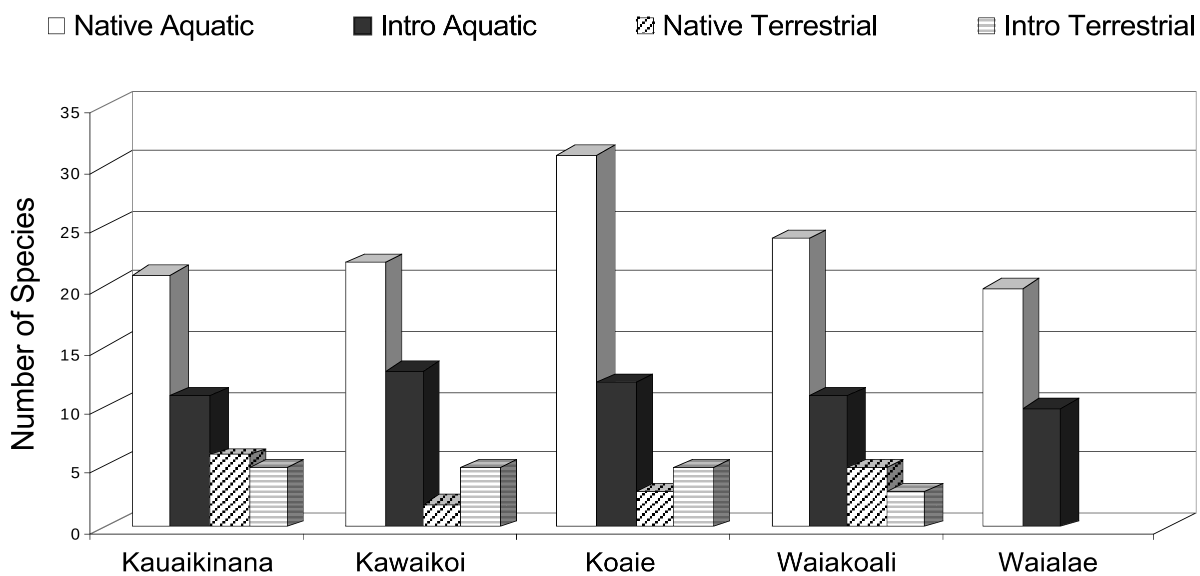


Figure 2. Summary of aquatic species collected in Kōke‘e State Park streams from all sampling methods combined (general sampling, Malaise traps, drift, benthic samples).

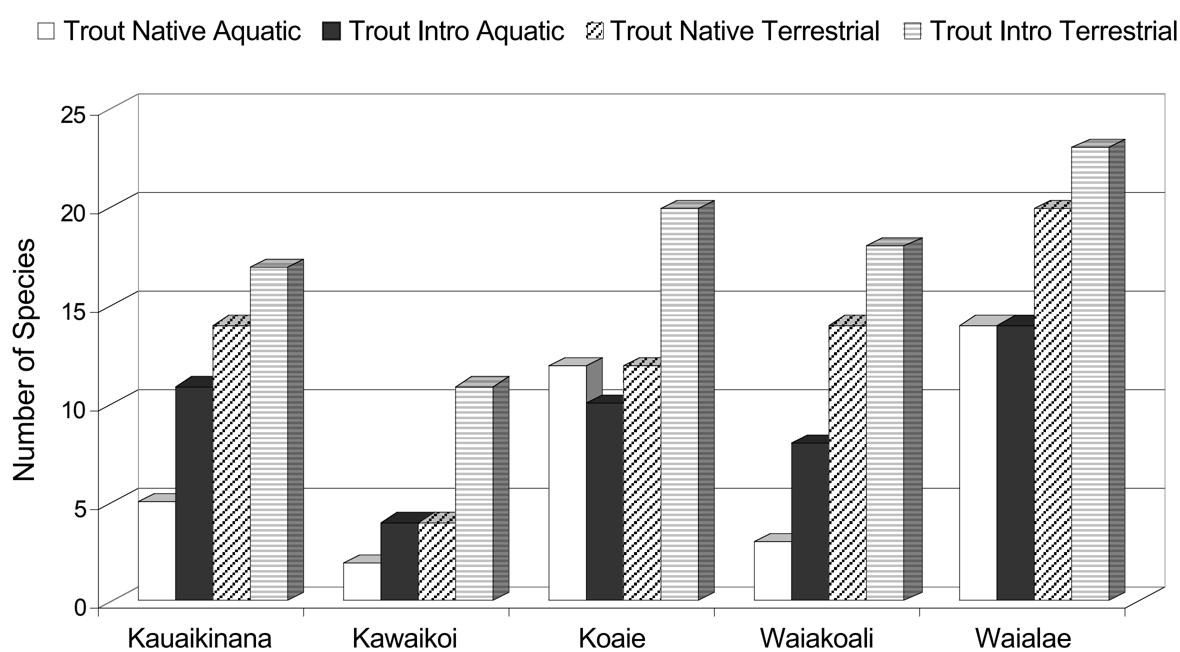


Figure 3. Summary of all species collected from rainbow trout stomachs only (n = 80) in Kōke‘e State Park streams.

There is evidence that the extra-Poisson dispersion model fits the data (p-value = 0.5584 > 0.05). Statistical tests of Surber samples using a Poisson regression indicate that the counts of *C. pettiti* in Kauaikinanā Stream, a stream with naturally reproducing trout, are higher than in Kawaikōī Stream that lacks trout (p-value = 0.0004). The mean number of *C. pettiti* counts are 3.5 times higher in Kauaikinanā Stream than in Kawaikōī Stream (95% CI = (1.75, 6.86)). A graphic representation of mean benthic sample densities is shown in Figure 4.

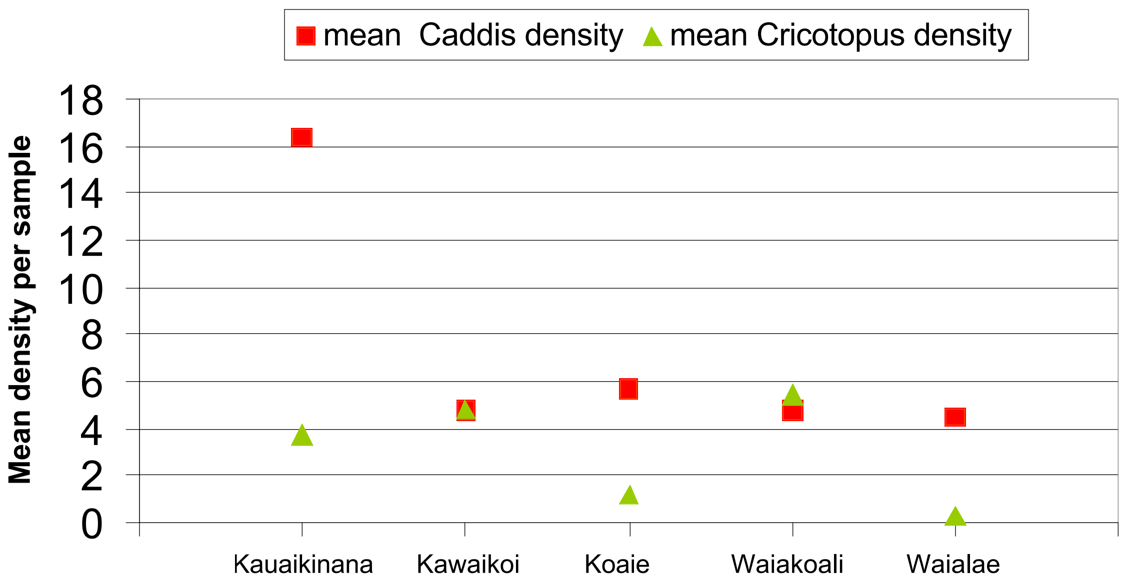


Figure 4. Mean density by stream for the two most important constituents of benthic samples, *Cheumatopsyche pettiti* and *Cricotopus bicinctus.*

In summary, this statistical test indicates the densities of the most important constituent of benthic aquatic insect fauna, *C. pettiti*, are independent of the presence or absence of rainbow trout. Rather, densities of these species are likely more dependent on favorable water quality characteristics, with more stable groundwater-fed streams such as Kauaikinanā having higher densities of introduced benthic fauna. Surber samples in Waiʻalae Stream were unintentionally taken upstream of several groundwater springs and tributaries that enter the stream just below Waiʻalae Cabin, and this is likely reflected by the lower numbers of *C. pettiti* in samples taken from Waiʻalae Stream.

Table 2. Summary of numbers of each aquatic taxon collected in Kōke‘e State Park streams during benthic (Surber) sampling.

Taxa	Kauaikinanā (n = 12)	Kawaikōī (n = 15)	Koai‘e (n = 17)	Waiakoali (n = 7)	Wai‘alae (n = 9)	Totals (%)
C. pettiti	196	71	97	33	40	437 (57%)
C. bicinctus	45	72	23	38	2	180 (23.4%)
Annelida	61	21	13	17	24	136 (17.7%)
M. heterogamias	0	3	2	0	1	6 (0.8%)
R. pacificus	0	1	1	0	0	2 (0.3%)
Tipulidae	0	0	2	0	1	3 (0.4%)
Gordius sp.	0	0	0	1	0	1 (0.1%)
Acari	0	0	0	2	0	2 (0.3%)
Totals	302	168	138	91	68	767 (100%)

B. General Aquatic Insect Collections

Collections conducted during this study with sweep and dip nets, mainly in the splash-zones of riffles and cascades, were an effective method of qualitatively assessing aquatic insect species composition in Kōke‘e State Park streams. Because the larval stages of most native aquatic insects in Hawai‘i have not yet been described or adequately associated with the adults on which most classifications are based, collection of adult stages was emphasized during this study. All streams sampled were found to have large numbers (and high relative percentages) of native aquatic insect taxa (Table 3). A low of 20 native aquatic insect species were collected in Wai‘alae Stream, while 31 native taxa were found in Koai‘e Stream. The native species assemblage found at Koai‘e represents the greatest number of native aquatic insect species so far recorded for any individual stream yet sampled in the Hawaiian archipelago (for comparative data see Polhemus 1995, Englund and Preston 1999), despite the presence of rainbow trout in this system.

A two-sample test for equality of proportions found the number of native aquatic insect species in streams with and without trout (p-value = 0.6861) did not significantly differ. Streams without trout included Kawaikōī, Lumaha‘i, and Hanalei; while streams containing trout included Kauaikinanā, Koai‘e, Waiakoali, and Wai‘alae. For the proportions test, the number of native and introduced aquatic insect species in Lumaha‘i (430 m elevation) and Hanalei Rivers (380 m elevation) was derived from previous Bishop Museum surveys by Polhemus (1995). A summary of native and introduced aquatic species during general sampling can be found in Table 3.

The reasons for these high native aquatic insect diversities, particularly in Koai‘e Stream, may be explained by several factors. The reach of Koai‘e Stream sampled exhibited greater habitat diversity than the other streams under study, having waterfalls, large rheocrene seeps (wetted rock faces), and a wide diversity of substrate size classes. Additionally, Koai‘e Stream received groundwater spring inputs that may provide more favorable water chemistry for aquatic insects than the acidic, tannin-rich surface waters typical of Wai‘alae and Kawaikōī streams.

Another significant finding of this study was the presence of large populations of the endemic Na Pali Hawaiian skating fly, *Sigmatineurum napali*, along Wai‘alae, Koai‘e and Kawaikōī Streams. Collections of this putatively rare insect were made in open, sunny areas of the stream channels by running a net through the turbulent water of cascade or riffle faces.

Table 3. Summary of number of aquatic insect species collected via general sampling as compared to benthic sampling in Kōke‘e State Park streams.

Stream	general sampling - native insects	general sampling - introduced insects	benthic - native insects	benthic - introduced insects
Kauaikinanā	21	6	0	2
Kawaikōī	22	6	2	2
Koai‘e	31	8	2	2
Waiakoali	23	5	0	2
Wai‘alae	20	6	1	2

C. Drift Samples

Drift samples were collected in Kauaikinanā, Kawaikōī, Waiakoali, and Koai‘e Streams. While it was beyond the scope of this study to provide a comprehensive and quantitative analysis of diel stream drift, these preliminary findings are of interest and will possibly stimulate further research into native aquatic insect drift in Hawaiian streams. The terrestrial component of drift was relatively small (15%) when compared to the large numbers of aquatic insects present (Figure 5). Introduced aquatic insects dominated and numerically accounted for 60% of drift for all streams combined. Our drift samples were taken during low basal flows, concurrently with obtaining rainbow trout stomach samples in the winter of 1999. It is likely that samples taken during a freshet would contain a higher proportion of terrestrial insects because of flooding of the riparian zones, and the action of rain in dislodging terrestrial insects from trees in the adjacent rain forest.

By far the most numerically abundant aquatic insect species captured in the drift samples was the introduced midge *Cricotopus bicinctus* at 45% of the drift, although the native midge *Forcipomyia hardyi* also represented an important (14%), though lesser, component (Figure 6). Other taxa found in large numbers in the drift samples included endemic midges such as *Chironomus* sp. at 9%, and introduced caddisflies at 5% (Trichoptera). Undescribed larvae of semi-aquatic moths in the genus *Hyposmocoma* (Family Cosmopterigidae), which graze on emergent boulders within the stream channels, were also found in the drift samples (Figure 6). Little is known regarding the biology of the Hawaiian *Hyposmocoma* species, and although there is anecdotal evidence that larvae enter the water to move between rocks (Merritt and Cummins 1996), it cannot currently be established whether they should be viewed as terrestrial taxa that are occasionally washed into the stream, or typical aquatic constituents of the stream drift. For this study however, we choose to categorize *Hyposmocoma* as aquatic species because of their clear relationship to stream habitats.

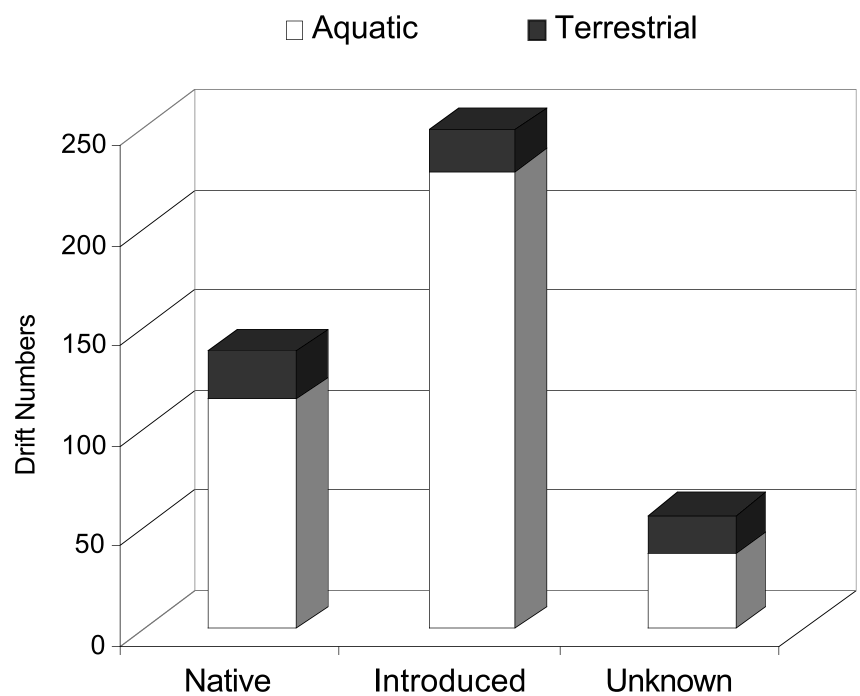


Figure 5. Numbers of native, introduced, and unknown aquatic insect species by biogeographic status collected in stream drift samples in Kauaikinanā, Kawaikōī, Waiakoali, and Koai‘e Streams.

Though common as immatures in the drift samples, adult individuals of the endemic midge *Forcipomyia hardyi* were not collected by other sampling methods employed during this study (e.g., aerial collections, Malaise traps, trout stomachs, benthic sampling). This absence of adults in general collecting samples could be related to seasonal emergence patterns, or to adults leaving the stream corridor following emergence. This anomaly also indicates the importance of using multiple sampling techniques at different times of year to obtain comprehensive biodiversity information on native aquatic insects in Hawaiian streams. A complete list and numbers of drift organisms collected in each stream can be found in Appendix D.

A wide variety of terrestrial taxa were also captured in drift samples, with terrestrial mites (Acari) predominating, intermixed with a wide variety of other groups including beetles (Coleoptera), flies (Diptera), bark lice (Psocoptera), planthoppers and aphids (Homoptera), and others (Figure 7). For those terrestrial drift taxa that could be identified to the species level, most proved to be native species. This reflects the nearly pristine character of the riparian vegetation found along

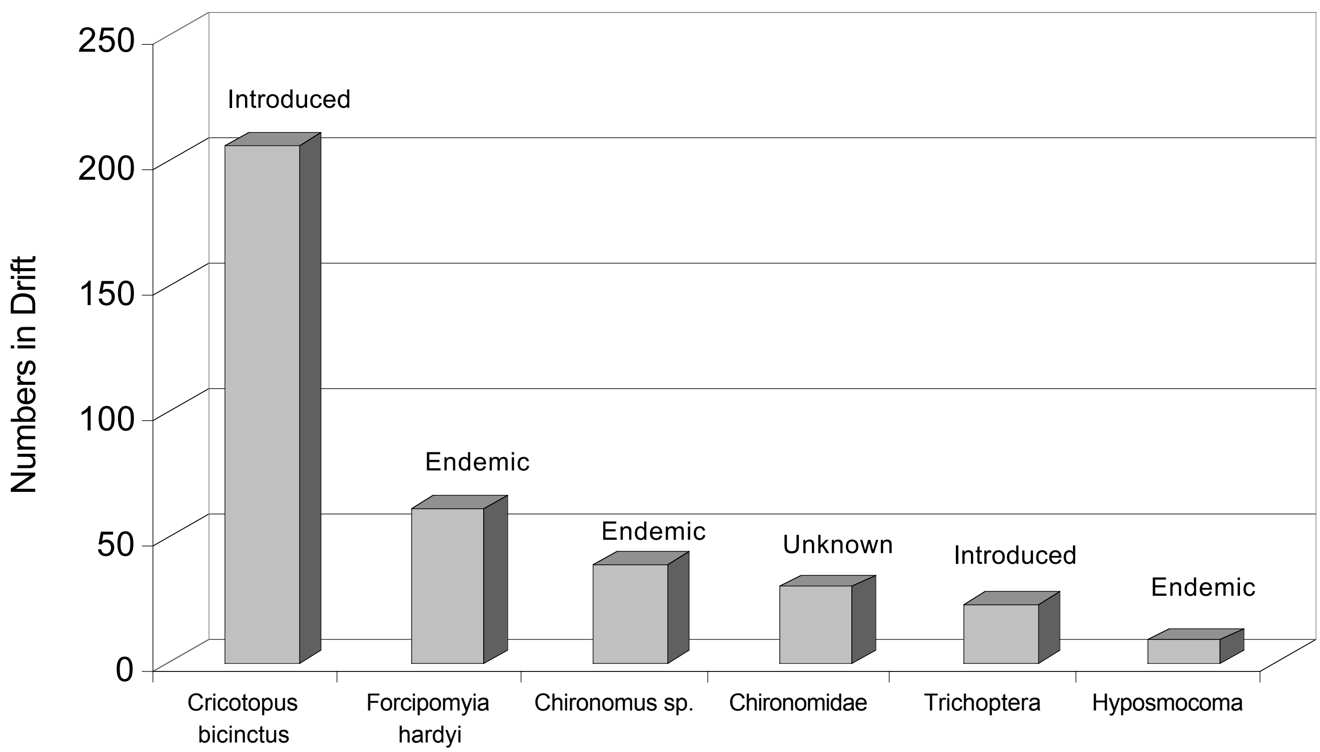


Figure 6. The six numerically most abundant aquatic insect taxa captured in drift samples taken in Kauaikinanā, Kawaikōī, Waiakoali, and Koai‘e Streams.

many of Kauai's upland streams. Although some ginger, blackberry and guava was encountered along the lower sections of streams that intersect the Camp 10 Road, such as Waiakoali and Kauaikinanā, the surrounding forests are nevertheless still dominated by an overstory of *M. polymorpha* and an understory of other native plants.

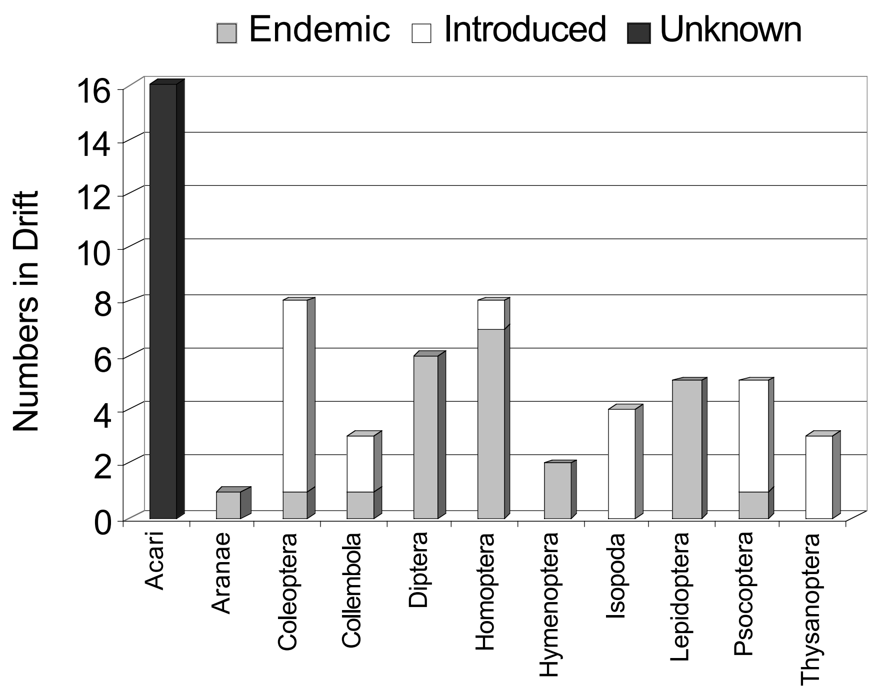


Figure 7. Terrestrial insect taxa, numbers, and biogeographic status collected in drift samples taken in Kauaikinanā, Kawaikōī, Waiakoali, and Koaiʻe Streams.

D. Trout Diet

A total of 80 rainbow trout stomachs were collected from the five streams under study. The potential impacts of rainbow trout on native aquatic insects were the primary focus of this study, because the streams examined were above the altitudinal ranges of native insectivorous fish. At the same time, the potential impacts on other native aquatic taxa of concern, including native aquatic snails and native freshwater shrimp, were also evaluated.

Of particular interest to the current study were the native damselflies in the genus *Megalagrion*. It was the potential impact to these insects, six of which are currently proposed for protection under the Endangered Species Act, that curtailed the stocking of rainbow trout into Kōkeʻe State Park streams beginning in 1992. Five native damselfly larvae, all representing the riffle-breeding species *Megalagrion heterogamias*, were collected in trout stomachs during this study, out of a total 1,596 identified prey items (Table 4). *Megalagrion heterogamias* were found in 5 of the 80 rainbow trout stomachs examined, for a frequency of occurrence of 6%. Four of the five *Megalagrion* larvae came from fish collected in Waiʻalae Stream, with the remaining individual coming from Koaiʻe Stream (Tables 4 and 5). The giant endemic dragonfly, *Anax strenuus*, was more commonly consumed by rainbow trout, with 28 individuals collected from 20% of examined trout stomachs (Tables 4 and 5). In contrast to the riffle dwelling immatures of *M. heterogamias,* the larvae of *A. strenuus* prefer slow-water habitats, allowing trout to take more opportunistic advantage of this largest Hawaiian aquatic insect.

Table 4. Summary numbers and percent frequency of native prey items of special concern collected in rainbow trout stomachs during this study, compared to the number of taxa collected per stream.

Stream	Native Damselflies	Native Dragonflies	Other Native Aquatic Insects	Introduced Aquatic Insects	Other Prey Items[1]	Total
Kauaikinanā	0	4	11	128	164	307
Kawaikōī	0	0	2	4	34	40
Koai‘e	1	23	17	99	363	503
Waiakoali	0	0	6	31	184	221
Wai‘alae	4	1	51	169	300	525
Totals (%)	5 (0.3%)	28 (1.8%)	87 (5.5%)	431 (27.0%)	1045 (65.4%)	1596 (100%)

[1]Includes snails, terrestrial insects, other invertebrates and vertebrates.

Native aquatic insects, the taxa of greatest concern, amounted to 7.5% (by number) of the prey items found in Kaua‘i rainbow trout stomachs. This likely reflects the fact that drift-feeding trout are finding relatively few native aquatic insects in the drift, and instead must rely on introduced aquatic insects, terrestrial insects, snails, and any other opportunistic food source, such as crayfish or frogs, that becomes available. Numerically, the three most important items in the rainbow trout diet were introduced caddisflies (Trichoptera) at 19%, followed by terrestrial millipedes (Polydesmida) at 13%, and aquatic snails (Lymnaeoidea) at 12% (Table 6). Trout diet appeared to vary between streams for reasons likely related to food availability. For example, lymnaeid snails were consumed by trout only in Koai‘e and Wai‘alae Streams, but then sometimes in great numbers, with up to 41 snails found in an individual trout.

Both native and introduced species of freshwater snails in the family Lymnaeidae are found in Hawai‘i (Cowie 1997), and it is possible that some of the snails found in the surveyed Kōke‘e State Park streams are native lymnaeids. However, except for *Erinna newcombi*, (a threatened species), and *Oligospira* spp., identification of native lymnaeids is currently problematic, because many taxonomic issues remain unresolved, and it is not currently possible to identify the snails found in this study to the species level (R. Cowie, Bishop Museum malacologist, pers. comm.). The biogeographic status of the lymnaeid snails collected during general sampling or found in trout stomachs therefore cannot currently be resolved.

The native freshwater shrimp *Atyoida bisulcata* proved to be extremely rare because of the high elevation of the study area (> 1037 m); this species is generally more abundant at lower elevations. *Atyoida bisulcata* were only found in trout stomachs and were not collected or observed despite numerous benthic and general collections conducted in all five streams. Diversions also likely limit the upstream range of *A. bisulcata*, because none were found in trout stomachs in streams diverted by the Mōhihi Ditch (e.g. Kauaikinanā and Waiakoali Streams).

Table 5. Frequency of prey items representing important aquatic species found in 80 rainbow trout stomachs collected during this study.

Stream	Native Damselflies	Native Dragonflies	Trichoptera	Lymnaeidae	*Atyoida bisulcata*
Kauaikinanā (n = 17)	0	2 (3%)	13 (16%)	0	0
Kawaikōī (n = 3)	0	0	2 (3%)	0	0
Koaiʻe (n = 24)	1 (1%)	13 (16%)	13 (16%)	12 (15%)	1 (1%)
Waiakoali (n = 18)	0	0	6 (8%)	0	0
Waiʻalae (n = 18)	4 (5%)	1 (1%)	16 (20%)	12 (15%)	5 (6%)
Totals (80)	5 (6%)	16 (20%)	50 (63%)	24 (30%)	6 (7%)

A complete breakdown of the aquatic, terrestrial, and native or introduced status of all identified prey items found in rainbow trout stomachs is presented in Table 6. As is evident in this table, rainbow trout consume a wide variety of prey items, but native aquatic insects, the category of greatest interest to this study, accounted for only 7.5% of the diet. Introduced aquatic insects accounted for 28.9% of the diet, while organisms with an unknown biogeographic status represented 16.2% (Table 6). Species with an unknown biogeographic status can be considered cryptogenic, which is defined as widespread species of uncertain origin that may be introduced (Carlton 1996). The majority of cryptogenic aquatic species consumed by rainbow trout in this study were lymnaeid snails, which as noted previously accounted for a substantial portion of trout diet in Waiʻalae and Koaiʻe Streams.

Two rare species of terrestrial beetles were also collected from the same rainbow trout in Koaiʻe Stream. Most significant is an extremely rare elaterid beetle, *Eopenthes muticus*. This beetle was last collected in 1896 by Perkins, and only two specimens are known to exist (Nishida 1997). An alleculid beetle, *Pseudocistela kauaiensis*, also taken from the same trout, was last collected in 1937 by E.C. Zimmerman (Nishida 1997). *Pseudocistela kauaiensis* is endemic to Maui and Kauaʻi, and only 13 specimens are known from museum collections. Other rare terrestrial beetles collected from trout stomachs included *Nesotocus kauaiensis*, *Itodacnus* sp. prob. *sordidus*, and *Blackburnia insignis*. These rare endemic beetles further indicate that native biodiversity remains high in the riparian ecosystem of the Kōkeʻe area; for example, *N. kauaiensis* is a large beetle that requires native plants in the Araliaceae family such as *Cheirodendron* spp.

Table 6. Biogeographic status of prey items found in 80 Kōke‘e trout stomachs, 1997– 1999.

Taxon	Native Aquatic	Introduced Aquatic	Unknown Aquatic	Native Terrestrial	Introduced Terrestrial	Unknown Terrestrial	Total
Amphipoda					23		23
Anura		2					2
Aranae				16		1	17
Arhynchobdellida		53					53
Basommatophora		1					1
Blattodea					12		12
Coleoptera	9	1	2	18	12	16	58
Collembola					1		1
Cypriniformes		3					3
Decapoda	6	3					9
Diptera	27	64	35		1	6	133
Gordioidea		6					6
Heteroptera	8	22		25	5	6	66
Homoptera				30		6	36
Hymenoptera				4	94	5	103
Isopoda					35		35
Isoptera					1		1
Lepidoptera	37			11		46	94
Limacoidea					35		35
Lymnaeoidea			198				198
Neuroptera				1			1
Odonata	33	1					34
Oligochaeta			21				21
Oribatida						2	2
Orthoptera				5	1	5	11
Phthiraptera						1	1
Planorbioidea			2				2
Polydesmida					215		215
Psocoptera				2			2
Spirostreptida				115			115
Trichoptera		306					306
Totals:	120	462 (28.9%)	258 (16.2%)	227	435	94	1596
(%)	(7.5%)			(14.2%)	(27.3%)	(5.9%)	(100%)

E. Rainbow Trout Natural Reproduction in Kōke‘e State Park Streams

A definitive assessment of natural reproduction in rainbow trout could be made for the streams under study, since trout stocking in Kōke‘e State Park streams was discontinued in 1992. Naturally reproducing rainbow trout were observed in Kauaikinanā, Kōke‘e, Koai‘e, and Wai‘alae streams (Table 7). These fish were obviously natural recruits, and differed from escaped ditch fish because of their small size (as small as 60 mm observed), parr marks, lack of eroded fins, and straight fin-rays. The following section briefly discusses the status of rainbow trout populations in each stream.

Table 7. Status of naturalized rainbow trout populations in Kōke‘e State Park streams.

Stream	Reproducing Populations	Trout Escaped From Ditch	Stream Temperatures- Jan. 1999
Kauaikinanā	X	X	14° C (57° F)
Kawaikōī [1]		X	15° C (59° F)
Koai‘e	X		15° C (59° F)
Kōke‘e [2]	X		not sampled
Waiakoali [1]		X	13° C (55° F)
Wai‘alae	X		15° C (59° F)

[1]Temporary populations not established, see text for explanation.
[2]Stream not sampled due to thick ginger

Kawaikōī Stream

Rainbow trout were captured and observed only below a large cascade adjacent to the Mōhihi Ditch, although Kawaikōī Stream above Camp 10 Road was stocked prior to 1992 and has in the past been a favorite fishing area for trout anglers. Water visibility was good because of dry weather and low-flow conditions, and no rainbow trout were observed above Camp 10 Road. Anglers also confirmed that rainbow trout have not been caught from this stream in several years, and attempts by us to capture trout above Camp 10 road were not successful during this study. In the past, poaching has been a problem at Kawaikōī Stream (Dennis Shinno, HDAR, personal communication). This is probably because of the ease of fishing along the large, open stream channel paralleled by a maintained trail that provides easy public access. Natural reproduction of rainbow trout in Kawaikōī Stream may also be hampered by high water temperatures and a lack of spring-fed groundwater inputs. Water temperatures were 22.7° C (73° F) in August 1998, the highest measured in any stream sampled during this study.

Kauaikinanā Stream

Numerous fingerling sized (<5 cm) rainbow trout were observed throughout Kauaikinanā Stream. A few large rainbow trout that had escaped from Mōhihi ditch were captured at the pool formed by the diversion weir for the ditch. Ditch fish were not captured above Camp 10 Road. Since rainbow trout were last stocked at Kauaikinanā Stream in 1992 at the approximate 11–12 cm size class (Dennis Shinno, HDAR personal communication), these fingerlings were obviously the result of natural reproduction. Kauaikinanā Stream clearly originates from a groundwater spring source, because the measured pH was 7.9, as compared to the 6.8 reading at the USGS gaging station on Koai‘e Stream. Greater surface water runoff from the Alaka‘i swamp is the likely reason for the lower pH found in Koai‘e Stream upstream of the USGS gaging station.

Koai‘e Stream

Natural reproduction was observed for rainbow trout in Koai‘e Stream both above and below the USGS gaging station at Koai‘e Camp. Reproduction was especially evident downstream of the falls, and may result from a combination of emergent springs and potentially the greater availability of fine spawning gravels. Several cold springs emerged downstream of the waterfalls below Koaiʻe Camp, with their temperatures of 17.5° C contrasting with the temperature of 21° C taken in the main stream channel near the USGS gaging station. The influence of groundwater at the springs was also apparent, with the pH in the main channel reading 6.8, as compared to 7.3 at the spring area. Small (< 12 cm) fish with parr marks and pristine fin rays were caught in Koaiʻe Stream, although the last stocking of here occurred in 1992. Reproduction above the USGS gaging station appears to be less successful than in the spring-fed area below, because small fish were not observed in here 1997 but were captured in 1999. It is possible that trout reproduction above the USGS gaging station may only occur every few years when water temperatures and stream flows are suitable.

Kōkeʻe Stream

Kōkeʻe Stream was not sampled during this study, as the stream is completely overgrown with ginger. However, small rainbow trout (<5 cm) were observed at a road crossing in an area where the stream was open for a short distance. Springs (with their resulting lower water temperatures) and stable stream flows appear to provide ideal trout habitat in this catchment, and a lack of freshets in this system was evidenced by the completely closed, undisturbed ginger canopy over the stream. Needham and Welsh (1953) commented that trout as long 45 cm (18 inches) were found in Kōkeʻe Stream. Removal of ginger along the stream banks could lead to the restoration of this stream as a viable recreational fishing site, and would also increase open areas with a resulting increase in perching habitats required by adults of the native *Megalagrion* damselflies.

Waiakoali Stream

Rainbow trout found in this stream were the result of upstream migration from the Mōhihi Ditch that diverts this stream at Camp 10 Road. Ditch-escaped rainbow trout were observed and captured in the summer of 1998 upstream of the point where the stream splits into two much smaller branches. This upper area was accessed by hiking upstream and then mainly swimming through deep pools for a period of 2–3 hours. However, for an unknown reason these fish do not appear to hold-over in Waiakoali Stream. By the end of the extended March 2000 trout season, rainbow trout were not observed or captured in here, even in areas far upstream of normal angling pressure. It is likely that stream temperatures may be sub-optimal in this Alakaʻi surface-water runoff stream, with rainbow trout possibly migrating downstream to the Mōhihi Ditch during unfavorable periods. Additionally, there appeared to be less riffle habitat and more large pools in this stream when compared to the others sampled during this study. It is unknown whether habitat differences resulting in lower food production because of sparse riffle habitat caused the emigration of rainbow trout from this stream to the Mōhihi Ditch, or if water temperatures in the summer are sub-optimal for this stream.

Wai‘alae Stream

Wai‘alae Stream is even more remote than Koai‘e Stream, accessible only by helicopter, or by a difficult hike or horseback ride of many hours duration. Trout densities were quite high here, and below Wai‘alae Cabin it was possible to catch small (<12 cm), naturally reproduced trout on nearly every cast. Because of a malfunctioning pH meter we were unable to infer if groundwater input occurred at Wai‘alae Stream, but as the waters are deeply tannin stained it appears there is a significant component of surface runoff from acidic bogs on the surrounding Alaka‘i Plateau. However, there must be some sizeable groundwater inputs that maintain cool year-round temperatures along this reach, because a wide range of naturally reproducing rainbow trout size classes were captured. Additionally, suitable spawning size gravels of widely varying size were found in the stream both above and below Wai‘alae Cabin. Below Wai‘alae Cabin the stream waters become noticeably clearer and less tannin stained than the upper blackwater areas of Halehaha and Halepaakai tribuataries. This is a likely result of groundwater inputs in the stream below Wai‘alae Cabin.

DISCUSSION

A. A summary of the Impacts of Rainbow Trout Introduced to Australasia and South Africa

Native to the Pacific drainages of western North America, rainbow trout have been introduced into the continents of Africa, Asia, Australasia, Europe, and South America and formed naturally reproducing populations in all of these areas (MacCrimmon 1971). An introduced species is considered to be invasive when it establishes self-maintaining populations without further stocking (Crowl et al. 1992). In the Pacific Island region (excluding Hawai‘i) trout have been unsuccessfully introduced into Fiji (Andrews 1985), Tahiti (Maciolek 1984), and New Caledonia (Gargominy et al. 1996). Brown trout (*Salmo trutta*) were introduced in 1949 to the highland region of Papua New Guinea, but it is unknown if reproducing stocks have become established; in 1952 rainbow trout did become established in this area (Werry 1998). In Papua New Guinea, the effect of rainbow trout on the native ichthyofauna appears to be minimal because rainbow trout have been stocked and only survive in high elevation (> 2000 m) areas lacking native fish (Allen 1991). Rainbow trout have also been documented to prey upon two species of endemic waterbugs, *Nesocricos mion* and *Tanycricos acumentum* in the highlands of Papua New Guinea (Polhemus and Polhemus 1985, 1986). The impacts of this predation are unknown, however these insect species still remain common enough after the introduction of trout to be used as trout bait by highland tribesman (Polhemus and Polhemus 1985).

Most research in Australia and New Zealand has focused on the impacts of introduced trout in relation to native fish, although a limited number of studies or observations have been published on impacts to invertebrates as well. The available literature regarding the impacts of trout on the invertebrate taxa of most interest to this study, Odonata, consisted of one study in Australia (Faragher 1980) and observations in

South Africa (Samways 1995, 1996, 1999). In New South Wales, a native Australian dragonfly, *Hemicordulia tau*, was found to play an important role in the diet of brown and rainbow trout in Lake Eucumbene (Faragher 1980). However, the long-term survival of the dragonfly population in Lake Eucumbene was not believed to be affected by trout predation because of seasonal changes in prey composition and density, as well as varying lake levels (Faragher 1980).

Although introduced trout did not appear to impact dragonflies in the Australian study mentioned above, in South Africa the situation appears to be different. Samways (1995, 1996, 1999) has observed that a rare and threatened damselfly (*Ecchlorolestes peringueyi*) living in clear upland streams in the southwestern Cape area may have had its range restricted by rainbow trout. This Gondwana relict damselfly was found only in streams above waterfalls that rainbow trout could not surmount, and the larvae appear to be behaviorally susceptible to trout predation as they crawl on the surfaces of rocks and plants. Other threats to this damselfly species include water diversions and habitat loss. *Ecchlorolestes peringueyi* is currently one of the eight damselflies on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List in South Africa.

Numerous studies have been conducted in Australia and New Zealand on the impacts of trout to native fishes, mainly in the family Galaxiidae. A comprehensive review of these studies can be found in Cadwallader (1996); unfortunately few of these studies have assessed the impacts of introduced trout on native aquatic insects or other stream invertebrate populations. Most of the 38 studies reviewed by Cadwallader (1996) found predation by trout to have a major impact on native fish species in Australia and New Zealand, leading to increasingly fragmented populations of endemic galaxiid fishes. Most of the studies reviewed by Cadwallader (1996) were general fish surveys not conducted to investigate the effects of salmonids on aquatic communities, however a few studies were designed to specifically investigate salmonid impacts. For example, an experimental field introduction study by Fletcher (1979, 1986) provides convincing evidence regarding the impacts of salmonids on native fishes in Victoria, Australia. This study indicated that fragmentation of native galaxiid and brown trout populations likely resulted from interspecific competition for food resources and brown trout predation. Brown trout fed selectively on the smallest *Galaxias olidus* in an experiment where brown trout were introduced above a waterfall in a section of a Victoria stream previously containing only native galaxiids (Fletcher 1986). Additionally, differences in fish diets were also examined in relation to the availability of benthic macroinvertebrates, and a significant overlap in prey items consumed was observed. Fletcher (1979) found the impacts of trout on benthic invertebrates to be uncertain during this controlled study. Some invertebrates were more common in the experimental stream reach containing trout than in the control reach, while others were found to be less common. During the study period trout predators did not influence benthic invertebrate densities, as overall densities did not vary between the two reaches (Fletcher 1979).

Other studies in Australia and New Zealand have found native fish species exhibit a fragmented distribution in the presence of rainbow and brown trout, with native species currently found in headwater regions or other habitats that trout have not yet been able to invade. In the lowland streams of New Zealand the large (up to 58 cm) *Galaxias argentus* has disappeared from habitats occupied by brown trout (McDowall 1984). Townsend and Crowl (1991) demonstrated that the presence of brown trout, rather than physical or chemical habitat differences, was responsible for the lack of *Galaxias vulgaris* in streams on New Zealand's South Island. While a large amount of evidence has accumulated from studies in Australia and New Zealand regarding the negative impacts of introduced trout on native fish (see Cadwallader 1996), few studies or even observations have been made on the impacts to invertebrates. Rainbow trout introduced into Lake Waingata, New Zealand were implicated in the decline of the freshwater koura crayfish (*Paranephrops planifrons*) and a freshwater crab species, although the effects on other benthic organisms were not investigated (Fish 1966; McDowall 1990).

While the major impacts to native fish populations from brown trout are typically believed to result from predation and/or competition (Moyle 1976; Taylor et al. 1984; Crowl et al. 1992), the primary negative impact of rainbow trout introduced into areas outside of their native range appears to be one of genetic pollution through hybridization with other native salmonid stocks (Allendorf 1988; Allendorf and Leary 1988). Rainbow trout also appear to be responsible for the decline and range contraction of native brook trout (*Salvelinus fontinalis*) in the southern Appalachian Mountains of the United States (Larson and Moore 1985). In Australasia, brown trout appeared to be more damaging than rainbow trout, and stream fish faunas were less affected by introduced trout than lake faunas, because habitat complexity in streams provides refugia for native species (Crowl et al. 1992). Although negative impacts of rainbow trout introductions into Lake Waingata, New Zealand (Fish 1966) were previously discussed, brown trout are considered a more aggressive and piscivorous fish than rainbow trout. For example, Taylor et al. (1984), in their review of impacts of introduced fish in the United States, list over 50 references regarding negative impacts of brown trout predation on the native freshwater fauna.

In summary, the situation in Hawai‘i, in which rainbow trout appear to be exerting a relatively minimal impact on the native aquatic fauna, appears to be more comparable to the situation in Papua New Guinea. In Papua New Guinea, rainbow trout are thermally restricted to highland regions lacking native fish, and they appear to have low impacts on the native aquatic fauna (Allen 1991); whereas in Australia and New Zealand brown trout, and rainbow trout to a lesser extent, have been shown to adversely impact native fish species.

B. A Brief Review of Aquatic Insect Drift and the General Impacts of Trout on Drift

Invertebrate drift is the voluntary or involuntary transport of organisms in running water. Drift is an important phenomenon that allows invertebrates to colonize disturbed stream areas and escape unfavorable conditions, and also provides food for other animals. Patterns of invertebrate drift are highly variable between different taxa, and also within different life stages of the same species (Brittain and Eikeland 1988). This downstream transport of invertebrates is not constant, but can vary by season, from day to day, and throughout the day (Townsend 1980). Diel periodicity is a nearly universal pattern found in invertebrate drift, both in temperate (Brittain and Eikeland 1988) and tropical streams (Ramirez and Pringle 1998; Dudgeon 1999). The most common diel pattern is increasing drift during the night, with the largest peak in drift occurring just after sunset. Distances traveled by aquatic insects in the drift are usually short, with most travelling from a few centimeters to several meters, although longer distances have been reported (Townsend 1980). In one study the percentage of the benthos changing their position each day by entering the drift averaged 2.6%, and ranged from 14% for a net spinning caddisfly (*Plectrocnemia conspersa*) to zero for the pea mussell, *Pisidium* sp. (Townsend and Hildrew 1976). Spates or flooding have long been recognized to increase drift rates, and frequent fluctuations in flow have less effect on invertebrate drift than a sudden flow change after periods of long, stable flow (Brittain and Eikeland 1988). Invertebrate drift has been intensively studied in temperate regions, but less so in tropical areas. Many of the general patterns in temperate streams such as diel periodicity (Benson and Pearson 1987) and seasonal fluctuations in drift are broadly similar to those found in temperate streams (Dudgeon 1999).

In tropical Pacific insular streams, and in Hawai‘i specifically, little research has been published on aquatic insect drift. Barnes and Shiozawa (1985) sampled four Hawaiian streams, only one of which was undiverted. The only aquatic insects identified in their drift study were hydropsychid larvae (*Cheumatopsyche pettiti*) and chironomid larvae; however no chironomid taxa were identified to the species level. In Hawaiian streams *C. pettiti* were found to drift in peak numbers just after sunset, while Chironomidae generally exhibited little diel behavioral drift pattern (Barnes and Shiozawa 1985). The only other available report on Hawaiian aquatic insect drift was that by Kinzie et al. (1997) in a study on the lower Wainiha River, Kaua‘i, below 215 m elevation. Only two drifting aquatic insect taxa were identified in this report, *C. bicinctus* and *C. pettiti*, both introduced taxa that comprised a substantial portion of overall drift.

The role of vertebrate predation in streams and specifically whether drift-feeding salmonids influence or regulate benthic invertebrate communities has received considerable attention and is the subject of controversy. Predominately drift feeding salmonids have been shown to have weak effects on benthic prey in some experimental studies (Allan 1982; Culp 1986; Reice and Edwards 1986), but have also been shown to have effects on certain epibenthic and drifting insects (Bechara et al. 1993; Flecker 1992; Forrester 1994).

Recently, the impacts of benthic feeding fish that feed on prey near the stream bottom have been compared to drift feeders such as salmonids that usually feed throughout the water column and at the water surface (Dahl and Greenberg 1996; Englund and Olsson 1996; Dahl 1998; Miyasaka and Nakano 1999). These studies have found predation by benthic feeding fish such as sculpins (*Cottus* spp.) can have stronger impacts on the invertebrate fauna than drift feeding brown or rainbow trout (Dahl 1998; Miyasaka and Nakano 1999). The impacts of drift feeding trout on aquatic insects should be low if the number of terrestrial animals available in the drift is great (Dahl and Greenberg 1996). This appears to be the case in Hawai‘i, because we found rainbow trout consume a substantial (47.4%) amount of terrestrial drift. Additionally, terrestrial drift should take on a greater importance in Hawaiian streams because of the paucity of native autochthonous aquatic insect production available to trout, particularly drifting insects. In Kōke‘e streams, native aquatic insects amounted to only 7.5% of rainbow trout diet, reflecting the inability of the major benthic insect groups such as mayflies, caddisflies, and stoneflies to naturally colonize Hawaiian aquatic habitats.

C. Impacts of Rainbow Trout on Native Aquatic Invertebrates in Kōke‘e State Park

A major objective of this study was to quantify the forage base and resource utilization patterns of rainbow trout in upland Kaua‘i streams. Rainbow trout are opportunistic predators and usually select the largest and most readily accessible prey (Tilzey 1977). Based on an analysis of contents from 80 individual trout stomachs, we concluded that rainbow trout in these systems are functioning primarily as opportunistic drift feeders, exploiting the steady stream of terrestrial insects and other arthropods falling into the streams from the adjacent forest. Aquatic species accounted for 52.6% of rainbow trout diet (by number), while native aquatic species amounted to only 7.5% of rainbow trout diet. The low percentage of native aquatic insects found in the trout diet reflects the low number of native aquatic insects in stream drift, a phenomenon that is likely related to the natural absence of the major orders of drifting stream insects in Hawai‘i such as Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (Howarth and Polhemus 1991). By contrast, the aquatic insect fauna in the five streams surveyed consisted mainly of native species dwelling in splash zones, which appear less prone to drift. Our analysis of stomach contents indicates that rainbow trout are instead utilizing the available and abundant terrestrial insect drift, as well as introduced aquatic insects such as larval caddisflies for their primary food source.

Native prey organisms that could potentially be impacted by rainbow trout predation in Kōke‘e State Park streams can be narrowed down to native aquatic insects and native aquatic snails. Because trout are drift feeders and aquatic snails are not normally part of the drift, trout would likely have little impact on aquatic snail populations during the course of epibenthic feeding. In the course of an extensive literature review for this project, no papers were found documenting adverse impacts by trout on aquatic snail populations.

Additionally, the lymnaeid snail identified as the native species *Errina aulacospira* in Kido et al. (1999) may be a misidentification, because both native and introduced species of freshwater snails in the family Lymnaeidae are found in Hawai'i (Cowie 1997), and it is not currently possible to identify lymnaeid snails found in Wai'alae Stream at the species level unless they represent either *Errina newcombi* or *Oligospira* spp. (R. Cowie, Bishop Museum malacologist, pers. comm.).

The areas of Kōke'e State Park containing trout are completely above the elevational range of native gobiid fish, and above the main range of the native freshwater shrimp *Atyoida bisulcata*, as shown by the complete lack of the shrimp species in benthic sampling during this study and also by Kido et al. (1999). A total of six *A. bisulcata* were collected in trout stomachs in the undiverted Koai'e and Wai'alae Streams but none collected in trout stomachs in streams diverted by the Mōhihi Ditch. It is unlikely that rainbow trout preclude *A. bisulcata* from inhabiting these high elevation streams, as surveys in pristine stream systems such as Hanawī, Maui indicate this species becomes uncommon around 885 m elevation (Englund and Polhemus 1993).

The feeding mode of rainbow trout on Kaua'i, skewed toward utilization of drifting terrestrial insects, was also noted by Needham and Welsh (1953). They found that rainbow trout diet in Kōke'e Stream consisted of 34.7% (by number) terrestrial millipedes (Needham and Welsh 1953), which is similar to the 40% we found in Koai'e and Kauaikinanā rainbow trout during the summer of 1997. This feeding mode for Kaua'i trout is not unusual, and a terrestrial diet component of up to 80% has been found for brown trout (Dahl 1998).

The major difference in rainbow trout diet analysis between this study and the Needham and Welsh study was their 33.8% (by number of individuals) representation of native *Megalagrion* damselflies in Kōke'e Stream rainbow trout. We could not effectively sample Kōke'e Stream since conditions have substantially changed when fieldwork was conducted in 1949 during the Needham and Welsh study. Ginger plants now completely obscure this small stream, and the complete shading of the stream would be expected to nearly or completely eliminate *Megalagrion* populations because they require sunny, open conditions (Polhemus and Asquith 1996). The presence of *Megalagrion* in 1949 indicates damselflies persisted in this stream even after 29 years of heavy trout stocking.

Our study, by contrast, found only 5 *Megalagrion* damselflies out of 1,596 identifiable prey items, accounting for 0.3% of rainbow trout diet. Five of the 80 (6% frequency of occurrence) rainbow trout examined during this study contained immature *Megalagrion* in their guts, with most from Wai'alae (n = 4) and one native damselfly from a trout collected in Koai'e Stream. This compares to a 13% frequency of occurrence of *Megalagrion* found in the diet of the native freshwater gobiid *Lentipes concolor* (Way and

Burky 1991). *Megalagrion* damselfly adults were abundant in the summer months in Kōke‘e State Park streams, while immatures were found in benthic samples year round.

This study also found that the introduced midge *Cricotopus bicinctus* composed a substantial (23.3% by number) portion of the stream benthic fauna and also comprised 46% of qualitative drift samples. Although it composed a dominant portion of stream drift and benthos, *C. bicinctus* comprised only 4% of trout diet, likely because this midge is small when compared to other available prey items. Likewise, the endemic midge *Forcipomyia hardyi* was the most important native component of stream drift at 14%, but was absent from trout diet. *Cricotopus bicinctus* is nearly three times the size of the native *F. hardyi* (Hardy 1960) and may either be too small for trout to notice, or its behavior may exclude it from trout habitats such as deep pool areas. These data clearly indicate that the proportional abundance of any given aquatic insect taxon does not correlate with its relative utilization by rainbow trout.

According to the classic stream ecology textbook by Hynes (1970) “If one is interested in the effect of a fish species on one particular invertebrate, say *Simulium*, the rest of the food may be of little consequence, but it is clearly necessary to count the *Simulium* in the stomachs”. This study was designed with this in mind, and as we were not interested in trout energetics, total organism counts were made to the level of highest taxonomic certainty instead of assessing the wet or ash-free dry weight of various taxa consumed by trout. As all specimens from the present study are preserved in the Bishop Museum, this latter analysis could be performed if these energetics data are deemed important sometime in the future. Hynes (1970) also stressed that stomach analysis should be made in conjunction with a thorough faunistic study, which was conducted during the course of our research. This study employed a broad array of sampling methods (see Methods section) and used a comprehensive approach when assessing invertebrate diversity in areas where trout were both present or absent.

D. Environmental Impacts of Continued Rainbow Trout Stocking in Kōke‘e State Park

Freshwater habitats, even in continental areas, are easily invaded by nonindigenous species and these invasive species are becoming an increasing environmental and economic problem throughout the world. In Hawai‘i it is clear that native stream vertebrate and invertebrate species usually do poorly in disturbed aquatic habitats, while by contrast there are also numerous examples of introduced aquatic species adapting well to undiverted or nearly pristine aquatic habitats. A selected list of nonindigenous species found in undisturbed freshwater habitats would include a species of aquatic beetle (*Rhantus gutticollis*), three species of damselflies, two species of dragonflies, numerous aquatic flies such as *Cricotopus bicinctus* or *Limonia advena*, and several caddisfly species. In Hawai‘i, it is quite probable that given the opportunity, many introduced species would thrive or at least persist in ‘pristine’ aquatic habitats that they currently are unable to access. A prime example in Hawai‘i are introduced poeciliid fishes whose upstream colonization is limited by waterfalls. For instance, poeciliids are abundant upstream of the 300 m high Hiilawe Falls on Hawai‘i Island, or Waimea Falls on O‘ahu, having apparently gained access to these streams via irrigation ditches that intersect these streams above their falls.

There is a misconception in Hawai‘i that introduced species will not become established in healthy or nearly pristine aquatic habitats as “most invading species only do well in altered habitats” (Brown et al. 1999). However, as more introduced species become established in a habitat it becomes more probable that additional introduced species will find a suitable niche (Howarth 1985). This can be through ecosystem modification by such fish as carp (*Cyprinus carpio*) and tilapia (*Sarotherodon melanotheron*) that degrade water quality, rendering habitats less suitable for native species, or it can be through predation or competition for food and habitat resources (Taylor et al. 1984). For instance, numerous species of birds, insects, snails, and other nonindigenous species are abundant even in the best-preserved high elevation native Hawaiian forests (Howarth et al. 1999), while in aquatic systems the large Tahitian prawn (*Macrobrachium lar*) is common in streams on the north shore of Moloka‘i, which are among the most pristine remaining in Hawai‘i.

Newly established species also often alter an ecosystem by either consuming the resident species or consuming the resources of resident species (Howarth 1985). The introduction of suckermouth catfish and an atyid shrimp (Englund and Cai 1999) into Hawaiian streams are noteworthy examples. The two suckermouth catfish (Loricariidae) species introduced to Hawai‘i are herbivorous (Sabaj and Englund 1999), as is a native species of freshwater goby, *Sicyopterus stimpsoni*. Extremely high densities of suckermouth catfish in certain O‘ahu streams have an obvious impact on available food and habitat resources for the native *S. stimpsoni*. Although factors such as increased sedimentation and stream urbanization are also undoubtedly related to the decline of *S. stimpsoni* on O‘ahu, this native species’ distribution is currently not sympatric with the introduced suckermouth catfish (Sabaj and Englund 1999), suggesting competitive exclusion. Predation from other introduced fish species, particularly on small returning post-larval native gobiids, also contributes to the low numbers of adult gobies observed in urban O‘ahu watersheds such as Mānoa/Pālolo or Nu‘uanu Streams.

Regardless of the mechanism, introduced aquatic species in Hawai‘i have been extremely successful even in undisturbed habitats, and in many cases have nearly or completely displaced native species from those habitats. Thus, non-native species introductions into Hawaiian waters for recreational or food purposes should be carefully evaluated and examined for potential risks to the endemic aquatic fauna.

The following section outlines potential environmental impacts from continued or renewed rainbow trout stocking within the waters of Kōke‘e State Park. According to the results of our study, the stocking of rainbow trout within Kōke‘e State Park waters would not violate the U.S. Federal Endangered Species Act because no threatened or endangered aquatic species were found or expected to be found within the areas affected by trout stocking (Table 8). Other aquatic

Table 8. Aquatic insect, mollusk, and fish species listed as Threatened, Endangered, Species of Concern, or Candidate for listing on the Federal Register (updated as of November 29, 1999), and their presence or absence in surveyed Kōke‘e State Park streams.

Species	Federal Status[1]	Distribution	Presence or Absence in Kōke‘e State Park Streams
Lentipes concolor	SOC	Hawaiian Islands	Absent
Erinna newcombi	T	Kaua‘i	Absent
Megalagrion adytum	SOC	Kaua‘i[2]	Absent
Megalagrion a. peles	SOC	Hawai‘i	n/a
Megalagrion a. waianaeanum	SOC	O‘ahu	n/a
Megalagrion molokaiense	SOC	Moloka‘i	n/a
Megalagrion nigrohamatum	SOC	Maui, Moloka‘i	n/a
Megalagrion oahuense	SOC	O‘ahu	n/a
Megalagrion leptodemas	C	O‘ahu	n/a
Megalagrion nesiotes	C	Maui	n/a
Megalagrion nigrolineatum	C	O‘ahu	n/a
Megalagrion oceanicum	C	O‘ahu	n/a
Megalagrion pacificum	C	Maui, Moloka‘i, Hawai‘i, (extinct on Kaua‘i)	Absent
Megalagrion xanthomelas	C	O‘ahu, Maui, Moloka‘i, Hawai‘i, (extinct on Kaua‘i)	Absent

[1]Species status: **E** = Endangered; **T** = Threatened; **C** = Candidate for listing; **SOC** = species of concern (USFWS 1999). [2]This species is mainly found in Mt. Wai‘ale‘ale swamp area in low ohia bog forests

candidate species and species of concern on the Federal Register (Table 8) also were not observed within Kōke‘e State Park streams. The threatened Newcomb’s Snail (*Erinna newcombi*), and two other species of concern, *Lentipes concolor* and *Megalagrion adytum*, were not observed or are not likely to be found in areas of overlapping distribution with rainbow trout in Kōke‘e State Park.

Impacts to Newcomb’s Snail

Generally found at lower elevations, the threatened *Erinna newcombi* was not observed or collected in any of the Kōke‘e streams sampled, although it is possible it could be found at the high elevations targeted by this study. Habitat use by *Erinna newcombi* differs from that of rainbow trout, and habitat requirements of rainbow trout and Newcomb’s snail appear to be mutually exclusive. According to the U.S. Fish & Wildlife Service (2000): “specific habitat requirements of Newcomb’s snail include fast flowing perennial streams with stable overhanging rocks, springs, rock seeps, and waterfalls. Surveys of main stream channels of many of the perennial streams of Kaua‘i indicate that Newcomb's snail is rarely found in these main channels". The limited occurrence of this snail in the main stream channel is believed to be related to heavy scouring storm flows typical of Kaua‘i streams, and available habitat is usually smaller feeder streams, seeps and waterfalls (USFWS 2000). Rainbow trout are anticipated to have no impacts to this Federally threatened snail species because rainbow trout are found in the main channel area of streams, and Newcomb's snails were not observed in any of the surveyed habitats in Kōke‘e State Park, including rheocrenes, seeps, springs, and waterfall areas carefully examined during these surveys.

Impacts to Native Damselflies

Unlike amphidromous animals such as native stream fish and shrimp, native aquatic damselflies and other native aquatic insects complete the immature stage of their life cycles entirely within streams or other freshwater ecosystems. Until recently, native endemic *Megalagrion* damselflies were common in virtually every such ecosystem throughout the Hawaiian Islands, being found from slightly brackish basal spring wetlands near the ocean to upland springs, seeps, rheocrenes, and riverine habitats, exploiting a full range lotic and lentic habitats (Polhemus and Asquith 1996). Immature damselflies in Hawai‘i occupy all aquatic habitats, including fast-velocity riffles and terrestrial leaf litter habitats (Simon et al. 1984), while most species elsewhere in the world prefer slower-velocity areas in lakes and streams. In recent decades, however, a combination of alien species introductions, stream channelization and diversion, and water quality degradation has caused a significant reduction or local extirpation of many native damselfly populations throughout Hawai‘i (Polhemus and Asquith 1996, Englund 1999). Because Hawaiian streams differ from larger continental stream systems in that longitudinal movement of native aquatic insects occurs primarily during the aerial adult stage, rather than as upstream migration or downstream drift, the local extirpation of species within Hawaiian watersheds can often be persistent.

Two primary ecological requirements for native damselflies are good water quality (clear, low turbidity water) and the absence of certain alien fish species such as tilapia (*Sarotherodon melanotheron*) and members of the family Poeciliidae. In particular, native damselflies are sensitive to the presence of introduced poeciliid fishes such as the green swordtail (*Xiphophorus helleri*) or the shortfin molly (*Poecilia mexicana*) (Englund 1999). Extensive surveys on O‘ahu have determined that the distributions of introduced Poeciliidae, including green swordtails, mollies and guppies (*Poecilia reticulata*), show a negative correlation with those of *Megalagrion* damselflies (Englund 1999), indicating a negative interaction between the two groups. A similar strongly allopatric distribution pattern was not found between introduced rainbow trout and native damselflies (or any other aquatic insect taxon) in the Kōke‘e State Park streams examined during this study.

The following section provides a brief description of habitat requirements for native damselfly species found in streams surveyed for this report. None of the native damselflies found in this survey are considered rare, and none are among the six species listed on the Federal Register as candidate Threatened or Endangered species.

Frosty Hawaiian Damselfly (*Megalagrion eudytum*)

The immatures of this species are found only on sheer waterfall faces, or vertical moss covered seep faces, and during this study were found only in Koaiʻe Stream. The breeding habitat needs are sheer vertical drops of > 2 m; small seeps or cascades do not appear to be suitable. This damselfly remains common throughout Kauaʻi; *Megalagrion eudytum* exhibits a wide elevational range being found from near sea level (Filbert and Englund 1995) to at least 1220 m elevation, as found in this study. *Megalagrion eudytum* were not recovered in any trout stomachs, probably because of their habitat preference for sheer waterfall faces.

Kauaʻi Mountain Damselfly (*Megalagrion heterogamias*)

Megalagrion heterogamias is the most abundant damselfly in the Kōkeʻe State Park area and is the most conspicuous and common stream-dwelling damselfly on Kauaʻi (Polhemus and Asquith 1996). The immatures of this species dwell strictly in the main stream channel, in fast water run, riffle, and cascade habitats, and adults were mainly observed flying around these areas. Five *M. heterogamias* were recovered from 1,596 identifiable prey items found in 80 rainbow trout stomachs. Rainbow trout were primarily found in slower water habitats of the streams we assessed, while the larvae of *M. heterogamias* generally inhabit faster water riffle and cascade habitats. Apparently the limited trout predation observed on *M. heterogamias* occurs when immatures become dislodged from their preferred fast-water habitats and enter the water column. Along with its sharply pointed lanceolate gills, the current study provided further evidence immatures of this species prefer riffle habitats, because *M. heterogamias* was one of the few native species collected in the benthos of riffles.

Scarlet Kauaʻi Damselfly (*Megalagrion vagabundum*)

This damselfly was the second most common damselfly observed in this study and was abundant. Adult *Megalagrion vagabundum* were commonly observed around seeps and mossy areas, and occasionally slow-water stream areas. None were found in rainbow trout stomachs, probably because seep habitats are favored by the immatures (Polhemus and Asquith 1996).

Slender Kauaʻi Damselfly (*Megalagrion oresitrophum*)

This damselfly was abundant during this study, being found mainly in slack sidewater pools, and stream side-channel habitats. Adults of this species were also found in calm side tributaries away from the main stream channel. *Megalagrion oresitrophum* would appear to be the native damselfly species at the greatest risk from rainbow trout predation, as both species prefer pools. However, none were found in rainbow trout stomachs, which is somewhat surprising because there appears to be an obvious overlap in preferred habitat between rainbow trout and immature *M. oresitrophum.*

Impacts of Trout to *Telmatogeton*, and *Sigmatineurum*, Sensitive Native Aquatic Species

Native aquatic diptera such as species in the endemic genera *Sigmatineurum* and *Telmatogeton* are sensitive to environmental disturbance (Evenhuis and Polhemus 1994; Benbow et al. 1997; Englund and Preston 1999; Benbow 1999). Specific habitat requirements for these native Diptera are quite narrow, and include high water velocity sections of riffles, cascades, and waterfalls. Evenhuis and Polhemus (1994) found that adults of *Sigmatineurum* were tightly restricted to riparian microhabitats consisting of wet, shaded, vertical bedrock exposures next to small splashing waterfalls in areas of mesic forest. In Hanawī Stream, Maui, adults preferred vertical wet bedrock walls in the splash zone of small cascades (Englund and Polhemus 1993). Presumably, a reduction in habitat caused by water diversions and increased sedimentation has restricted the range of species such as *Sigmatineurum binodatum*, an Oʻahu species last collected in the 1930's (Evenhuis 1997), and other *Telmatogeton* species found on Oʻahu (Polhemus 1995), Kauaʻi, and in many other localities throughout the Hawaiian Islands.

Sigmatineurum species were generally thought to be restricted to areas above 600 m elevation (Evenhuis and Polhemus 1994), however, this may be more an artifact of these higher elevation areas still containing undiverted stream flow. The recent finding (Englund and Preston 1999) of an undescribed *Sigmatineurum* species at elevation of only 90 m above sea-level in undiverted Waimanu Stream, Hawaiʻi Island, indicates that species in this genus may have formerly been more common in low elevation areas. Further evidence for this hypothesis comes from surveys on Hawaiʻi Island where *Sigmatineurum* spp. were not found below the Lower Hamakua Ditch water diversions (Englund and Filbert 1997).

In contrast to other areas surveyed on Kauaʻi (see Evenhuis and Polhemus 1994; Polhemus 1995), *Sigmatineurum* were common in Kōkeʻe streams with and without trout populations. *Sigmatineurum napali* should be considered one of the native aquatic insects most sensitive to disturbance, yet high numbers were found in two streams (Waiʻalae and Koaiʻe) with naturally reproducing populations of rainbow trout, and none were found in rainbow trout stomachs. Waiʻalae, Koaiʻe and Kawaikōī Streams appear to have a more robust population of *Sigmatineurum* than other areas sampled in the Hawaiian Islands, and during this study several hundred *S. napali* were captured along these streams. Prior to the present study, only five individual *S. napali* from Hanakoa and Hanakāpī‘ai Streams had been collected (Evenhuis and Polhemus 1994), despite extensive Kaua‘i surveys by the authors of the present study. Populations of *Sigmatineurum* flies are generally quite small, and it can take an entire day of sampling to capture 10 individuals (Evenhuis and Polhemus 1994) in areas outside of Kōke‘e State Park.

Hawai‘i has the distinction of having the only freshwater *Telmatogeton* in the world (Hardy 1960), with five endemic species in this genus evolved from ancestors inhabiting wave-swept coastal areas, forming one of most distinctive components of Hawaii's stream fauna. In coastal areas of Hawai‘i, marine *Telmatogeton* form an important food source for reef fish (Hardy 1960). In freshwater areas, the large white pupal cases 12–16 mm long (Wirth 1947) are easily observed in the splash-zones of high gradient riffles and cascades. Recently, however, there appears to have been a general decline in *Telmatogeton* populations when compared to locations this genus has been documented from in the past, based on records from the Bishop Museum (Nishida 1997) or in the historic scientific literature (Williams 1944; Wirth 1947; Hardy 1960). Despite intensive island-wide stream surveys starting in the late 1980s by the authors of this report, only two streams on O‘ahu are currently known to contain *Telmatogeton* (Polhemus 1995; Nishida 1997). Because of their specific habitat requirements for clear, cool water and an undisturbed environment, *Telmatogeton* are considered to be one of the Hawaiian aquatic species most sensitive to disturbance (Benbow et al. 1997; Benbow 1999).

The status of *Telmatogeton* on Kaua‘i may also be declining, although this island was far less intensively sampled than O‘ahu by entomologists in the early 1900s. Needham and Welsh (1953) documented the abundance of *Telmatogeton hirtus* in the lower Waimea River, but found none in the upper Kōke‘e streams, even though such streams are the upper tributaries of the Waimea River. This contrasts with the present study where two adult *Telmatogeton* sp. (prob. *hirtus*) were found in one individual trout collected in Koai‘e Stream. The long white silk cases of *Telmatogeton* were also observed in the splash-zone of the waterfalls located below the USGS gaging station at Koai‘e Stream, at an elevation of 1113 m. The continued presence of *Telmatogeton* within Koai‘e Stream, further indicates the high native biodiversity of the aquatic fauna found in this catchment, despite the fact that this stream has supported naturally reproducing trout populations for over 70 years. Trout predation on adult *Telmatogeton* probably has little impact on this species, because all life stages live in areas inaccessible to trout. The individuals found in trout stomachs from Koai‘e Stream were likely either dead in the drift or had been accidentally dislodged into the main stream channel from their preferred cascade habitat.

Continued Rainbow Trout Stocking in Puu Lua Reservoir and Irrigation Ditches

No measurable environmental impacts to Federally Threatened or Endangered native aquatic species are anticipated to occur because of continued stocking in Puu Lua Reservoir or the irrigation ditches flowing out from the reservoir. These artificial aquatic habitats lack sensitive native species that may be impacted by introduced rainbow trout. Rainbow trout washed downstream from the ditches will either perish in agricultural fields or eventually die from thermal stresses of the warmer water in low-elevation areas. Evidence of the rainbow trout's limited thermal tolerance and capacity to survive in high elevation Kōke'e State Park streams was found during this study. Rainbow trout only survived and naturally reproduced in a limited number of spring-fed streams in the uppermost elevations of Kōke'e State Park, such as Kauaikinanā Stream, but did not reproduce or hold-over in the adjacent Kawaikōī and Waiakoali Streams. Rainbow trout washed down from the ditch system into lower elevation streams and reservoirs would also soon perish because of predation from more aggressive introduced gamefish such as tucanare (*Cichla ocellaris*), smallmouth bass (*Micropterus dolomieui*) and largemouth bass (*Micropterus salmoides*).

Impacts of Renewed Stocking within Kōke'e State Park Streams

Because we have found no measurable impacts of rainbow trout on the biodiversity of the aquatic insect fauna in streams surveyed during this study, we conclude that a renewal of the put-and-take fishery that existed prior to 1992 would not adversely impact native invertebrate aquatic species. After examining 80 rainbow trout stomachs collected between 1997–1999 we have found no evidence that either stocked or naturally reproducing rainbow trout impact or even prey upon Federally Endangered aquatic species, or sensitive native aquatic species currently not listed on the Federal Register. Rainbow trout maintain a precarious existence in Kaua'i streams, persisting only in streams with the proper hydrological and geomorphological conditions. Kōke'e State Park streams at the identical high elevation of 1035 m and less than a 1 km apart (such as Kauaikinanā and Kawaikōī Streams) varied in their ability to support trout. Contrary to the findings of Kido et al. (1999), we found that stocked trout do not survive even in many upper elevation areas of Kōke'e State Park streams and therefore cannot impact native biota in low-elevation areas.

The lower Waimea River receives stream flow from the upper elevation Kōke'e tributaries we assessed during this study, but was not within the scope of the present study. Needham and Welsh (1953) intensively surveyed the lower Waimea River between 300–460 m elevation in 1949, and only found native gobiid fish. Rainbow trout were not found in the Waimea River by Needham and Welsh (1953) despite the fact that intensive stocking was taking place in upstream Kōke'e tributaries during their study, and they surmised trout would not survive the impacts of the many large waterfalls. Temperatures as high as 25.5°C (78° F) also likely rendered the lower Waimea River unsuitable for the long-term survival of rainbow trout.

This study found that reproducing strains of rainbow trout already exist in Kōkeʻe, Kauaikinanā, Koaiʻe, and Waiʻalae Streams, and there seems to be no need to restock these streams. It would be most cost-effective to avoid restocking these streams with domesticated trout that are unlikely to survive. The out-migration or mortality of ditch-escaped trout from Waiakoali Stream in the winter of 2000 indicates hatchery trout poorly adjust to wild stream conditions. We would caution that the stocking of any introduced aquatic species in Hawaiian waters carries certain risks; such as the introduction of parasites to native species, the transfer of the stocked organism into other watersheds by anglers or irrigation ditches, and other potential unforeseen impacts to native species. The continuation of the rainbow trout stocking program should be in agreement with the overall DLNR policy regarding nonindigenous species. However, because we found that rainbow trout reproduce and hold-over only in high elevation sections of certain Kōkeʻe streams, and feed primarily on terrestrial drift, we conclude that the impacts and risks, if any, to native species as a result of the continued presence of trout in these catchments are relatively minor.

Impacts of No Renewed Stocking within Kōkeʻe State Park Streams

Rainbow trout would continue to naturally reproduce and be found in Kōkeʻe State Park streams if stocking was discontinued. If stocking was discontinued in the Mōhihi Ditch system and trout no longer escaped from the reservoir into the ditch system, trout would still persist in at least four widely separated upper Kōkeʻe State Park watersheds: the Kōkeʻe, Kauaikinanā, Koaiʻe, and Waiʻalae systems. Thus, discontinuing stocking would not adversely impact these stream populations. Maintaining the present status quo of not stocking streams such as Kawaikōī or Waiakoali Streams would maintain the current fishless states of these streams, with the exception of introduced green swordtails and dojo loaches which are found only in limited areas.

The only way to restore these watersheds to a more natural system would be to use a chemical piscicide (fish poison) such as rotenone. Although the rugged terrain of Kōkeʻe State Park would make rainbow trout removal difficult, it would likely be possible, although prohibitively expensive. Not only would the extensive use of helicopters be required, but many repeated treatments of the selected piscicide would be needed. Such a program would also likely be unpopular; according to a recent review of the use of rotenone in North America from 1988–1997, public acceptance was one of the most important issues facing management agencies when using rotenone (McClay 2000). Rotenone is also toxic to arthropods and was originally used as an insecticide prior to the use of synthetic chemicals (Hynes 1970). Potential non-target impacts of the large-scale use of rotenone in Kōkeʻe streams could be the potential extirpation of locally common endemic aquatic insect species with ranges restricted to upper elevation areas, such as *Sigmatineurum napali* and other rare native aquatic insects and crustaceans. Large-scale use of an alternative antibiotic piscicide, antimycin (Fintrol), may have somewhat lesser non-target effects on aquatic arthropods but would be a much more expensive and less practical alternative to rotenone. Similar to rotenone, antimycin kills aquatic animals by inhibiting respiration, but would be less effective in Hawaiian conditions that include high water temperatures or areas of higher pH (Nielsen and Johnson 1983). In Kōke‘e Streams rainbow trout were most common in spring areas having a pH of up to 7.9.

We see four major problems with the complete or partial removal of trout from Kōke‘e streams where naturally reproducing populations are maintained: 1) a piscicide would not eliminate other introduced aquatic fauna found in these watersheds. Thus restoring these streams to a completely native state is currently not feasible; 2) a piscicide, particularly rotenone, would definitely have non-target impacts on native aquatic arthropods, while antimycin would have lesser but unpredictable impacts on native arthropods; 3) according to the results of our study, the removal of rainbow trout would not measurably enhance the native aquatic fauna of these streams. Kawaikōī Stream (with the exception of a 50 m section near the Mōhihi Ditch) has not had rainbow trout stocked since 1992. Even so, the native aquatic fauna in Kawaikōī Stream above areas from which rainbow trout are unable to access is not different from that of Koai‘e, Kauaikinanā, or Wai‘alae Streams, all of which have naturally reproducing rainbow trout populations. Other streams lacking stocked rainbow trout, such as the upper Hanalei, also have similarly high percentages and numbers of native aquatic insect species (Polhemus 1995); 4) the chemical treatment of Kōke‘e State Park streams to remove rainbow trout would face nearly unanimous opposition from anglers on Kaua‘i and throughout Hawai‘i. If the streams were restored to their formerly fishless state, it is almost certain these streams would be clandestinely restocked with rainbow trout by anglers.

Although the scope of this study does not cover the economics of the rainbow trout fishery on Kaua‘i, we conclude that the removal of rainbow trout from Kōke‘e State Park streams would be cost-ineffective and difficult, and could lead to the local extinction of rare endemic aquatic insects because fish poisons are also toxic to native aquatic insects. As previously discussed (See Discussion, Impacts to Native Damselflies), the local extirpation of aquatic species within a Hawaiian watershed is often permanent and has been frequently documented from Bishop Museum records (Liebherr and Polhemus 1997; Englund 1999).

Rainbow trout appear to have low impacts on native aquatic fauna, and the streams assessed during this study containing naturally reproducing rainbow trout exhibited the highest biological diversity of native aquatic invertebrate species of any streams yet sampled in the Hawaiian Islands. Elimination of rainbow trout in Kōke‘e State Park streams would therefore be unlikely to result in the restoration of a single native aquatic species not already present. Unless extreme actions are taken to remove rainbow trout, there will continue to be naturally reproducing populations in the upper elevation areas of certain Kōke‘e streams. A seemingly reasonable course of action might be to manage this low impact fishery in a manner determined by the Hawaii Division of Aquatic Resources for the benefit of local anglers. Given the marginal existence of the Kōke‘e trout populations, it seems likely that these limited naturally reproducing trout populations will decline over time in any event in response to normal variations in temperature and discharge rate typical of Hawaiian stream environments.

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APPENDICES

APPENDIX A- Stomach Contents of Individual Rainbow Trout Collected in Kōkeʻe State Park Streams

TROUT GUT Totals

		Total
Trout Number:	**1 Koaie**	
Phylum: Annelida		
Order: Oligochaeta		
Family:		
Oligochaeta (Unknown) -- Aquatic		6
Phylum: Arthropoda		
Order: Homoptera		
Family: Cixiidae		
Oliarus sp (Endemic) -- Terrestrial		1
Order: Hymenoptera		
Family: Apidae		
Apis mellifera (Purposely Introduced) -- Terrestrial		1
Order: Orthoptera		
Family: Gryllidae		
Gryllus bimaculatus (Introduced) -- Terrestrial		1
Phylum: Mollusca		
Order: Lymnaeoidea		
Family: Lymnaeidae		
Lymnaeidae sp (Unknown) -- Aquatic		4
Trout Number:	**2 Koaie**	
Phylum: Arthropoda		
Order: Odonata		
Family: Aeshnidae		
Anax strenuus (Endemic) -- Aquatic		1
Order: Polydesmida		
Family: Paradoxosomatidae		
Oxidus gracilis (Introduced) -- Terrestrial		10
Trout Number:	**3 Koaie**	
Phylum: Annelida		
Order: Arhynchobdellida		
Family: Erpobdellidae		
Barbronia weberi formosana (Introduced) -- Aquatic		9
Order: Oligochaeta		
Family:		
Oligochaeta (Unknown) -- Aquatic		2
Phylum: Arthropoda		
Order: Odonata		
Family: Aeshnidae		
Anax strenuus (Endemic) -- Aquatic		3

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 2

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 2

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial 2

Trout Number: __4__ **Koaie**

Phylum: Arachnida

Order: Aranae

Family: Tetragnathidae

Tetragnatha sp (Endemic) -- Terrestrial 1

Phylum: Arthropoda

Order: Isopoda

Family: Porcellionidae

Porcellio laevis (Introduced) -- Terrestrial 1

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic) -- Aquatic 1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 5

Order: Spirostreptida

Family: Cambalidae

Nannolene sp (Endemic) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial 3

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 4

Trout Number: __5__ **Koaie**

Phylum: Arthropoda

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic) -- Aquatic 1

Trout Number: **6** **Koaie**

Phylum: Arthropoda
Order: Homoptera
Family: Cixiidae
Oliarus sp (Endemic) -- Terrestrial 1
Order: Polydesmida
Family: Paradoxosomatidae
Oxidus gracilis (Introduced) -- Terrestrial 6
Order: Trichoptera
Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Trout Number: **7** **Koaie**

Phylum: Annelida
Order: Arhynchobdellida
Family: Erpobdellidae
Barbronia weberi formosana (Introduced) -- Aquatic 2
Phylum: Arthropoda
Order: Lepidoptera
Family:
Lepidoptera (Unknown) -- Terrestrial 1
Order: Polydesmida
Family: Paradoxosomatidae
Oxidus gracilis (Introduced) -- Terrestrial 1
Phylum: Mollusca
Order: Lymnaeoidea
Family: Lymnaeidae
Lymnaeidae sp (Unknown) -- Aquatic 4

Trout Number: **8** **Koaie**

Phylum: Arthropoda
Order: Coleoptera
Family: Nitidulidae
Gonioryctus kauaiensis (Endemic) -- Terrestrial 1
Order: Lepidoptera
Family:
Lepidoptera (Unknown) -- Terrestrial 1
Order: Odonata
Family: Aeshnidae
Anax strenuus (Endemic) -- Aquatic 2
Order: Polydesmida
Family: Paradoxosomatidae
Oxidus gracilis (Introduced) -- Terrestrial 12

Order: Spirostreptida		
Family: Cambalidae		
Nannolene sp (Endemic) -- Terrestrial		1

Trout Number: **9** **Koaie**

Phylum: Arthropoda	
Order: Coleoptera	
Family: Staphylinidae	
Staphylinidae (Unknown) -- Terrestrial	1
Thyreocephalus albertisi (Purposely Introduced) --	1
Order: Diptera	
Family: Chironomidae	
Telmatogeton sp (Endemic) -- Aquatic	2
Family: Tipulidae	
Tipulidae (Unknown) -- Aquatic	1
Order: Homoptera	
Family:	
Homoptera (Unknown) -- Terrestrial	1
Order: Hymenoptera	
Family: Apidae	
Apis mellifera (Purposely Introduced) -- Terrestrial	8
Order: Polydesmida	
Family: Paradoxosomatidae	
Oxidus gracilis (Introduced) -- Terrestrial	53
Order: Trichoptera	
Family: Hydropsychidae	
Cheumatopsyche pettiti (Introduced) -- Aquatic	1
Phylum: Mollusca	
Order: Lymnaeoidea	
Family: Lymnaeidae	
Lymnaeidae sp (Unknown) -- Aquatic	2

Trout Number: **10** **Koaie**

Phylum: Annelida	
Order: Arhynchobdellida	
Family: Erpobdellidae	
Barbronia weberi formosana (Introduced) -- Aquatic	13
Phylum: Arthropoda	
Order: Diptera	
Family: Muscidae	
Muscidae (Unknown) -- Terrestrial	1
Order: Lepidoptera	
Family: Crambidae	
Crambidae (Unknown) -- Terrestrial	1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 3

Phylum: Mollusca

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 4

Trout Number: **11** **Koaie**

Phylum: Arthropoda

Order: Coleoptera

Family: Dytiscidae

Rhantus pacificus (Endemic) -- Aquatic 1

Order: Isopoda

Family: Porcellionidae

Porcellio laevis (Introduced) -- Terrestrial 1

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic) -- Aquatic 2

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 2

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial 2

Trout Number: **12** **Koaie**

Phylum: Arthropoda

Order: Coleoptera

Family: Dytiscidae

Rhantus pacificus (Endemic) -- Aquatic 2

Order: Hymenoptera

Family: Apidae

Apis mellifera (Purposely Introduced) -- Terrestrial 1

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic) -- Aquatic 2

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 10

Trout Number: **13** **Koaie**

Phylum: Arthropoda
Order: Coleoptera
Family:
Alleculidae (Pseudocistela kauaiensis) -- Terrestrial 1
Family: Elateridae
Elateridae (Eopenthes muticus) -- Terrestrial 1
Order: Heteroptera
Family: Nabidae
Nabis sharpianus (Endemic) -- Terrestrial 1
Order: Homoptera
Family: Cixiidae
Oliarus sp (Endemic) -- Terrestrial 1
Order: Orthoptera
Family:
Orthoptera (Unknown) -- Terrestrial 1
Order: Polydesmida
Family: Paradoxosomatidae
Oxidus gracilis (Introduced) -- Terrestrial 13
Order: Spirostreptida
Family: Cambalidae
Nannolene sp (Endemic) -- Terrestrial 2
Order: Trichoptera
Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 2

Trout Number: **14** **Koaie**

Phylum: Arachnida
Order: Aranae
Family: Tetragnathidae
Tetragnatha sp (Endemic) -- Terrestrial 1
Phylum: Arthropoda
Order: Homoptera
Family: Cixiidae
Oliarus sp (Endemic) -- Terrestrial 1
Order: Isopoda
Family: Porcellionidae
Porcellio laevis (Introduced) -- Terrestrial 2
Order: Lepidoptera
Family: Crambidae
Crambidae (Unknown) -- Terrestrial 1
Order: Odonata
Family: Aeshnidae
Anax strenuus (Endemic) -- Aquatic 3
Order: Polydesmida
Family: Paradoxosomatidae

	Oxidus gracilis (Introduced) -- Terrestrial	2
Order:	Spirostreptida	
Family:	Cambalidae	
	Nannolene sp (Endemic) -- Terrestrial	1
Phylum:	Mollusca	
Order:	Lymnaeoidea	
Family:	Lymnaeidae	
	Lymnaeidae sp (Unknown) -- Aquatic	1

Trout Number: **15 Koaie**

Phylum:	Arthropoda	
Order:	Heteroptera	
Family:	Veliidae	
	Microvelia vagans (Endemic) -- Aquatic	2
Order:	Homoptera	
Family:	Cixiidae	
	Oliarus sp (Endemic) -- Terrestrial	2
Order:	Lepidoptera	
Family:		
	Lepidoptera (Unknown) -- Terrestrial	1
Order:	Odonata	
Family:	Aeshnidae	
	Anax strenuus (Endemic) -- Aquatic	2
Order:	Polydesmida	
Family:	Paradoxosomatidae	
	Oxidus gracilis (Introduced) -- Terrestrial	5
Order:	Trichoptera	
Family:	Hydropsychidae	
	Cheumatopsyche pettiti (Introduced) -- Aquatic	2
Phylum:	Mollusca	
Order:	Lymnaeoidea	
Family:	Lymnaeidae	
	Lymnaeidae sp (Unknown) -- Aquatic	1

Trout Number: **16 Koaie**

Phylum:	Arthropoda	
Order:	Odonata	
Family:	Aeshnidae	
	Anax strenuus (Endemic) -- Aquatic	3
Order:	Polydesmida	
Family:	Paradoxosomatidae	
	Oxidus gracilis (Introduced) -- Terrestrial	34
Order:	Spirostreptida	
Family:	Cambalidae	
	Nannolene sp (Endemic) -- Terrestrial	9

Trout Number:	**<u>17</u> Koaie**	
Phylum: Arthropoda		
Order: Coleoptera		
Family: Hydrophilidae		
Hydrophilidae (Unknown) -- Aquatic		2
Order: Hymenoptera		
Family: Apidae		
Apis mellifera (Purposely Introduced) -- Terrestrial		1
Order: Lepidoptera		
Family: Geometridae		
Scotorythra sp (Endemic) -- Terrestrial		1
Order: Odonata		
Family: Coenagrionidae		
Megalagrion heterogamias (Endemic) -- Aquatic		1
Order: Polydesmida		
Family: Paradoxosomatidae		
Oxidus gracilis (Introduced) -- Terrestrial		5
Order: Spirostreptida		
Family: Cambalidae		
Nannolene sp (Endemic) -- Terrestrial		1

Trout Number:	**<u>18</u> Koaie**	
Phylum: Arachnida		
Order: Aranae		
Family: Tetragnathidae		
Tetragnatha sp (Endemic) -- Terrestrial		2
Phylum: Arthropoda		
Order: Blattodea		
Family: Blattidae		
Periplaneta sp (Introduced) -- Terrestrial		1
Order: Coleoptera		
Family: Dytiscidae		
Rhantus pacificus (Endemic) -- Aquatic		1
Order: Decapoda		
Family: Atyidae		
Atyoida bisulcata (Endemic) -- Aquatic		1
Order: Diptera		
Family: Dolichopodidae		
Dolichopodidae (Unknown) -- Aquatic		1
Family: Ephydridae		
Scatella kauaiensis (Endemic) -- Aquatic		1
Family: Muscidae		
Muscidae (Unknown) -- Terrestrial		1
Order: Heteroptera		

Family:
Heteroptera (Unknown) -- Terrestrial 2

Family: Lygaeidae
Lygaeidae (Unknown) -- Terrestrial 1

Family: Pentatomidae
Oechalia sp (Endemic) -- Terrestrial 1

Family: Saldidae
Saldula exulans (Endemic) -- Aquatic 1

Order: Homoptera

Family: Cixiidae
Oliarus sp (Endemic) -- Terrestrial 1

Order: Hymenoptera

Family: Apidae
Apis mellifera (Purposely Introduced) -- Terrestrial 1

Order: Isopoda

Family: Porcellionidae
Porcellio laevis (Introduced) -- Terrestrial 1

Order: Lepidoptera

Family:
Lepidoptera (Unknown) -- Terrestrial 3

Family: Cosmopterigidae
Hyposmocoma sp (Endemic) -- Aquatic 1

Order: Polydesmida

Family: Paradoxosomatidae
Oxidus gracilis (Introduced) -- Terrestrial 13

Order: Trichoptera

Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 9

Phylum: Mollusca

Order: Lymnaeoidea

Family: Lymnaeidae
Lymnaeidae sp (Unknown) -- Aquatic 5

Trout Number: **19** **Kauaikinana**

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae
Barbronia weberi formosana (Introduced) -- Aquatic 1

Phylum: Arthropoda

Order: Heteroptera

Family: Cydnidae
Geotomus pygmaeus (Introduced) -- Terrestrial 1

Order: Homoptera

Family: Cixiidae
Oliarus sp (Endemic) -- Terrestrial 1

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial	2
Family: Crambidae	
Crambidae (Unknown) -- Terrestrial	4
Family: Geometridae	
Scotorythra sp (Endemic) -- Terrestrial	1
Order: Odonata	
Family: Aeshnidae	
Anax strenuus (Endemic) -- Aquatic	3
Order: Trichoptera	
Family: Hydropsychidae	
Cheumatopsyche pettiti (Introduced) -- Aquatic	1

Trout Number: **<u>20</u> Kauaikinana**

Phylum: Arthropoda	
Order: Amphipoda	
Family: Talitridae	
Talitroides topitotum (Introduced) -- Terrestrial	1
Order: Hymenoptera	
Family: Apidae	
Apis mellifera (Purposely Introduced) -- Terrestrial	2
Order: Lepidoptera	
Family:	
Lepidoptera (Unknown) -- Terrestrial	1
Order: Orthoptera	
Family: Gryllidae	
Tettigoniidae (Unknown) -- Terrestrial	1
Order: Polydesmida	
Family: Paradoxosomatidae	
Oxidus gracilis (Introduced) -- Terrestrial	1
Order: Psocoptera	
Family: Psocidae	
Psocidae (Endemic) -- Terrestrial	1
Order: Spirostreptida	
Family: Cambalidae	
Nannolene sp (Endemic) -- Terrestrial	1
Order: Trichoptera	
Family: Hydropsychidae	
Cheumatopsyche pettiti (Introduced) -- Aquatic	4

Trout Number: **<u>21</u> Kauaikinana**

Phylum: Arthropoda	
Order: Amphipoda	
Family: Talitridae	
Talitroides topitotum (Introduced) -- Terrestrial	1
Order: Coleoptera	
Family: Elateridae	

Elateridae (Unknown) -- Terrestrial 1

Order: Heteroptera

Family: Reduviidae

Haematolocha rubescens (Introduced) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 29

Trout Number: **22 Kauaikinana**

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana (Introduced) -- Aquatic 1

Phylum: Arthropoda

Order: Diptera

Family: Chironomidae

Cricotopus bicinctus (Introduced) -- Aquatic 1

Order: Hymenoptera

Family: Apidae

Apis mellifera (Purposely Introduced) -- Terrestrial 1

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial 1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 1

Trout Number: **23 Kauaikinana**

Phylum: Arthropoda

Order: Diptera

Family: Chironomidae

Cricotopus bicinctus (Introduced) -- Aquatic 5

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Trout Number: **24 Kauaikinana**

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana (Introduced) -- Aquatic 1

Phylum: Arthropoda

Order: Isopoda

Family: Porcellionidae

Porcellio laevis (Introduced) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 6

Family: Hydroptilidae

Oxyethira maya (Introduced) -- Aquatic 1

Trout Number: **<u>25</u> Kauaikinana**

Phylum: Acari

Order: Oribatida

Family: Phthiracaridae

Phthiracarus sp (Unknown) -- Terrestrial 1

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana (Introduced) -- Aquatic 2

Phylum: Arthropoda

Order: Diptera

Family: Tipulidae

Tipulidae (Unknown) -- Aquatic 1

Order: Isopoda

Family: Porcellionidae

Porcellio laevis (Introduced) -- Terrestrial 1

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial 1

Order: Spirostreptida

Family: Cambalidae

Nannolene sp (Endemic) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 6

Trout Number: **<u>26</u> Kauaikinana**

Phylum: Arachnida

Order: Aranae

Family: Tetragnathidae

Tetragnatha sp (Endemic) -- Terrestrial 1

Phylum: Arthropoda

Order: Amphipoda

Family: Talitridae

Talitroides topitotum (Introduced) -- Terrestrial 16

Order: Coleoptera

Family:

Coleoptera (Unknown) -- Terrestrial 1

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial 1

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic) -- Aquatic 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 10

Phylum: Chordata

Order: Anura

Family: Ranidae

Rana rugosa (Purposely Introduced) -- Aquatic 1

Trout Number: **<u>27</u> Waiakoali**

Phylum: Arachnida

Order: Aranae

Family: Salticidae

Salticidae (Unknown) -- Terrestrial 1

Family: Tetragnathidae

Tetragnatha sp (Endemic) -- Terrestrial 1

Phylum: Arthropoda

Order: Blattodea

Family: Blattellidae

Balta similis (Introduced) -- Terrestrial 1

Order: Heteroptera

Family: Mesoveliidae

Mesovelia mulsanti (Introduced) -- Aquatic 2

Order: Hymenoptera

Family: Apidae

Apis mellifera (Purposely Introduced) -- Terrestrial 22

Family: Ichneumonidae

Enicospilus sp (Endemic) -- Terrestrial 2

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial 2

Phylum: Nematomorpha

Order: Gordioidea

Family: Gordiidae

Gordius sp (Introduced) -- Aquatic 1

Trout Number: **<u>28</u> Waiakoali**

Phylum: Arthropoda

Order: Blattodea

Family: Blattellidae

	Balta similis (Introduced) -- Terrestrial	2
Order:	Diptera	
Family:	Tipulidae	
	Limonia sp (Unknown) -- Aquatic	1
Order:	Heteroptera	
Family:	Mesoveliidae	
	Mesovelia mulsanti (Introduced) -- Aquatic	3
Family:	Nabidae	
	Nabis sp (Endemic) -- Terrestrial	1
Order:	Hymenoptera	
Family:	Apidae	
	Apis mellifera (Purposely Introduced) -- Terrestrial	3

Trout Number: **29** **Waiakoali**

Phylum:	Arthropoda	
Order:	Coleoptera	
Family:	Elateridae	
	Conoderus exsul (Introduced) -- Terrestrial	1
	Elateridae (Unknown) -- Terrestrial	2
Order:	Heteroptera	
Family:	Mesoveliidae	
	Mesovelia mulsanti (Introduced) -- Aquatic	3
Order:	Hymenoptera	
Family:	Apidae	
	Apis mellifera (Purposely Introduced) -- Terrestrial	4
Order:	Lepidoptera	
Family:		
	Lepidoptera (Unknown) -- Terrestrial	2
Order:	Trichoptera	
Family:	Hydropsychidae	
	Cheumatopsyche pettiti (Introduced) -- Aquatic	1

Trout Number: **30** **Waiakoali**

Phylum:	Arthropoda	
Order:	Blattodea	
Family:	Blattellidae	
	Balta similis (Introduced) -- Terrestrial	1
Order:	Coleoptera	
Family:	Elateridae	
	Conoderus exsul (Introduced) -- Terrestrial	1
	Elateridae (Unknown) -- Terrestrial	5
	Itodacnus sordidus (Endemic) -- Terrestrial	3
Order:	Heteroptera	
Family:	Mesoveliidae	
	Mesovelia mulsanti (Introduced) -- Aquatic	2
Order:	Hymenoptera	

Family: Apidae
Apis mellifera (Purposely Introduced) -- Terrestrial 6
Order: Lepidoptera

Family:
Lepidoptera (Unknown) -- Terrestrial 1

Trout Number: **31 Waiakoali**

Phylum: Arthropoda
Order: Hymenoptera

Family: Apidae
Apis mellifera (Purposely Introduced) -- Terrestrial 1
Order: Isopoda

Family: Porcellionidae
Porcellio laevis (Introduced) -- Terrestrial 1

Trout Number: **32 Waiakoali**

Phylum: Arthropoda
Order: Blattodea

Family: Blattellidae
Balta similis (Introduced) -- Terrestrial 3
Order: Coleoptera

Family: Curculionidae
Asynonychus godmanni (Introduced) -- Terrestrial 1

Family: Elateridae
Conoderus exsul (Introduced) -- Terrestrial 1
Order: Heteroptera

Family: Mesoveliidae
Mesovelia mulsanti (Introduced) -- Aquatic 11

Family: Nabidae
Nabis silvestris (Endemic) -- Terrestrial 1
Order: Hymenoptera

Family:
Hymenoptera (Unknown) -- Terrestrial 1

Family: Apidae
Apis mellifera (Purposely Introduced) -- Terrestrial 10

Phylum: Nematomorpha
Order: Gordioidea

Family: Gordiidae
Gordius sp (Introduced) -- Aquatic 3

Trout Number: **33 Waiakoali**

Phylum: Arthropoda
Order: Blattodea

Family: Blattellidae
Balta similis (Introduced) -- Terrestrial 1

Order: Coleoptera

Family: Coccinellidae

Halmus chalybeus (Purposely Introduced) -- Terrestrial 1

Family: Nitidulidae

Nesopeplus roridus (Endemic) -- Terrestrial 3

Order: Diptera

Family: Chironomidae

Chironomus sp (Endemic) -- Aquatic 1

Order: Heteroptera

Family: Miridae

Orthotylus sp (Endemic) -- Terrestrial 1

Family: Pentatomidae

Oechalia sp (Endemic) -- Terrestrial 2

Order: Homoptera

Family: Cicadellidae

Nesophrosyne (Endemic) -- Terrestrial 1

Family: Cixiidae

Oliarus sp (Endemic) -- Terrestrial 2

Order: Hymenoptera

Family: Apidae

Apis mellifera (Purposely Introduced) -- Terrestrial 3

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Phylum: Chordata

Order: Cypriniformes

Family: Cobitidae

Misgurnus anguillicaudatus (Introduced) -- Aquatic 1

Trout Number: **34** **Waiakoali**

Phylum: Mollusca

Order: Basommatophora

Family: Physidae

Physa sp (Introduced) -- Aquatic 1

Trout Number: **35** **Waiakoali**

Phylum: Arthropoda

Order: Homoptera

Family: Cixiidae

Oliarus sp (Endemic) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Trout Number: **3 6** **Waiakoali**

Phylum: Arthropoda

Order: Diptera

Family: Dolichopodidae

Eurynongaster sp (Endemic) -- Aquatic 1

Order: Heteroptera

Family:

Heteroptera (Unknown) -- Terrestrial 1

Family: Miridae

Miridae sp 1 (Unknown) -- Terrestrial 1

Miridae sp 2 (Unknown) -- Terrestrial 1

Order: Hymenoptera

Family: Apidae

Apis mellifera (Purposely Introduced) -- Terrestrial 8

Order: Lepidoptera

Family: Crambidae

Crambidae (Unknown) -- Terrestrial 4

Order: Phthiraptera

Family:

Phthiraptera (Unknown) -- Terrestrial 1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 10

Order: Spirostreptida

Family: Cambalidae

Nannolene sp (Endemic) -- Terrestrial 3

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Trout Number: **3 7** **Waiakoali**

Phylum: Arthropoda

Order: Coleoptera

Family: Elateridae

Elateridae (Unknown) -- Terrestrial 1

Order: Decapoda

Family: Cambaridae

Procambarus clarkii (Purposely Introduced) -- Aquatic 2

Trout Number: **3 8** **Waiakoali**

Phylum: Arthropoda

Order: Decapoda

Family: Cambaridae

Procambarus clarkii (Purposely Introduced) -- Aquatic 1

Order: Heteroptera

Family: Nabidae

Nabis silvestris (Endemic) -- Terrestrial 1

Phylum: Chordata

Order: Cypriniformes

Family: Cobitidae

Misgurnus anguillicaudatus (Introduced) -- Aquatic 1

Trout Number: **39** **Waiakoali**

Phylum: Arthropoda

Order: Blattodea

Family: Blattellidae

Blattella lituricollis (Introduced) -- Terrestrial 1

Order: Coleoptera

Family: Elateridae

Itodacnus sordidus (Endemic) -- Terrestrial 2

Order: Hymenoptera

Family: Apidae

Apis mellifera (Purposely Introduced) -- Terrestrial 6

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial 1

Family: Crambidae

Crambidae (Unknown) -- Terrestrial 1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 1

Order: Spirostreptida

Family: Cambalidae

Nannolene sp (Endemic) -- Terrestrial 1

Trout Number: **40** **Waiakoali**

Phylum: Arthropoda

Order: Homoptera

Family: Cixiidae

Oliarus sp (Endemic) -- Terrestrial 1

Order: Hymenoptera

Family: Apidae

Apis mellifera (Purposely Introduced) -- Terrestrial 1

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial 1

Trout Number: **41** **Waiakoali**

Phylum: Arachnida
Order: Aranae
Family:
Arachnida (Endemic) -- Terrestrial 1
Phylum: Arthropoda
Order: Hymenoptera
Family: Apidae
Apis mellifera (Purposely Introduced) -- Terrestrial 1
Order: Isopoda
Family: Porcellionidae
Porcellio laevis (Introduced) -- Terrestrial 3
Order: Lepidoptera
Family:
Lepidoptera (Unknown) -- Terrestrial 1
Order: Polydesmida
Family: Paradoxosomatidae
Oxidus gracilis (Introduced) -- Terrestrial 8
Order: Spirostreptida
Family: Cambalidae
Nannolene sp (Endemic) -- Terrestrial 1

Trout Number: **42 Waiakoali**

Phylum: Arthropoda
Order: Coleoptera
Family: Nitidulidae
Nesopeplus floricola (Endemic) -- Terrestrial 2
Order: Hymenoptera
Family: Apidae
Apis mellifera (Purposely Introduced) -- Terrestrial 1
Order: Isopoda
Family: Porcellionidae
Porcellio laevis (Introduced) -- Terrestrial 1
Order: Lepidoptera
Family: Noctuidae
Agrotis sp (Endemic) -- Terrestrial 2
Order: Polydesmida
Family: Paradoxosomatidae
Oxidus gracilis (Introduced) -- Terrestrial 2

Trout Number: **43 Kawaikoi**

Phylum: Arthropoda
Order: Amphipoda
Family: Talitridae
Talitroides topitotum (Introduced) -- Terrestrial 1
Order: Coleoptera

Family: Dytiscidae	
Rhantus pacificus (Endemic) -- Aquatic	1
Family: Elateridae	
Conoderus exsul (Introduced) -- Terrestrial	1
Family: Hydrophilidae	
Limnonexus semicylindricus (Endemic) -- Aquatic	1
Tropisternus lateralis (Introduced) -- Aquatic	1
Family: Scarabaeidae	
Adoretus sinicus (Introduced) -- Terrestrial	1
Order: Hymenoptera	
Family: Apidae	
Apis mellifera (Purposely Introduced) -- Terrestrial	3
Order: Isoptera	
Family: Kalotermitidae	
Neotermes connexus (Introduced) -- Terrestrial	1
Order: Polydesmida	
Family: Paradoxosomatidae	
Oxidus gracilis (Introduced) -- Terrestrial	2
Order: Spirostreptida	
Family: Cambalidae	
Nannolene sp (Endemic) -- Terrestrial	1
Order: Trichoptera	
Family: Hydropsychidae	
Cheumatopsyche pettiti (Introduced) -- Aquatic	1
Phylum: Chordata	
Order: Cypriniformes	
Family: Cobitidae	
Misgurnus anguillicaudatus (Introduced) -- Aquatic	1

Trout Number: **44 Kawaikoi**

Phylum: Arthropoda	
Order: Isopoda	
Family: Porcellionidae	
Porcellio laevis (Introduced) -- Terrestrial	2
Order: Lepidoptera	
Family:	
Lepidoptera (Unknown) -- Terrestrial	1
Order: Polydesmida	
Family: Paradoxosomatidae	
Oxidus gracilis (Introduced) -- Terrestrial	2
Order: Spirostreptida	
Family: Cambalidae	
Nannolene sp (Endemic) -- Terrestrial	3
Order: Trichoptera	
Family: Hydropsychidae	
Cheumatopsyche pettiti (Introduced) -- Aquatic	1

Trout Number: **45** **Kawaikoi**

Phylum: Arthropoda

Order: Coleoptera

Family: Carabidae

Colpodes buchannani (Introduced) -- Terrestrial 1

Family: Cucujidae

Cryptomorpha desjardinsi (Introduced) -- Terrestrial 1

Order: Diptera

Family: Chironomidae

Cricotopus bicinctus (Introduced) -- Aquatic 1

Order: Homoptera

Family: Cixiidae

Oliarus sp (Endemic) -- Terrestrial 1

Family: Delphacidae

Nesothoe sp (Endemic) -- Terrestrial 1

Order: Hymenoptera

Family: Apidae

Apis mellifera (Purposely Introduced) -- Terrestrial 5

Family: Ichneumonidae

Ichneumonidae (Unknown) -- Terrestrial 1

Order: Neuroptera

Family: Chrysopidae

Anomalochrysa sp (Endemic) -- Terrestrial 1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 1

Order: Spirostreptida

Family: Cambalidae

Nannolene sp (Endemic) -- Terrestrial 3

Trout Number: **46** **Waialae**

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana (Introduced) -- Aquatic 2

Order: Oligochaeta

Family:

Oligochaeta (Unknown) -- Aquatic 1

Phylum: Arachnida

Order: Aranae

Family:

Arachnida (Endemic) -- Terrestrial 1

Phylum: Arthropoda

Order: Amphipoda

Family: Talitridae

	Talitroides topitotum (Introduced) -- Terrestrial	1
Order:	Decapoda	
Family:	Atyidae	
	Atyoida bisulcata (Endemic) -- Aquatic	1
Order:	Diptera	
Family:	Calliphoridae	
	Calliphoridae (Unknown) -- Terrestrial	1
Family:	Chironomidae	
	Chironomus sp (Endemic) -- Aquatic	1
	Cricotopus bicinctus (Introduced) -- Aquatic	5
	Orthocladius sp (Endemic) -- Aquatic	2
Family:	Tipulidae	
	Limonia sp (Unknown) -- Aquatic	1
	Tipulidae (Unknown) -- Aquatic	1
Order:	Homoptera	
Family:	Cicadellidae	
	Nesophrosyne (Endemic) -- Terrestrial	1
Order:	Lepidoptera	
Family:	Cosmopterigidae	
	Hyposmocoma sp 1 (Endemic) -- Aquatic	3
Family:	Geometridae	
	Geometridae (Endemic) -- Terrestrial	1
Order:	Trichoptera	
Family:	Hydropsychidae	
	Cheumatopsyche pettiti (Introduced) -- Aquatic	30
Phylum:	Mollusca	
Order:	Lymnaeoidea	
Family:	Lymnaeidae	
	Lymnaeidae sp (Unknown) -- Aquatic	1

Trout Number: **47 Waialae**

Phylum:	Arachnida	
Order:	Aranae	
Family:		
	Arachnida (Endemic) -- Terrestrial	1
Phylum:	Arthropoda	
Order:	Diptera	
Family:	Ephydridae	
	Scatella (Endemic) -- Aquatic	1
Order:	Hymenoptera	
Family:		
	Hymenoptera (Unknown) -- Terrestrial	1
Family:	Braconidae	
	Apanteles sp (Unknown) -- Terrestrial	1
Order:	Lepidoptera	
Family:	Cosmopterigidae	
	Hyposmocoma sp 1 (Endemic) -- Aquatic	2

Hyposmocoma sp 4 (Endemic) -- Aquatic 1
Hyposmocoma sp 5 (Endemic) -- Aquatic 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 3

Trout Number: **<u>48</u> Waialae**

Phylum: Arthropoda

Order: Collembola

Family: Entomobryidae

Entomobrya unostrigata (Introduced) -- Terrestrial 1

Order: Decapoda

Family: Atyidae

Atyoida bisulcata (Endemic) -- Aquatic 1

Order: Diptera

Family: Calliphoridae

Calliphoridae (Unknown) -- Terrestrial 2

Family: Chironomidae

Chironomidae (Unknown) -- Aquatic 1

Order: Heteroptera

Family: Lygaeidae

Nysius sp (Endemic) -- Terrestrial 1

Family: Reduviidae

Zelus renardii (Introduced) -- Terrestrial 2

Order: Homoptera

Family: Cicadellidae

Cicadellidae (Unknown) -- Terrestrial 1

Family: Cixiidae

Cixiidae (Endemic) -- Terrestrial 1

Family: Delphacidae

Delphacidae (Unknown) -- Terrestrial 1

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp 1 (Endemic) -- Aquatic 1
Hyposmocoma sp 2 (Endemic) -- Aquatic 2

Order: Orthoptera

Family:

Orthoptera (Unknown) -- Terrestrial 1

Family: Gryllidae

Paratrigonidium pacificum (Endemic) -- Terrestrial 1
Trigonidium sp (Endemic) -- Terrestrial 1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 2

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 3

Family: Hydroptilidae

	Oxyethira maya (Introduced) -- Aquatic	1
Phylum: Mollusca		
Order: Lymnaeoidea		
Family: Lymnaeidae		
	Lymnaeidae sp (Unknown) -- Aquatic	7

Trout Number: <u>**49**</u> **Waialae**

Phylum: Annelida		
Order: Oligochaeta		
Family:		
	Oligochaeta (Unknown) -- Aquatic	2
Phylum: Arthropoda		
Order: Diptera		
Family: Chironomidae		
	Cricotopus bicinctus (Introduced) -- Aquatic	12
Family: Tipulidae		
	Tipulidae (Unknown) -- Aquatic	1
Order: Homoptera		
Family: Cicadellidae		
	Nesophrosyne (Endemic) -- Terrestrial	2
Order: Hymenoptera		
Family: Bethylidae		
	Sierola sp (Endemic) -- Terrestrial	1
Order: Isopoda		
Family: Styloniscidae		
	Styloniscus spinosus (Introduced) -- Terrestrial	2
Order: Lepidoptera		
Family: Cosmopterigidae		
	Hyposmocoma sp 3 (Endemic) -- Aquatic	1
Order: Odonata		
Family: Coenagrionidae		
	Megalagrion heterogamias (Endemic) -- Aquatic	1
Order: Polydesmida		
Family: Paradoxosomatidae		
	Oxidus gracilis (Introduced) -- Terrestrial	1
Order: Trichoptera		
Family: Hydropsychidae		
	Cheumatopsyche pettiti (Introduced) -- Aquatic	4
Family: Hydroptilidae		
	Hydroptilla arcitia (Introduced) -- Aquatic	1
	Oxyethira maya (Introduced) -- Aquatic	1
Phylum: Mollusca		
Order: Lymnaeoidea		
Family: Lymnaeidae		
	Lymnaeidae sp (Unknown) -- Aquatic	5

Trout Number: **<u>50</u> Waialae**

Phylum: Arthropoda

Order: Coleoptera

Family:

Coleoptera (Unknown) -- Terrestrial	1

Family: Dytiscidae

Rhantus sp (Endemic) -- Aquatic	1

Order: Diptera

Family: Chironomidae

Cricotopus bicinctus (Introduced) -- Aquatic	2

Order: Hymenoptera

Family: Apidae

Apis mellifera (Purposely Introduced) -- Terrestrial	1

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp 1 (Endemic) -- Aquatic	1
Hyposmocoma sp 5 (Endemic) -- Aquatic	1

Family: Noctuidae

Noctuidae (Unknown) -- Terrestrial	1

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic) -- Aquatic	1

Family: Coenagrionidae

Megalagrion heterogamias (Endemic) -- Aquatic	1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial	1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic	14

Family: Hydroptilidae

Oxyethira maya (Introduced) -- Aquatic	1

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial	9

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic	41

Trout Number: **<u>51</u> Waialae**

Phylum: Arachnida

Order: Aranae

Family:

Arachnida (Endemic) -- Terrestrial	1

Phylum: Arthropoda

Order: Coleoptera

Family:
Coleoptera (Unknown) -- Terrestrial 1

Family: Coccinellidae
Hyperaspis pantherina (Purposely Introduced) -- Terrestrial 2

Order: Diptera

Family: Calliphoridae
Calliphoridae (Unknown) -- Terrestrial 1

Family: Ephydridae
Scatella (Endemic) -- Aquatic 2
Scatella kauaiensis (Endemic) -- Aquatic 1

Order: Heteroptera

Family: Miridae
Orthotylus sp (Endemic) -- Terrestrial 1

Family: Veliidae
Microvelia vagans (Endemic) -- Aquatic 1

Order: Hymenoptera

Family: Apidae
Apis mellifera (Purposely Introduced) -- Terrestrial 1

Order: Lepidoptera

Family:
Lepidoptera (Unknown) -- Terrestrial 4

Family: Cosmopterigidae
Hyposmocoma sp 1 (Endemic) -- Aquatic 1
Hyposmocoma sp 3 (Endemic) -- Aquatic 4

Order: Polydesmida

Family: Paradoxosomatidae
Oxidus gracilis (Introduced) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 3

Trout Number: **52 Waialae**

Phylum: Arachnida

Order: Aranae

Family:
Arachnida (Endemic) -- Terrestrial 1

Family: Theridiidae
Theridiidae (Endemic) -- Terrestrial 1

Phylum: Arthropoda

Order: Diptera

Family: Chironomidae
Chironomidae (Unknown) -- Aquatic 2

Family: Ephydridae
Scatella (Endemic) -- Aquatic 1

Family: Tipulidae
Limonia sp (Unknown) -- Aquatic 1

Order: Isopoda		
Family: Styloniscidae		
	Styloniscus spinosus (Introduced) -- Terrestrial	1
Order: Lepidoptera		
Family:		
	Lepidoptera (Unknown) -- Terrestrial	1
Family: Cosmopterigidae		
	Hyposmocoma sp 1 (Endemic) -- Aquatic	2
Order: Odonata		
Family: Coenagrionidae		
	Ischnura ramburii (Introduced) -- Aquatic	1
	Megalagrion heterogamias (Endemic) -- Aquatic	1
Order: Orthoptera		
Family: Gryllidae		
	Trigonidium sp (Endemic) -- Terrestrial	1
Order: Polydesmida		
Family: Paradoxosomatidae		
	Oxidus gracilis (Introduced) -- Terrestrial	1
Order: Trichoptera		
Family: Hydropsychidae		
	Cheumatopsyche pettiti (Introduced) -- Aquatic	5
Family: Hydroptilidae		
	Oxyethira maya (Introduced) -- Aquatic	1
Phylum: Mollusca		
Order: Limacoidea		
Family: Zonitidae		
	Oxychilus alliarius (Introduced) -- Terrestrial	2
Order: Lymnaeoidea		
Family: Lymnaeidae		
	Lymnaeidae sp (Unknown) -- Aquatic	15

Trout Number: **53 Waialae**

Phylum: Arthropoda		
Order: Hymenoptera		
Family: Ichneumonidae		
	Pimpla punicipes (Introduced) -- Terrestrial	1
Order: Lepidoptera		
Family:		
	Lepidoptera (Unknown) -- Terrestrial	1
Order: Trichoptera		
Family: Hydropsychidae		
	Cheumatopsyche pettiti (Introduced) -- Aquatic	6
Phylum: Mollusca		
Order: Limacoidea		
Family: Zonitidae		
	Oxychilus alliarius (Introduced) -- Terrestrial	1

Trout Number: **<u>54</u> Waialae**

Phylum: Arthropoda
Order: Coleoptera
Family: Carabidae
Blackburnia posticata (Endemic) -- Terrestrial 1
Family: Nitidulidae
Nesopeplus curtithorax (Endemic) -- Terrestrial 2
Order: Decapoda
Family: Atyidae
Atyoida bisulcata (Endemic) -- Aquatic 1
Order: Diptera
Family: Sphaerocridae
Copromyza equina (Introduced) -- Terrestrial 1
Order: Heteroptera
Family: Lygaeidae
Nysius sp (Endemic) -- Terrestrial 1
Order: Homoptera
Family:
Homoptera (Unknown) -- Terrestrial 1
Order: Lepidoptera
Family: Cosmopterigidae
Hyposmocoma sp 2 (Endemic) -- Aquatic 1
Order: Polydesmida
Family: Paradoxosomatidae
Oxidus gracilis (Introduced) -- Terrestrial 1
Order: Trichoptera
Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 16
Phylum: Mollusca
Order: Limacoidea
Family: Zonitidae
Oxychilus alliarius (Introduced) -- Terrestrial 1

Trout Number: **<u>55</u> Waialae**

Phylum: Annelida
Order: Arhynchobdellida
Family: Erpobdellidae
Barbronia weberi formosana (Introduced) -- Aquatic 1
Phylum: Arthropoda
Order: Amphipoda
Family: Talitridae
Talitroides topitotum (Introduced) -- Terrestrial 3
Order: Homoptera
Family:
Homoptera (Unknown) -- Terrestrial 1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 3

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial 1

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 4

Trout Number: **56** **Waialae**

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana (Introduced) -- Aquatic 2

Phylum: Arthropoda

Order: Decapoda

Family: Atyidae

Atyoida bisulcata (Endemic) -- Aquatic 1

Order: Diptera

Family: Chironomidae

Cricotopus bicinctus (Introduced) -- Aquatic 1

Order: Isopoda

Family: Porcellionidae

Porcellio laevis (Introduced) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 9

Phylum: Mollusca

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 7

Trout Number: **57** **Waialae**

Phylum: Arachnida

Order: Aranae

Family: Thomisidae

Thomisidae (Endemic) -- Terrestrial 1

Phylum: Arthropoda

Order: Diptera

Family: Calliphoridae

Calliphora vomitoria (Introduced) -- Aquatic 1

Family: Chironomidae

Cricotopus bicinctus (Introduced) -- Aquatic 2

Order: Heteroptera

Family: Cydnidae

Geotomus pygmaeus (Introduced) -- Terrestrial 1

Order: Isopoda

Family: Styloniscidae

Styloniscus spinosus (Introduced) -- Terrestrial 2

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial 2

Family: Cosmopterigidae

Hyposmocoma sp 1 (Endemic) -- Aquatic 1

Hyposmocoma sp 2 (Endemic) -- Aquatic 1

Hyposmocoma sp 4 (Endemic) -- Aquatic 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Family: Hydroptilidae

Hydroptilla arcitia (Introduced) -- Aquatic 1

Oxyethira maya (Introduced) -- Aquatic 1

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial 2

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 4

Trout Number: **58** **Waialae**

Phylum: Arachnida

Order: Aranae

Family: Tetragnathidae

Tetragnatha sp (Endemic) -- Terrestrial 1

Phylum: Arthropoda

Order: Coleoptera

Family: Curculionidae

Nesotocus kauaiensis (Endemic) -- Terrestrial 1

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial 1

Order: Orthoptera

Family: Gryllidae

Trigonidium sp (Endemic) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Trout Number: **<u>59</u> Waialae**

Phylum: Arthropoda

Order: Decapoda

Family: Atyidae

Atyoida bisulcata (Endemic) -- Aquatic 1

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp 1 (Endemic) -- Aquatic 1

Hyposmocoma sp 3 (Endemic) -- Aquatic 3

Order: Orthoptera

Family: Gryllidae

Tettigoniidae (Unknown) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 5

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial 1

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 5

Trout Number: **<u>60</u> Waialae**

Phylum: Arthropoda

Order: Heteroptera

Family: Nabidae

Nabis silvestris (Endemic) -- Terrestrial 1

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp 1 (Endemic) -- Aquatic 1

Family: Crambidae

Eudonia sp (Endemic) -- Terrestrial 2

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial 1

Trout Number: **<u>61</u> Waialae**

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana (Introduced) -- Aquatic 2

Phylum: Arthropoda

Order: Diptera

Family: Chironomidae

Chironomidae (Unknown) -- Aquatic 1

Cricotopus bicinctus (Introduced) -- Aquatic 8

Order: Isopoda

Family: Porcellionidae

Porcellio laevis (Introduced) -- Terrestrial 1

Order: Odonata

Family: Coenagrionidae

Megalagrion heterogamias (Endemic) -- Aquatic 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 10

Family: Hydroptilidae

Oxyethira maya (Introduced) -- Aquatic 1

Phylum: Mollusca

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 31

Phylum: Nematomorpha

Order: Gordioidea

Family: Gordiidae

Gordius sp (Introduced) -- Aquatic 1

Trout Number: **62** **Waialae**

Phylum: Arthropoda

Order: Coleoptera

Family: Carabidae

Blackburnia insignis (Endemic) -- Terrestrial 1

Order: Heteroptera

Family: Lygaeidae

Nysius sp (Endemic) -- Terrestrial 5

Order: Homoptera

Family: Cixiidae

Oliarus sp (Endemic) -- Terrestrial 5

Family: Delphacidae

Aloha sp (Endemic) -- Terrestrial 5

Phylum: Mollusca

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 2

Trout Number: **63** **Waialae**

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana (Introduced) -- Aquatic 2

Order: Oligochaeta

Family:

Oligochaeta (Unknown) -- Aquatic 1

Phylum: Arthropoda

Order: Diptera

Family: Chironomidae

Chironomus sp (Endemic) -- Aquatic 7

Cricotopus bicinctus (Introduced) -- Aquatic 3

Order: Isopoda

Family: Styloniscidae

Styloniscus spinosus (Introduced) -- Terrestrial 2

Order: Lepidoptera

Family:

Lepidoptera (Unknown) -- Terrestrial 1

Order: Orthoptera

Family:

Orthoptera (Unknown) -- Terrestrial 1

Family: Gryllidae

Paratrigonidium pacificum (Endemic) -- Terrestrial 1

Order: Polydesmida

Family: Paradoxosomatidae

Oxidus gracilis (Introduced) -- Terrestrial 2

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 4

Family: Hydroptilidae

Oxyethira maya (Introduced) -- Aquatic 1

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial 1

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 41

Order: Planorbioidea

Family: Ancylidae

Ferrisia sharpei (Unknown) -- Aquatic 1

Trout Number: **64 Koaie**

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana (Introduced) -- Aquatic 7

Phylum: Arthropoda

Order: Diptera

Family: Chironomidae

Cricotopus bicinctus (Introduced) -- Aquatic 4

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic) -- Aquatic 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Phylum: Mollusca

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 6

Trout Number: **<u>65</u> Koaie**

Phylum: Annelida

Order: Oligochaeta

Family:

Oligochaeta (Unknown) -- Aquatic 2

Phylum: Arthropoda

Order: Coleoptera

Family: Anobiidae

Xyletobius nuptus (Endemic) -- Terrestrial 1

Family: Dytiscidae

Rhantus sp (Endemic) -- Aquatic 1

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp 1 (Endemic) -- Aquatic 1

Family: Crambidae

Eudonia sp (Endemic) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 4

Phylum: Mollusca

Order: Limacoidea

Family: Zonitidae

Oxychilus alliarius (Introduced) -- Terrestrial 6

Order: Lymnaeoidea

Family: Lymnaeidae

Lymnaeidae sp (Unknown) -- Aquatic 1

Trout Number: **<u>66</u> Koaie**

Phylum: Acari

Order: Oribatida

Family: Phthiracaridae		
	Phthiracarus sp (Unknown) -- Terrestrial	1
Phylum: Annelida		
Order: Arhynchobdellida		
Family: Erpobdellidae		
	Barbronia weberi formosana (Introduced) -- Aquatic	3
Order: Oligochaeta		
Family:		
	Oligochaeta (Unknown) -- Aquatic	1
Phylum: Arthropoda		
Order: Blattodea		
Family: Blattellidae		
	Balta similis (Introduced) -- Terrestrial	1
Order: Diptera		
Family: Chironomidae		
	Cricotopus bicinctus (Introduced) -- Aquatic	1
Order: Heteroptera		
Family: Lygaeidae		
	Nysius sp (Endemic) -- Terrestrial	1
Family: Nabidae		
	Nabis silvestris (Endemic) -- Terrestrial	1
Order: Hymenoptera		
Family: Apidae		
	Apis mellifera (Purposely Introduced) -- Terrestrial	1
Order: Isopoda		
Family: Porcellionidae		
	Porcellio laevis (Introduced) -- Terrestrial	2
Order: Spirostreptida		
Family: Cambalidae		
	Nannolene sp (Endemic) -- Terrestrial	1
Order: Trichoptera		
Family: Hydropsychidae		
	Cheumatopsyche pettiti (Introduced) -- Aquatic	30
Phylum: Mollusca		
Order: Limacoidea		
Family: Zonitidae		
	Oxychilus alliarius (Introduced) -- Terrestrial	1
Order: Lymnaeoidea		
Family: Lymnaeidae		
	Lymnaeidae sp (Unknown) -- Aquatic	2

Trout Number: **67 Koaie**

Phylum: Annelida		
Order: Arhynchobdellida		
Family: Erpobdellidae		
	Barbronia weberi formosana (Introduced) -- Aquatic	2
Order: Oligochaeta		

Family:
Oligochaeta (Unknown) -- Aquatic 2

Phylum: Arachnida
Order: Aranae

Family:
Arachnida (Endemic) -- Terrestrial 1

Phylum: Arthropoda
Order: Lepidoptera

Family:
Lepidoptera (Unknown) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 18

Family: Hydroptilidae
Hydroptilla arcitia (Introduced) -- Aquatic 1
Oxyethira maya (Introduced) -- Aquatic 1

Trout Number: **68** **Koaie**

Phylum: Annelida
Order: Arhynchobdellida

Family: Erpobdellidae
Barbronia weberi formosana (Introduced) -- Aquatic 2

Order: Oligochaeta

Family:
Oligochaeta (Unknown) -- Aquatic 4

Phylum: Arthropoda
Order: Coleoptera

Family: Dytiscidae
Rhantus sp (Endemic) -- Aquatic 1

Order: Diptera

Family: Chironomidae
Cricotopus bicinctus (Introduced) -- Aquatic 1

Order: Isopoda

Family: Styloniscidae
Styloniscus spinosus (Introduced) -- Terrestrial 3

Order: Lepidoptera

Family: Cosmopterigidae
Hyposmocoma sp 1 (Endemic) -- Aquatic 1
Hyposmocoma sp 3 (Endemic) -- Aquatic 1

Order: Odonata

Family: Aeshnidae
Anax strenuus (Endemic) -- Aquatic 1

Order: Trichoptera

Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 12

Family: Hydroptilidae
Oxyethira maya (Introduced) -- Aquatic 3

Phylum: Mollusca
Order: Lymnaeoidea
Family: Lymnaeidae
Lymnaeidae sp (Unknown) -- Aquatic 1

Trout Number: **69** **Koaie**

Phylum: Arthropoda
Order: Odonata
Family: Aeshnidae
Anax strenuus (Endemic) -- Aquatic 1

Trout Number: **70** **Kauaikinana**

Phylum: Arachnida
Order: Aranae
Family: Thomisidae
Thomisidae (Endemic) -- Terrestrial 1

Phylum: Arthropoda
Order: Diptera
Family: Chironomidae
Chironomidae (Unknown) -- Aquatic 1
Order: Heteroptera
Family: Lygaeidae
Nysius sp (Endemic) -- Terrestrial 1
Order: Homoptera
Family: Cixiidae
Oliarus sp (Endemic) -- Terrestrial 1
Order: Isopoda
Family: Porcellionidae
Porcellio laevis (Introduced) -- Terrestrial 1
Order: Spirostreptida
Family: Cambalidae
Nannolene sp (Endemic) -- Terrestrial 21
Order: Trichoptera
Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 2

Trout Number: **71** **Kauaikinana**

Phylum: Arthropoda
Order: Diptera
Family: Chironomidae
Cricotopus bicinctus (Introduced) -- Aquatic 2
Order: Isopoda
Family: Porcellionidae
Porcellio laevis (Introduced) -- Terrestrial 2

Order: Spirostreptida

Family: Cambalidae

Nannolene sp (Endemic) -- Terrestrial 1

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 1

Trout Number: **72 Kauaikinana**

Phylum: Arthropoda

Order: Diptera

Family: Chironomidae

Chironomidae (Unknown) -- Aquatic 1

Order: Homoptera

Family:

Homoptera (Unknown) -- Terrestrial 1

Order: Hymenoptera

Family: Ichneumonidae

Enicospilus sp (Endemic) -- Terrestrial 1

Order: Isopoda

Family: Porcellionidae

Porcellio laevis (Introduced) -- Terrestrial 1

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp (Endemic) -- Aquatic 1

Family: Crambidae

Eudonia sp (Endemic) -- Terrestrial 1

Order: Spirostreptida

Family: Cambalidae

Nannolene sp (Endemic) -- Terrestrial 14

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced) -- Aquatic 3

Trout Number: **73 Kauaikinana**

Phylum: Arthropoda

Order: Blattodea

Family: Blattellidae

Blattella lituricollis (Introduced) -- Terrestrial 1

Order: Diptera

Family: Chironomidae

Chironomus sp (Endemic) -- Aquatic 1

Family: Tipulidae

Tipulidae (Unknown) -- Aquatic 2

Order: Isopoda

Family: Porcellionidae

Porcellio laevis (Introduced) -- Terrestrial 1

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp 1 (Endemic) -- Aquatic 1

Family: Geometridae

Scotorythra sp (Endemic) -- Terrestrial 1

Order: Spirostreptida

Family: Cambalidae

Nannolene sp (Endemic) -- Terrestrial 18

Phylum: Nematomorpha

Order: Gordioidea

Family: Gordiidae

Gordius sp (Introduced) -- Aquatic 1

Trout Number: **74** **Kauaikinana**

Phylum: Arthropoda

Order: Diptera

Family: Chironomidae

Cricotopus bicinctus (Introduced) -- Aquatic 12

Order: Heteroptera

Family: Nabidae

Nabis silvestris (Endemic) -- Terrestrial 1

Order: Spirostreptida

Family: Cambalidae

Nannolene sp (Endemic) -- Terrestrial 2

Phylum: Chordata

Order: Anura

Family: Ranidae

Rana rugosa (Purposely Introduced) -- Aquatic 1

Trout Number: **75** **Kauaikinana**

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana (Introduced) -- Aquatic 1

Phylum: Arthropoda

Order: Coleoptera

Family: Nitidulidae

Nesopeplus curtithorax (Endemic) -- Terrestrial 1

Family: Staphylinidae

Staphylinidae (Unknown) -- Terrestrial 1

Order: Diptera

Family: Chironomidae

Chironomidae (Unknown) -- Aquatic 8

Cricotopus bicinctus (Introduced) -- Aquatic 2

Order: Hymenoptera

Family: Apidae
Apis mellifera (Purposely Introduced) -- Terrestrial 1
Order: Isopoda
Family: Porcellionidae
Porcellio laevis (Introduced) -- Terrestrial 1
Order: Lepidoptera
Family: Cosmopterigidae
Hyposmocoma sp 1 (Endemic) -- Aquatic 1
Order: Spirostreptida
Family: Cambalidae
Nannolene sp (Endemic) -- Terrestrial 7
Order: Trichoptera
Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 4
Family: Hydroptilidae
Hydroptilla arcitia (Introduced) -- Aquatic 1

Trout Number: **76** **Kauaikinana**

Phylum: Arthropoda
Order: Diptera
Family: Chironomidae
Chironomidae (Unknown) -- Aquatic 2
Family: Tipulidae
Tipulidae (Unknown) -- Aquatic 2
Order: Heteroptera
Family: Miridae
Orthotylus sp (Endemic) -- Terrestrial 1
Order: Hymenoptera
Family: Braconidae
Braconidae (Unknown) -- Terrestrial 1
Order: Isopoda
Family: Porcellionidae
Porcellio laevis (Introduced) -- Terrestrial 1
Order: Lepidoptera
Family: Crambidae
Udea sp (Endemic) -- Terrestrial 1
Order: Spirostreptida
Family: Cambalidae
Nannolene sp (Endemic) -- Terrestrial 12
Order: Trichoptera
Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 6

Trout Number: **77** **Kauaikinana**

Phylum: Arthropoda
Order: Diptera

	Family: Chironomidae		
		Chironomus sp (Endemic) -- Aquatic	4
		Clunio sp (Indigenous) -- Aquatic	2
	Family: Tipulidae		
		Limonia sp (Unknown) -- Aquatic	7
Order: Heteroptera			
	Family: Nabidae		
		Nabis sharpianus (Endemic) -- Terrestrial	1
Order: Lepidoptera			
	Family: Cosmopterigidae		
		Hyposmocoma sp (Endemic) -- Aquatic	1
	Family: Crambidae		
		Crambidae (Unknown) -- Terrestrial	1
Order: Psocoptera			
	Family: Psocidae		
		Psocidae (Endemic) -- Terrestrial	1
Order: Spirostreptida			
	Family: Cambalidae		
		Nannolene sp (Endemic) -- Terrestrial	5
Order: Trichoptera			
	Family: Hydropsychidae		
		Cheumatopsyche pettiti (Introduced) -- Aquatic	7
Phylum: Mollusca			
Order: Limacoidea			
	Family: Zonitidae		
		Oxychilus alliarius (Introduced) -- Terrestrial	1
Order: Planorbioidea			
	Family: Ancylidae		
		Ferrisia sharpei (Unknown) -- Aquatic	1

Trout Number: **78 Waiakoali**

Phylum: Arthropoda			
Order: Diptera			
	Family: Chironomidae		
		Cricotopus bicinctus (Introduced) -- Aquatic	1
Order: Heteroptera			
	Family: Nabidae		
		Nabis silvestris (Endemic) -- Terrestrial	1
Order: Lepidoptera			
	Family:		
		Lepidoptera (Unknown) -- Terrestrial	1
Order: Spirostreptida			
	Family: Cambalidae		
		Nannolene sp (Endemic) -- Terrestrial	3
Order: Trichoptera			
	Family: Hydropsychidae		
		Cheumatopsyche pettiti (Introduced) -- Aquatic	2

Trout Number: **7 9** **Waiakoali**

Phylum: Arthropoda
Order: Heteroptera
Family: Mesoveliidae
Mesovelia mulsanti (Introduced) -- Aquatic 1
Family: Nabidae
Nabis silvestris (Endemic) -- Terrestrial 1
Family: Veliidae
Microvelia vagans (Endemic) -- Aquatic 4
Order: Spirostreptida
Family: Cambalidae
Nannolene sp (Endemic) -- Terrestrial 1
Order: Trichoptera
Family: Hydropsychidae
Cheumatopsyche pettiti (Introduced) -- Aquatic 1
Phylum: Mollusca
Order: Limacoidea
Family: Zonitidae
Oxychilus alliarius (Introduced) -- Terrestrial 1

Trout Number: **8 0** **Kauaikinana**

Phylum: Arthropoda
Order: Spirostreptida
Family: Cambalidae
Nannolene sp (Endemic) -- Terrestrial 1

APPENDIX B- Aquatic Species Collected in Kōke‘e State Park Streams – General (Aerial) Collections

General Collection of Species by Stream

Kauaikinana Stream

Phylum: Arthropoda

Order: Decapoda

Family: Cambaridae

Procambarus clarkii (Purposely Introduced)

Order: Diptera

Family: Canacidae

Procanace sp (Endemic)

Family: Chironomidae

Cricotopus bicinctus (Introduced)

Family: Dolichopodidae

Campsicnemus nigricollis (Endemic)
Campsicnemus sp (Endemic)
Dolichopus exsul (Introduced)
Eurynogaster minor (Endemic)

Family: Ephydridae

Scatella cilipes (Endemic)
Scatella hawaiiensis (Endemic)
Scatella kauaiensis (Endemic)

Family: Tipulidae

Limonia hawaiiensis (Endemic)
Limonia jacoba (Endemic)
Limonia stygipennis (Endemic)

Order: Heteroptera

Family: Saldidae

Saldula exulans (Endemic)
Saldula procellaris (Endemic)

Family: Veliidae

Microvelia vagans (Endemic)

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp (Endemic)
Hyposmocoma sp nr montivolans (Endemic)
Hyposmocoma sp nr saccophora (Endemic)

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic)

Family: Coenagrionidae

Megalagrion heterogamias (Endemic)
Megalagrion oresitrophum (Endemic)
Megalagrion vagabundum (Endemic)

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced)

Phylum: Chordata

Order: Anura

Family: Ranidae

Rana rugosa (Purposely Introduced)

Order: Cypriniformes

Family: Cobitidae

Misgurnus anguillicaudatus (Introduced)

Order: Salmoniformes

Family: Salmonidae

Onchorhynchus mykiss (Introduced)

Kawaikoi Stream

Phylum: Arthropoda

Order: Decapoda

Family: Cambaridae

Procambarus clarkii (Purposely Introduced)

Order: Diptera

Family: Ceratopongonidae

Forcipomyia sp (Endemic)

Family: Chironomidae

Cricotopus bicinctus (Introduced)

Family: Dolichopodidae

Campsicnemus nigricollis (Endemic)
Dolichopus exsul (Introduced)
Sigmatineurum napali (Endemic)
Syntormon flexible (Introduced)

Family: Ephydridae

Ochthera circularis (Introduced)
Scatella clavipes (Endemic)
Scatella hawaiiensis (Endemic)
Scatella kauaiensis (Endemic)

Family: Tipulidae

Limonia hawaiiensis (Endemic)
Limonia jacoba (Endemic)
Limonia stygipennis (Endemic)

Order: Heteroptera

Family: Saldidae

Saldula exulans (Endemic)
Saldula procellaris (Endemic)

Family: Veliidae

Microvelia vagans (Endemic)

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp nr montivolans (Endemic)
Hyposmocoma sp nr saccophora (Endemic)

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic)

Family: Coenagrionidae

Ischnura posita (Introduced)
Megalagrion heterogamias (Endemic)
Megalagrion oresitrophum (Endemic)
Megalagrion vagabundum (Endemic)

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced)

Phylum: Chordata

Order: Anura

Family: Ranidae

Rana rugosa (Purposely Introduced)

Order: Cypriniformes

Family: Cobitidae

Misgurnus anguillicaudatus (Introduced)

Order: Cyprinodontiformes

Family: Poecillidae

Xiphophorus helleri (Purposely Introduced)

Order: Salmoniformes

Family: Salmonidae

Onchorhynchus mykiss (Introduced)

Koaie Stream

Phylum: Arthropoda

Order: Coleoptera

Family: Dytiscidae

Rhantus pacificus (Endemic)

Order: Diptera

Family: Canacidae

Procanace bifurcata (Endemic)
Procanace nigroviridis (Endemic)
Procanace quadrisetosa (Endemic)

Family: Ceratopongonidae

Forcipomyia sp (Endemic)

Family: Chironomidae

Cricotopus bicinctus (Introduced)
Telmatogeton sp. (Endemic)

Family: Dolichopodidae

Campsicnemus nigricollis (Endemic)
Campsicnemus sp (Endemic)
Dolichopus exsul (Introduced)
Eurynogaster mediocris (Endemic)
Eurynogaster minor (Endemic)
Paraliancalus metallicus (Endemic)
Sigmatineurum napali (Endemic)

Family: Ephydridae

Scatella cilipes (Endemic)
Scatella hawaiiensis (Endemic)
Scatella kauaiensis (Endemic)

Family: Tipulidae

Limonia advena (Introduced)
Limonia hawaiiensis (Endemic)
Limonia jacoba (Endemic)

Limonia stygipennis (Endemic)

Order: Heteroptera

Family: Saldidae

Saldula exulans (Endemic)

Saldula procellaris (Endemic)

Family: Veliidae

Microvelia vagans (Endemic)

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp nr montivolans (Endemic)

Hyposmocoma sp nr saccophora (Endemic)

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic)

Family: Coenagrionidae

Ischnura posita (Introduced)

Megalagrion eudytum (Endemic)

Megalagrion heterogamias (Endemic)

Megalagrion oresitrophum (Endemic)

Megalagrion vagabundum (Endemic)

Family: Libellulidae

Nesogonia blackburni (Endemic)

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced)

Family: Hydroptilidae

Oxyethira maya (Introduced)

Phylum: Chordata

Order: Anura

Family: Ranidae

Rana rugosa (Purposely Introduced)

Order: Salmoniformes

Family: Salmonidae

Onchorhynchus mykiss (Introduced)

Waiakoali Stream

Phylum: Arthropoda

Order: Decapoda

Family: Cambaridae

Procambarus clarkii (Purposely Introduced)

Order: Diptera

Family: Ceratopongonidae

Forcipomyia sp (Endemic)

Family: Chironomidae

Cricotopus bicinctus (Introduced)

Micropsectra sp (Endemic)

Family: Ephydridae

Scatella hawaiiensis (Endemic)

Scatella kauaiensis (Endemic)

Family: Tipulidae

Limonia hawaiiensis (Endemic)

Limonia jacoba (Endemic)

Order: Heteroptera

Family: Saldidae

Saldula oahuensis (Endemic)

Saldula procellaris (Endemic)

Family: Veliidae

Microvelia vagans (Endemic)

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp nr montivolans (Endemic)

Hyposmocoma sp nr saccophora (Endemic)

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic)

Family: Coenagrionidae

Enallgma civile (Introduced)

Ischnura posita (Introduced)

Megalagrion heterogamias (Endemic)

Megalagrion oresitrophum (Endemic)

Megalagrion vagabundum (Endemic)

Family: Libellulidae

Nesogonia blackburni (Endemic)

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced)

Phylum: Chordata

Order: Anura

Family: Ranidae

Rana rugosa (Purposely Introduced)

Order: Cypriniformes

Family: Cobitidae

Misgurnus anguillicaudatus (Introduced)

Order: Salmoniformes

Family: Salmonidae

Onchorhynchus mykiss (Introduced)

Waialae Stream

Phylum: Arthropoda

Order: Coleoptera

Family: Dytiscidae

Rhantus pacificus (Endemic)

Order: Diptera

Family: Canacidae

Procanace nigroviridis (Endemic)

Procanace quadrisetosa (Endemic)

Family: Chironomidae

Cricotopus bicinctus (Introduced)

Family: Dolichopodidae

Campsicnemus nigricollis (Endemic)
Sigmatineurum napali (Endemic)

Family: Ephydridae

Scatella cilipes (Endemic)
Scatella hawaiiensis (Endemic)
Scatella kauaiensis (Endemic)

Family: Tipulidae

Limonia hawaiiensis (Endemic)
Limonia jacoba (Endemic)
Limonia stygipennis (Endemic)

Order: Heteroptera

Family: Saldidae

Saldula exulans (Endemic)
Saldula procellaris (Endemic)

Family: Veliidae

Microvelia vagans (Endemic)

Order: Lepidoptera

Family: Cosmopterigidae

Hyposmocoma sp nr montivolans (Endemic)
Hyposmocoma sp nr saccophora (Endemic)

Order: Odonata

Family: Aeshnidae

Anax strenuus (Endemic)

Family: Coenagrionidae

Enallgma civile (Introduced)
Ischnura posita (Introduced)
Ischnura ramburii (Introduced)
Megalagrion heterogamias (Endemic)
Megalagrion oresitrophum (Endemic)

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced)

Phylum: Chordata

Order: Anura

Family: Ranidae

Rana rugosa (Purposely Introduced)

Order: Salmoniformes

Family: Salmonidae

Onchorhynchus mykiss (Introduced)

APPENDIX C- Aquatic Species Collected in Kōkeʻe State Park Streams – Surber (Benthic) Samples

SURBER Totals by Stream

	Total Numbers:	# Stations found	# Stations sampled
Kauaikinana Stream			
Phylum: Annelida			
Order: Oligochaeta			
Family:			
Oligochaeta (Unknown)	61	9	
7 Aug 1997	26	4	4
11 Jan 1999	35	5	8
Phylum: Arthropoda			
Order: Diptera			
Family: Chironomidae			
Cricotopus bicinctus (Introduced)	45	10	
7 Aug 1997	3	3	4
11 Jan 1999	42	7	8
Order: Trichoptera			
Family: Hydropsychidae			
Cheumatopsyche pettiti (Introduced)	196	12	
7 Aug 1997	48	4	4
11 Jan 1999	148	8	8
Kawaikoi Stream			
Phylum: Annelida			
Order: Arhynchobdellida			
Family: Erpobdellidae			
Barbronia weberi formosana	2	2	
6 Aug 1997	2	2	9
Order: Oligochaeta			
Family:			
Oligochaeta (Unknown)	19	9	
6 Aug 1997	9	5	9
11 Jan 1999	10	4	6
Phylum: Arthropoda			
Order: Coleoptera			
Family: Dytiscidae			
Rhantus pacificus (Endemic)	1	1	
11 Jan 1999	1	1	6
Order: Diptera			
Family: Chironomidae			
Cricotopus bicinctus (Introduced)	72	9	
6 Aug 1997	11	3	9
11 Jan 1999	61	6	6
Order: Odonata			
Family: Coenagrionidae			

Megalagrion heterogamias (Endemic)	3	3	
6 Aug 1997	2	2	9
11 Jan 1999	1	1	6
Order: Trichoptera			
Family: Hydropsychidae			
Cheumatopsyche pettiti (Introduced)	71	6	
6 Aug 1997	71	6	9

<u>Koaie Stream</u>

Phylum: Annelida			
Order: Arhynchobdellida			
Family: Erpobdellidae			
Barbronia weberi formosana	6	4	
4 Aug 1997	2	2	9
7 Jan 1999	4	2	6
8 Jan 1999	1	1	1
Order: Oligochaeta			
Family:			
Oligochaeta (Unknown)	5	3	
4 Aug 1997	4	2	9
7 Jan 1999	1	1	6
8 Jan 1999	1	1	1
Phylum: Arthropoda			
Order: Coleoptera			
Family: Dytiscidae			
Rhantus pacificus (Endemic)	1	1	
4 Aug 1997	1	1	9
Order: Diptera			
Family: Chironomidae			
Cricotopus bicinctus (Introduced)	20	9	
2 Aug 1997	1	1	1
4 Aug 1997	7	5	9
7 Jan 1999	12	3	6
8 Jan 1999	3	1	1
Family: Tipulidae			
Tipulidae (Unknown)	2	2	
4 Aug 1997	1	1	9
7 Jan 1999	1	1	6
Order: Odonata			
Family: Coenagrionidae			
Megalagrion heterogamias (Endemic)	1	1	
4 Aug 1997	1	1	9
8 Jan 1999	1	1	1
Order: Trichoptera			
Family: Hydropsychidae			

Cheumatopsyche pettiti (Introduced)	96	16	
2 Aug 1997	8	1	1
4 Aug 1997	56	9	9
7 Jan 1999	32	6	6
8 Jan 1999	1	1	1

Waiakoali Stream

Phylum: Annelida

Order: Oligochaeta

Family:

Oligochaeta (Unknown)	17	5	
10 Jan 1999	17	5	7

Phylum: Arthropoda

Order: Acari

Family: Trhypochthoniidae

Trhypochthoniellus sp (Endemic)	2	1	
10 Jan 1999	2	1	7

Order: Diptera

Family: Chironomidae

Cricotopus bicinctus (Introduced)	38	5	
10 Jan 1999	38	5	7

Order: Trichoptera

Family: Hydropsychidae

Cheumatopsyche pettiti (Introduced)	33	6	
10 Jan 1999	33	6	7

Phylum: Nematomorpha

Order: Gordioidea

Family: Gordiidae

Gordius sp (Introduced)	1	1	
10 Jan 1999	1	1	7

Waialae Stream

Phylum: Annelida

Order: Arhynchobdellida

Family: Erpobdellidae

Barbronia weberi formosana	4	3	
6 Jan 1999	4	3	9

Order: Oligochaeta

Family:

Oligochaeta (Unknown)	20	4	
6 Jan 1999	20	4	9

Phylum: Arthropoda

Order: Diptera

Family: Chironomidae			
Cricotopus bicinctus (Introduced)	2	2	
6 Jan 1999	2	2	9
Family: Tipulidae			
Tipulidae (Unknown)	1	1	
6 Jan 1999	1	1	9
Order: Odonata			
Family: Coenagrionidae			
Megalagrion heterogamias (Endemic)	1	1	
6 Jan 1999	1	1	9
Order: Trichoptera			
Family: Hydropsychidae			
Cheumatopsyche pettiti (Introduced)	40	8	
6 Jan 1999	40	8	9

APPENDIX D- Aquatic Species Collected in Kōke‘e State Park Streams – Drift Samples

DRIFT Totals by Stream

	Total:
Kauaikinana Stream	
Phylum: Arachnida	
Order: Aranae	
Family: Tetragnathidae	
Tetragnatha sp (Endemic) -- Terrestrial	1
Phylum: Arthropoda	
Order: Acari	
Family: Oribatulidae	
Oribatulidae (Unknown) -- Terrestrial	12
Order: Coleoptera	
Family: Carabidae	
Tachys arcanicola (Endemic) -- Terrestrial	1
Order: Diptera	
Family: Cecidomyiidae	
Cecidomyiidae (Unknown) -- Terrestrial	2
Family: Ceratopongonidae	
Forcipomyia hardyi (Endemic) -- Aquatic	2
Family: Chironomidae	
Cricotopus bicinctus (Introduced) -- Aquatic	76
Family: Drosophilidae	
Drosophila sp (Unknown) -- Terrestrial	1
Family: Sciaridae	
Sciara sp (Endemic) -- Terrestrial	4
Family: Tipulidae	
Tipulidae (Unknown) -- Aquatic	4
Order: Homoptera	
Family: Delphacidae	
Leialoha sp (Endemic) -- Terrestrial	1
Order: Isopoda	
Family: Porcellionidae	
Porcellio laevis (Introduced) -- Terrestrial	3
Order: Lepidoptera	
Family: Crambidae	
Eudonia sp (Endemic) -- Terrestrial	2
Order: Psocoptera	
Family: Psocidae	
Palistreptus inconstans (Endemic) -- Terrestrial	1
Order: Thysanoptera	
Family: Thripidae	
Heliothrips haemorrhoidalis (Introduced) -- Terrestrial	3
Order: Trichoptera	
Family: Hydropsychidae	
Cheumatopsyche pettiti (Introduced) -- Aquatic	2
Family: Hydroptilidae	
Hydroptilla arcitia (Introduced) -- Aquatic	1
Oxyethira maya (Introduced) -- Aquatic	6

Kawaikoi Stream

Phylum: Arthropoda

Order: Acari

Family: Oribatulidae

Oribatulidae (Unknown) -- Terrestrial	3

Order: Collembola

Family: Entomobryidae

Siera terrestris (Introduced) -- Terrestrial	1

Family: Onychiuridae

Onychiurus fimetarius (Introduced) -- Terrestrial	1

Order: Diptera

Family: Ceratopongonidae

Forcipomyia hardyi (Endemic) -- Aquatic	53

Family: Chironomidae

Chironomus sp (Endemic) -- Aquatic	31
Cricotopus bicinctus (Introduced) -- Aquatic	39

Family: Sciaridae

Sciara sp (Endemic) -- Terrestrial	1

Order: Homoptera

Family: Aphidae

Aphis sp (Introduced) -- Terrestrial	1

Family: Psyllidae

Trioza sp (Endemic) -- Terrestrial	4

Order: Psocoptera

Family: Caeciliidae

Caecilius analis (Introduced) -- Terrestrial	1

Koaie Stream

Phylum: Arthropoda

Order: Acari

Family: Oribatulidae

Oribatulidae (Unknown) -- Terrestrial	1

Order: Coleoptera

Family: Cucujidae

Cryptomorpha desjardinsi (Introduced) -- Terrestrial	1

Family: Scolytidae

Xyleborus affinis (Introduced) -- Terrestrial	2
Xyleborus ferrugineus (Introduced) -- Terrestrial	4

Order: Collembola

Family: Sminthuridae

Dicyrtoma sp (Endemic) -- Terrestrial	1

Order: Diptera

Family: Ceratopongonidae

Forcipomyia hardyi (Endemic) -- Aquatic	7

Family: Chironomidae

Chironomidae (Unknown) -- Aquatic	30
Chironomus sp (Endemic) -- Aquatic	3
Cricotopus bicinctus (Introduced) -- Aquatic	53
Orthocladius sp (Endemic) -- Aquatic	1
Family: Tipulidae	
Tipulidae (Unknown) -- Aquatic	1
Order: Hymenoptera	
Family: Eucoilidae	
Hypodiranchis sp (Endemic) -- Terrestrial	1
Family: Mymaridae	
Polynema sp (Endemic) -- Terrestrial	1
Order: Trichoptera	
Family: Hydropsychidae	
Cheumatopsyche pettiti (Introduced) -- Aquatic	2
Family: Hydroptilidae	
Oxyethira maya (Introduced) -- Aquatic	8
Phylum: Mollusca	
Order:	
Family: Zonitidae	
Oxychilus alliarius (Introduced) -- Terrestrial	4

<u>Waiakoali Stream</u>

Phylum: Annelida	
Order: Oligochaeta	
Family:	
Oligochaeta (Unknown) -- Aquatic	1
Phylum: Arthropoda	
Order: Diptera	
Family: Canacidae	
Procanace wirthi (Endemic) -- Aquatic	1
Family: Chironomidae	
Chironomus sp (Endemic) -- Aquatic	6
Cricotopus bicinctus (Introduced) -- Aquatic	37
Orthocladius sp (Endemic) -- Aquatic	1
Family: Drosophilidae	
Drosophila sp (Unknown) -- Terrestrial	1
Family: Sciaridae	
Sciara sp (Endemic) -- Terrestrial	1
Family: Tipulidae	
Limonia sp (Unknown) -- Aquatic	1
Order: Heteroptera	
Family: Saldidae	
Saldula exulans (Endemic) -- Aquatic	1
Order: Homoptera	
Family: Psyllidae	
Megatryoza sp (Endemic) -- Terrestrial	2
Order: Isopoda	

Family: Porcellionidae	
Porcellio laevis (Introduced) -- Terrestrial	1
Order: Lepidoptera	
Family: Cosmopterigidae	
Hyposmocoma sp (Endemic) -- Aquatic	2
Hyposmocoma sp 1 (Endemic) -- Aquatic	7
Family: Crambidae	
Eudonia sp (Endemic) -- Terrestrial	1
Family: Geometridae	
Scotorythra sp (Endemic) -- Terrestrial	1
Family: Nymphalidae	
Vanessa sp (Endemic) -- Terrestrial	1
Order: Psocoptera	
Family: Caeciliidae	
Caecilius analis (Introduced) -- Terrestrial	3
Order: Trichoptera	
Family: Hydropsychidae	
Cheumatopsyche pettiti (Introduced) -- Aquatic	5

APPENDIX E- Glossary of Biological Terms

GLOSSARY- Some aquatic terms derived from Armantrout (1998)

Adaptive radiation: the phenomenon wherein a single species, through time, evolves and speciates to a high degree adapting to an environment or other external condition. Excellent examples in the Hawaiian Islands are the 800 or so endemic Hawaiian *Drosophila* flies (which account for about 50 % of the world's fauna of that genus).

Adventive: relating to organisms introduced to an area by means other than purposeful.

Alien: (see also **adventive**, **exotic**, **introduced**, **non-indigenous**, **or non-native**) relating to a species that is not native, i.e., one introduced accidentally or purposefully by humans. In Hawai'i, these include Polynesian introductions (such as kukui, coconut, pig, rat, and jungle fowl) and many post-contact (1778) introductions (such as guava, Christmas berry, mosquitoes, pigs, goats, cattle, deer, and sheep). See **Endemic**, **Indigenous**, **Native**.

Amphidromous: life history strategy used to describe diadromous species in which migration between fresh water and the sea is not for the purpose of breeding, but is necessary for native Hawaiian stream fish, crustaceans and certain mollusks at some point in their life cycle. See **Diadromous**.

Amphipod: a small crustacean invertebrate that can be found in aquatic or terrestrial habitats.

Arthropod: insects and related invertebrate animals (spiders, centipedes) that have an external hard skeleton and jointed legs.

Benthos: bottom-dwelling organisms including plants, invertebrates, and vertebrate animals that inhabit the bottom or bed of a water body. **Benthic sampling** through the use of **Surber** or **Hess** samplers are commonly used to assess the composition of the benthic community. See **Surber**.

Canopy: the highest vegetation cover of a community. In a forest, the canopy is made up of the tallest and most numerous trees. In a shrubland, the canopy is the tallest shrub layer. Closed canopies are those where the foliage interlocks to form a continuous layer over the underlying vegetation or ground. Open canopies are those where there are gaps in the foliage, and more light may reach the lower vegetation layers or ground.

Cascade: highly turbulent series of short falls and small scour basins, with rapid water movement as it passes over a steep channel bottom, with gradients exceeding 8%. Water surface is frequently broken by short, irregular plunges creating white-water and defined by large substrates. Many Hawaiian aquatic insects are restricted to this habitat.

Catadromous: Life history strategy involving the migration between fresh and saltwater in which fish reproduce and spend their early life stages in saltwater, move into freshwater to rear as sub-adults, and return to saltwater to spawn as adults. This pattern is not exhibited by Hawaiian stream organisms. See **Diadromous**, **Amphidromous**.

Diadromous: life history strategy that includes movement between fresh and saltwater and the organisms exhibit two migrations to spend various life stages in the ocean or stream. In Hawai'i, native stream fish, crustaceans, and certain mollusks exhibit this life history pattern. See **Amphidromous**.

Diel: pertaining to a 24 hr period or a regular occurrence in every 24 hr period.

Diptera, **dipteran**: two-winged insects, such as flies, mosquitoes.

Discharge: rate at which a volume of water flows past a point in the stream per unit of time, usually expressed as cubic meters per second or cubic feet per second.

DLNR: State of Hawaii Department of Land and Natural Resources.

Drift: the voluntary or involuntary transport of aquatic animals in running waters. Drift is an important phenomena that allows aquatic animals to colonize disturbed stream areas, escape unfavorable conditions, provides food for other animals, and allows native Hawaiian amphidromous organisms access to the sea and is a necessary part of their life cycle.

Ecosystem: a discrete assemblage of animals and plants and its interaction with the environment.

Edge effect: The influence of one habitat on an adjacent different habitat; results in a transition zone between the habitats; especially the indirect effect of human disturbance (e.g., road construction) on the undisturbed habitat adjacent to the activity.

Endangered: a species officially recognized by federal or state officials to be in immediate danger of extinction.

Endemic: naturally restricted to a locality. Most native Hawaiian plants and animals are endemic (restricted) to the Hawaiian Islands. Many are restricted to a single island, mountain range, or even gulch. See **Alien**, **Native**, **Indigenous**.

Endemism: the extent to which the species of a region are unique to that region. See **Endemic**.

Exotic: not native. See **Alien**.

Falls: free-falling water with vertical or nearly vertical drops as it falls over an obstruction.

Fauna: the animals of a specified region.

Federal Status: current U.S. Fish and Wildlife Service categories for endangered and candidate endangered taxa according to the Federal Register:

Feral: formerly domesticated animals reverted to wild state or living in wild habitat.

Fluvial: pertaining to or living in streams or rivers, or produced by the action of flowing water.

Freshets: a dangerous and rapid temporary rise in stream discharge and level caused by heavy rains, in Hawaiian streams often accompanied by a standing wave moving downstream and a loud thunder sound. Because of the short length of Hawaiian streams stream levels decrease quickly as well. See **Spates**.

Geomorphological processes: dynamic actions or events occurring at the earth's surface due to natural forces resulting from gravity, temperature changes, freezing and thawing, chemical reactions, seismic activity, and the forces of wind and moving water. Where and when a force exceeds the strength of the earth material, the material is changed by deformation, translocation, or chemical reaction.

Gobiidae: a large family of mostly marine fish with some species such as the native Hawaiian stream fish spending almost all of their lives in freshwater. Four species are found in Hawaiian streams, and all are considered sensitive to the impacts of introduced aquatic species.

High Gradient Riffle: a collective term for rapids and cascades. Steeper reaches of moderately deep, swift (> 4%), and very turbulent waters. Riffles generally have exposed substrates dominated by large boulders and rocks. See **Riffles**.

Holotype: the single specimen (only if so designated) on which an animal species was originally described, and which the scientific name for the species is based upon. The remainder of the series of specimens used by the original author in describing the species are termed **paratypes**. If no single specimen is designated as such, the original series of specimens upon which the species was described are termed **syntypes**. The term **type** or **type material** is an informal general term relating to all the above.

Immature: the stage of an animal that is not an adult. In the context of this report, damselfly and dragonfly immatures are termed naiads; other insect immatures are called larvae or nymphs.

Indigenous: naturally occurring in a given area as well as elsewhere. Indigenous Hawaiian taxa also occur naturally outside of the Hawaiian Islands (e.g., the long-legged fly genus *Campsicnemus* is indigenous to Hawaiʻi, but is also found naturally in French Polynesia and continental land masses above the equator). See **Alien**, **Endemic**, **Native**.

Insular: of or pertaining to an island or islands. Also applied to dwelling on an island, forming an island, or occurring alone.

Introduced: See **Alien**.

Invertebrate: animals without backbones, including such groups as insects, spiders, shrimps, and snails. Some Hawaiian invertebrates are rare and endangered.

Larva/larval: an immature stage of an insect.

Lentic: aquatic system with standing or slow flowing water (e.g. lake, pond, reservoir) and having a nondirectional net flow of water.

Lotic: aquatic system with rapidly flowing water (e.g. stream, river, irrigation ditch) where the net water flow is unidirectional from the headwaters to the mouth.

Lowland: one of five elevation zones used to classify Hawaiian natural communities. The Hawaiian lowland zone lies above the coastal zone, up to about 1000 m. [approx. 3300 feet] elevation. There is lowland zone on all of the main islands.

Malacology: the branch of zoology dealing with mollusks, including snails.

Malaise: a type of flight intercept trap using a fine mesh net to collect flying insects.

Microhabitat: habitats within habitats. For example, within a rainforest habitat, a microhabitat could include the moss growing on only a single species of plant.

Mollusk: invertebrates in the phylum Mollusca. Common representatives are snails, slugs, mussels, clams, oysters, squids, and octopuses.

Morphospecies: specimens grouped together based on similar appearance. This type of sorting is usually done as a preliminary step to more detailed analysis using other examination and identification techniques.

Naiad: the immature aquatic, arboreal, or terrestrial stage of a damselfly or dragonfly.

Native: found naturally in an area, not introduced accidentally or purposefully by humans; includes both indigenous and endemic taxa. See Alien, Endemic, Indigenous.

Nocturnal: active or most apparent at night.

Non-indigenous: See **Alien**.

Non-native: See **Alien**.

Odonata/odonates: damselflies and dragonflies.

Pool: aquatic habitat with a gradient <1% that is normally deeper and and wider and than habitats above and below it, also generally with lower water velocities than surrounding adjacent aquatic habitats.

Predatory: the state of being a predator; preying on other animals for food requirements.

Protected: legally dedicated to the perpetuation of native resources and managed to mitigate or remove threats to those resources, if necessary. Areas lacking either legal protection or management are considered incompletely protected.

Purposefully introduced: organisms that are brought into an area for a specific purpose; often as biological control agents in the control of unwanted plants or animals. See **Alien**.

Rare: threatened by extinction because of low numbers. Any plant, animal, or natural community that can be immediately threatened by such factors as alien invasion, direct destruction, or loss of habitat.

Rheocrene: perennial seeps and springs that flow only a short distance over a rock surface or in indistinct channels. See **Seep**.

Riffles: shallow reaches with low subcritical flow (1-4% gradient) in alluvial channels of finer particles that are unstable, characterized by small hydraulic jumps over rough bed material, causing small ripples, waves, and eddies without breaking surface tension. See **High Gradient Riffle**.

Riparian: the margin along the streamside or other water body, or areas along the banks of a stream.

Riparian vegetation: water dependent vegetation growing on or near streambanks, although in Hawai‘i few native plant species are exclusively found in riparian areas.

Seeps: small ground discharge that slowly oozes to the surface of the ground or into a stream. A seep oozes water slowly and differs from a spring that visibly flows from the ground. See **Rheocrene**.

Sensitive species: in the context of this report on invertebrates, those species that have been listed previously by the USFWS as either endangered, threatened, species of concern, or have not been listed, but are considered by experts in the group to be rare and their populations threatened.

Spates: periods of high water or flooding. See **Freshets**.

Speciate: to evolve into different species through time.

Species of concern: rare or threatened species not formally listed as endangered, threatened, or as candidates but given this designation by USFWS. Generally includes species considered rare but for which additional information is sought before a formal listing proposal can be made. See **Federal Status**.

sp.. abbreviation for species.

spp.: abbreviation for more than one species.

Spring: site where ground flows naturally from a rock or soil substrate to the surface to form a stream, pond, marsh, or other type of water body. See **Seep** and **Rheocrene**.

Stream Channel: bed and banks formed by fluvial processes where a natural stream of water runs continually or intermittently

Subspecies: (abbreviated ssp.) a taxonomically distinguishable geographic or ecological subdivision of a species. See **Variety**.

Surber Sampler: a square 30 x 30 cm metal frame with a very fine-meshed net attached that is used to obtain bottom samples in flowing water by stirring the substrate. Aquatic organisms are then retrieved from the end of the net. See **Benthos**.

Synonym: in the context of this report, one of two scientific names given independently to the same real species.

Taxon (plural = **Taxa**): a group of plants or animals making up one of the categories or formal units in taxonomic classification. In this report a taxon can be a phylum, order, family, genus, species, subspecies, variety, or form. This distinction is important because certain species have endemic Hawaiian subspecies and varieties that are considered rare.

Type locality: the locality at which the holotype or syntypes were collected. See **Holotype**.

USFWS: United States Fish and Wildlife Service.

USGS: United States Geological Survey.

Vagile/vagility: endowed with or having freedom of movement; wandering.

Variety: (abbreviated var.) a taxonomically distinguishable subdivision of a species or subspecies. See **Subspecies**.

Vertebrate: an animal with a backbone; native vertebrate species in Hawaiʻi include fish, birds, a bat, and a seal. See **Invertebrate**.

Volant: flying; capable of moving through the air.

Voucher specimen: specimen deposited in a recognized collection that can be used as a reference in future studies.

APPENDIX F- List of Authors, Taxonomic Consultants and Acknowledgements of Assistance

This study was conducted through the facilities of the Bishop Museum Department of Natural Sciences by:

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TAXONOMIC CONSULTANTS AND ACKNOWLEDGEMENTS

We thank Deane Gonzalez, Donna Gonzalez, Andy Baker, Urbi Nash, and Clifton Alston of Hawaii Trout Unlimited, Waikaheʻolu Chapter for collecting the trout examined in this study. Dr. Jim DiMarchi of Hawaii Trout Unlimited was an important catalyst in starting this study. Wade Ishikawa of the Hawaii Division of Aquatic Resources provided valuable assistance, and a special thanks goes to Myles Domingcil of Hanapēpē, Kauaʻi for providing Bishop Museum staff with logistical assistance on the island of Kauaʻi. Critical reviews of this study were provided by Dr. R.T. Nishimoto, Hawaii Division of Aquatic Resources, Dr. J.M. Fitzsimons, Louisiana State University, and Dr. L.G. Eldredge, Dr. N.L. Evenhuis, and Dr. A. Allison of the Bishop Museum. We especially would like to thank Tracie Mackenzie and Cheri Burke for their administrative support, and Bishop Museum librarians B.J. Short and Patty Belcher for their assistance.

Taxonomic expertise for identifying organisms was provided by the following individuals, and their efforts and contributions to this project are gratefully acknowledged.

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