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CASCADE MACROINVERTEBRATE ASSEMBLAGES FOR IN-STREAM FLOW
CRITERIA AND BIOMONITORING OF HIGH GRADIENT TROPICAL STREAMS

Thesis

Submitted to

The College of Arts and Sciences of the

UNIVERSITY OF DAYTON

in Partial Fulfillment of the Requirements for

The Degree

Master of Science in Biology

by


Megan Elizabeth Shoda

UNIVERSITY OF DAYTON

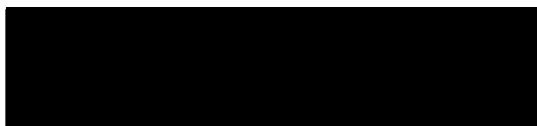
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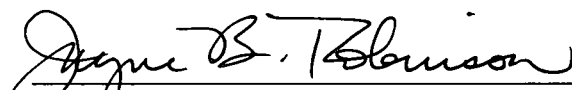
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ABSTRACT

CASCADE MACROINVERTEBRATE ASSEMBLAGES FOR IN-STREAM FLOW CRITERIA AND BIOMONITORING OF HIGH GRADIENT TROPICAL STREAMS

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Few comprehensive studies have been conducted in tropical freshwater streams. Currently under threat from climate change, urbanization and increasing freshwater demands, there is need for a more thorough approach to their assessment and management. This study investigated cascade habitats and their variation between four high gradient streams with differing percentages of flow removal. Two cascade microhabitats were evaluated for the density and diversity of endemic taxa. Two-way ANOVA found no main effects, but a significant interaction between mean densities for stream and location for the torrenticolous microhabitat. However, the opposite was true for the amphibious microhabitat. Diversity was significantly higher in upstream locations, ($t=4.213$, $df=272$, $p=0.0004$) and torrenticolous habitats ($t=3.864$, $df=272$, $p<0.0001$) over the entire study period. The amphibious microhabitat was composed of 38.5% endemic taxa, while the torrenticolous microhabitat contained only

6.34%. In addition, cascade habitats in general were reduced in downstream reaches, as much as 98%. This study provides new options for the biomonitoring of cascades as an unconventional, but valuable tool for understanding stream assemblages, especially in tropical streams where endemic populations are frequently at risk. Further studies that support the development of in-stream flow criteria that preserve cascade habitats are needed.

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CHAPTER 1: Literature Review

Introduction

Tropical streams are understudied compared to their temperate counterparts (Moulton and Wantzen, 2006). A need exists for comprehensive tropical research that takes into account variation that exists in the differing regions of the world (Craig, 2003). Tropical, high gradient streams are common in certain areas of the world. Oceanic, volcanically formed islands typical of the tropics are a dominant source of these streams. Areas like Micronesia, Polynesia and the Caribbean are some examples. Not only are these areas of the world home to this habitat type, they are also frequently classified as hotpots of biodiversity. The isolation of volcanic islands allows organisms that live there to adapt under a unique set of conditions. These conditions often produce organisms so specialized to a specific habitat they are found nowhere else in the world.

One classification of these organisms is the macroinvertebrate. Macroinvertebrates, such as insects and crustaceans, are ideal biological indicators of overall stream health and integrity and can be used to measure the disturbance of a stream system (Rosenberg and Resh, 1993).

They play a fundamental role in the biological community of aquatic ecosystems by facilitating energy flow and nutrient transport among higher and lower trophic levels. Through the use of macroinvertebrates, physical-biological coupling can aid our understanding of the dynamic organization of the ecological structure of streams and rivers. This structure is of particular interest in the Hawaiian Islands. As an isolated land mass with a high percentage of endemic organisms, the evolution of life in this area is of particular interest and the effect of current changes in stream habitat is in need of investigation (Zimmerman, 1970).

The macroinvertebrate communities of Hawaii display astounding adaptive radiation as a result of the isolation within which they have evolved. This has produced organisms that are constrained by specific conditions; in fact many invertebrate taxa in general are constrained by near-bed flow conditions, living within the roughness layer where turbulent flows are highly irregular and unpredictable (Dolédéc *et al.*, 2007). Previous studies have shown that benthic macroinvertebrates and food resources are influenced by water flow parameters. However, many such studies have not addressed specific relationships between the flow parameters in a way that could be used to confidently predict habitat preferences (Benbow *et al.*, 1997). Microhabitat characteristics have the ability to affect the size and growth of at least two endemic insects in Hawaii and at least one introduced species that may be a food source

for endemic fish (Benbow, *et al.*, 1997; McIntosh *et al.* 2003).

Chapter one is a brief review of Hawaiian stream systems, giving special attention to the characteristics and organisms that make them unique. It also covers the ecological challenges this area of the world is currently experiencing and introduces the habitat under study in this thesis project. Lastly, a review of previous work in Hawaiian streams is provided as a backdrop for the current study. Chapter two is the manuscript titled: Cascade Macroinvertebrate Assemblages for In-Stream Flow Criteria and Biomonitoring of High Gradient Tropical Streams.

Stream Disturbance

Streams are naturally subjected to various forms of disturbance. Seasonal changes in precipitation, shifts in chemical and mineral composition of riparian forests, faunal behavior patterns and stochastic events each contribute to overall disturbance of stream life. Doeg *et al.* notes that changes in discharge are probably the most important forms of disturbance (1989). In addition to natural discharge-driven disturbances, anthropogenic disturbances can further challenge an understanding of stream responses to discharge variation. In stream ecology, flow conditions are commonly altered by human activities such as dam construction, channelization, and urbanization (Hart and Finelli, 1999). Stream processes and patterns are regulated by flow dynamics, thus interruption of stream flow has the potential to disrupt natural community

structure, including the abundance and diversity of naturally occurring organisms (Hart and Finelli, 1999). Knowledge of how organisms colonize and persist in a habitat after such a disturbance can provide insight into the impact of human processes on natural systems (Dolédec *et al.*, 2007). There is evidence of these processes occurring due to human impacts in the freshwater mountain streams of the Hawaiian Islands (McIntosh *et al.*, 2002). The Hawaiian Islands are volcanically formed and thus are home to steep mountain ridges that create narrow watersheds. This geological structure creates a flashy hydrology that can result in violent floods and water levels that dramatically rise and fall, even within a period of hours. In addition to this highly variable freshwater flow, the Islands are subject to human disturbance in the primary form of water diversions. The dams, ditches and channelizations associated with the diversion system have had a historic impact on stream communities.

History of Water Diversion

Water is a valuable resource regardless of geography, but in the Hawaiian Islands, it is especially important, considering that these islands are surrounded by thousands of square kilometers of saltwater. Native practices of taro cultivation and harvesting of prawns, shrimp and snails for food rely upon a freshwater source that continually flows from the mountains to the ocean. During pre-historic times, diversions were used to provide water for village needs but excess water was always returned to

the stream and the stream continuum was never broken. The ahupua'a system was developed by the first Hawaiians and utilized an intricate parceling system to determine how and where water was to be taken from the streams and subsequently returned. Vital to the functioning of this system was the belief that water was never removed from the watershed of its collection. This ancient water management technique epitomized the balance of necessity, environment and culture.

Western contact brought modern development of mass agriculture and permanent water removal to support tropical sugarcane and pineapple plantations (Wilcox, 1996). Since then, a booming tourism industry has called for an increasing freshwater demand on the leeward sides of the islands. The island of Maui in particular, has suffered from the need for a continual water supply. Some streams in the West Maui mountains experience 97% diverted flow (McIntosh *et al.*, 2002). This water is diverted to ditches and pipelines that run through the mountains to resorts and golf courses far from the watersheds where it was collected. The removal of this magnitude of water has the potential for great detriment to stream life that, according to the Hawaii State Constitution, is protected and prioritized (H.I. Const. art.XI, §7).

At date of publication, the Hawaii State Commission on Water Resource Management is in deliberation on a case that involves the 4 study streams of this thesis project (Eagar, 2008). Renowned for their

cultural and ecological value, these streams of the West Maui mountains are known as the Na Wai Eha; all are currently diverted and their flow is controlled by a private owner, the Wailuku Water Company. Multiple environmental groups have collectively petitioned against Wailuku Water Co. to convince the commission that stream flow belongs under Maui County management. In September of 2008, a similar case involving eight East Maui streams was concluded with the mandate that water must be returned to the streams, restoring the mountain to ocean continuum (Hamilton, 2008). In light of this precedent-setting ruling, it is necessary that baseline bioassessment data be gathered from the Na Wai Eha streams. It is within this socio-economic legal context that the proposed research is relevant, and in part, has been structured.

Hawaiian Endemic Organisms

The Hawaiian Islands are the most isolated island system in the world, located 3,200 kilometers from the nearest continent (Loope and Mueller-Dombois, 1989). This geographic isolation has allowed for remarkable adaptive radiation that has produced a total of 9,246 endemic organisms, that is, organisms that are found nowhere else in the world (Eldredge, 2000). Endemic organisms are a subset of an area's native population, which includes species that are local but can be found in other locales. The endemic insect population of the islands comprises 59% of the total endemism and is the particular focus of this thesis.

Despite the high numbers of endemic insects in Hawaii, two-thirds of existing insect orders are completely absent from Island communities and there is an overall low species richness compared to continental populations (Zimmerman, 1970). The few orders that are present have evolved rapidly and under a unique set of conditions to produce an abundance of entirely new species.

In addition to the multitude of endemic insects of Hawaii, the Islands are also home to four species of endemic fish, one endemic snail and one endemic prawn. Each of these freshwater organisms reproduces through amphidromy. Amphidromy is a life cycle in which adults live and breed in a freshwater stream. When the embryos hatch in the stream, they are washed out to the ocean where as postlarvae they feed and develop. After several months of marine existence, the juveniles migrate back into the stream, against the current, and continue to live and breed in the freshwater. This unique life history is under threat with the presence of water diversions that break the stream to ocean continuum. The concrete structures of diversions are an impediment to climbing organisms traveling back to their headwaters, but even more so, the dry patches of stream bed they create makes it nearly impossible for aquatic organisms to pass. In addition to these logistical challenges, the reduction of flow decreases the magnitude of the freshwater plume that some believe attracts the juveniles from the ocean back into the stream (Keith, 2003).

One of the endemic gobies of special interest is the *Lentipes concolor*. It has been shown that *Lentipes* reproduction is diminished in diverted streams, with a decrease in egg size and a more irregular reproductive cycle (Way, *et al.*, 1998). This example illustrates the reliance endemic organisms have on the natural flow cycles to reach full reproductive potential. When environmental cues are absent and habitat quality is decreased, organisms that have evolved in under specific environmental conditions are put at risk by their inability to rapidly adapt.

It has been hypothesized that native island species have an increased vulnerability to extinction, in part due to the same forces that have allowed them to be so unique (Wilson, 1961). Evolving in an environment lacking predators, disease, parasites and competition creates organisms that are spectacular but unprepared for contact with ecologically superior organisms (Zimmerman, 1970). The arrival of the Polynesians to Hawaii in A.D. 400 marked a dramatic increase in the rate of immigration of new species and it has been shown that since then, 15-20 species of insects have immigrated and become established in Hawaii each year (Beardsley, 1979). This introduction of new insect orders has become a reason for concern, because there is evidence to show that they jeopardize endemic populations and are one of the reasons for the wave of recent Hawaiian extinctions (Simberloff, 2005). Preserving the biodiversity of the Hawaiian Islands and understanding the response of

endemic organisms to changes in habitat characteristics has become a priority for conservationists. Identifying ideal habitat conditions for endemic species and using management practices to create those habitats is one strategy for insuring their preservation and conservation.

Introduction to Cascade Habitat

The hydrology of Hawaiian streams is also of interest when studying endemic organisms and their response to decreased water volume and velocity. The volcanic formation of the Hawaiian Islands has created a steep gradient that makes the flow of its mountain streams variable and subject to floods. The geology of the area also contributes to the scouring floods, known as spates or freshets, that are common in mountain streams. As the result of an intense rainfall, these streams can reach maximum flow in just a few hours and return to baseflow just as quickly (Juvik, 1998). These flooding events wash boulders clean of accumulating algae and debris and contribute to the drifting of organism to new habitats. The hydrogeology of Hawaiian streams is one of the factors contributing to the presence of my habitat of study: the cascade.

The cascade is a unique channel unit and defined by Hauer and Lamberti as being a highly turbulent series of short falls (1996). The streams of the West Maui mountains are characterized by the presence of these cascade habitats as a result of the large boulder substrate and high gradient of the streams in general. It has been suggested that the fast

flowing cascade habitat is a hot spot for biodiversity in Hawaiian streams, however, little research has been performed on these habitats, perhaps because they are so confined to specific areas of the world (Benbow, *et al.*, 1997). This thesis project focuses on the Hawaiian cascade and separates it into microhabitats as a way to discern exactly which physical characteristics of the cascade are driving indications of change in community composition. By investigating the amphibious and torrential microhabitats of the in-stream cascade, we can determine what stream properties are the most important for dictating differences in community structure of the habitat.

Review of Hawaiian torrential research

Previous research has indicated that torrential cascade habitats are the in-stream habitats most severely impacted by interruptions in natural flow regimes (Benbow *et al.*, 1997). In the Hawaiian Islands, where a legacy of water diversion has caused a multitude of ecological impacts, cascade habitats are specifically threatened. The decrease of water volume and velocity due to diversion has caused a reduction in the number and magnitude of cascade habitats present in these streams today (Benbow, *et al.*, 2008; McIntosh, *et al.*, 2003). This in-stream habitat and associated microhabitats has also been reported to be the most ideal place for reproduction and proliferation of several endemic aquatic

insect species and thus, its decline has the potential for consequences that can extend into the riparian community (Benbow, *et al.*, 2008).

Some Hawaiian research has also been focused on the impact of introduced species on natural communities. Englund found that non-indigenous species compose a dominant portion of the biota in an Oahu estuary study, and in particular, he documented more introduced than native aquatic insects (2002). The same is true of similar stream surveys on Maui (McIntosh, *et al.*, 2003). An investigation done on one of the same study streams used in this project found decreased densities and biomass of macroinvertebrates in riffle habitats downstream of a water diversion (McIntosh, *et al.*, 2008). While it has been highlighted in previous studies that the torrential habitats are ideal for endemic communities, little quantitative data has been collected in these habitats and multiple watersheds have not been studied with the same objectives.

A thorough study of cascade habitats above and below water diversions will provide a more complete understanding of how flow variation affects the structure and function of a vital stream microhabitat home to endemic species. This will provide deeper insight into the ecological organization of streams and rivers, improve our ability to predict how flow alterations caused by human activities affect these unique ecosystems and their biodiversity, and guide water input strategies

in a manner that would achieve a better balance between economic and environmental benefits (Hart and Finelli, 1999).

CHAPTER 2: Cascade Macroinvertebrate Assemblages for In-Stream Flow Criteria and Biomonitoring of High Gradient, Tropical Streams

Introduction

There are a multitude of tropical, oceanic islands that are volcanic in origin, ranging from the Caribbean to Polynesia and Micronesia. The freshwater sources for these groups of islands are typically mountain streams of high gradient and fast flow. As a whole, these tropical streams are understudied compared to their continental counterparts and are in a more precarious state, due to climate changes, urbanization, the threat of introduced species and an overall freshwater demand (Malmqvist and Rundle, 2002). Despite these challenges, tropical streams are often a unique home to endemic insects and several native amphidromous fish and crustaceans. The reduction and degradation of stream habitats in these locations is reported to be acutely affecting native species (Brasher, 2003). Preservation of biodiversity in hotspots around the world, however, can be actively managed through the development of in-stream biological criteria.

Water is a valuable resource regardless of geography, but in the Hawaiian Islands, it is especially important, considering that these islands are surrounded by thousands of square kilometers of saltwater. Native practices of taro cultivation and harvesting of prawns (*Macrobrachium*

grandimanus), shrimp (*Atyoida bisulcata*) and snails (*Neritina granosa*) for food rely upon a freshwater source that continually flows from the mountains to the ocean (Stone and Scott, 1982). During pre-historic times, diversions were used to provide water for village needs but excess water was always returned to the stream and the stream continuum was never broken. Western contact brought modern development, mass agriculture and permanent water removal to support tropical sugarcane and pineapple plantations (Wilcox, 1996). Since then, a booming tourism industry has called for increasing freshwater demand on the leeward sides of the islands (Juvik and Juvik, 1998). The island of Maui in particular, has suffered from the need for a continual water supply. Some streams in the West Maui mountains experience 97% diverted flow (McIntosh *et al.*, 2002). This water is diverted to ditches and pipelines that run through the mountains to tourist areas of development far from the watersheds where it was collected.

Freshwater removal has the potential for devastating effects on stream communities, endemic communities in particular. Hawaii is understood to be a hot spot of biodiversity. The evolutionary radiation that began about 70 million years ago has produced 9,246 species that are found nowhere else in the world, 59% of these being insects (Eldridge, 2000). The common insect orders, Ephemeroptera, Plecoptera and Trichoptera are absent from native Hawaiian insect communities. The diversification of

native and extant insect orders has resulted in species occupying unusual niches to their genera or family (Zimmerman, 1970). The adaptations that have resulted in new species, in a niche unique to them, have made them highly specialized and thus sensitive to changing environmental conditions that drive shifts in community composition.

Cascades are common to tropical, mountain streams of high gradient and substrate comprised of large boulders and mixed cobble. Cascades are especially abundant in the first, second and third order streams of Hawaii. Despite the abundance of cascade habitat found in most tropical, island streams, bioassessment studies have primarily focused on riffle habitats, the study habitat for temperate, continental streams. While much can be understood from investigating the effects of changing habitat characteristics in riffle habitats, they are also relatively easily invaded by introduced species in tropical areas of the world. We have found in a companion study that investigated riffle communities of the same Maui streams of this study that native organisms comprised less than 1% of all samples, regardless of stream (Gorbach, *et al.*, unpublished data). Previous cascade studies on Maui, however, have shown that small scale flow is important in dictating benthic communities and amphibious and torrential microhabitats are ideal for supporting endemic insect life (Benbow *et al.*, 1997, 2003, 2005, 2008).

Investigations that have taken place on two of the four streams investigated here have suggested a decline in fast flowing, torrential habitats and highlighted the need for quantification of how changing flow characteristics affect benthic macroinvertebrate populations (McIntosh *et al.*, 2002, 2003, 2008; Benbow *et al.*, 1997, 2003, 2005, 2008). McIntosh studied riffles upstream and downstream of the highest diversion on Iao Stream and found significant decreases in invertebrate densities. This study also documented the complete lack of some endemic species in downstream reaches, such as the shrimp *A. bisulcata*, which is known to require torrential habitat (McIntosh, *et al.*, 2002). Benbow, *et al.* (2003) defined torrential and amphibious cascade microhabitats as optimal locations for the endemic midge, *Telmatogeton torrenticola*, and noted the loss of these habitats from a wet to a dry year.

There is also evidence indicating nonindigenous organisms have become dominant in a variety of Hawaiian habitats, most often riffles, due to changing environmental conditions (Englund, 2002). The caddisfly *Cheumatopsyche pettiti*, was introduced in the 1960's and has become dominant in Iao Stream (McIntosh, 2003). Kondratieff, *et al.* (1997) have shown that this species even alters its life cycle from univoltine in a temperate setting to multivoltine with continuous recruitment in the tropical streams of the Hawaiian Islands. The impact of these introduced

taxa on stream communities, primarily their impact on native taxa, requires further investigation.

Several researchers also indicate that the microhabitat scale is important to understanding human impacts on Hawaiian streams (Gingerich and Wolff, 2006; Brasher, 2003). The varied hydrogeology of tropical streams can make generalizations of a single reach type misleading and it is important to develop appropriate biomonitoring strategies for the region and stream type that take into account the presence and abundance endemic and native species. The objective of this study was to investigate cascade habitats for biomonitoring as a possible alternative to the more traditional programs developed for riffles, given the evidence from previous studies and preliminary data that native/endemic organisms can be found in higher abundance in these habitats. Another goal of this study was to use data collected from cascades to aid in the development of in-stream flow criteria. We hypothesized that a decrease in discharge as a result of water diversion reduced the quantity and quality of in-stream cascade habitat and thus would impact the macroinvertebrate community structure within four West Maui streams, with the most profound negative impacts on endemic and native macroinvertebrates. We believed that this impact would be the most severe on the largest streams that are subject to the highest degree of water removal.

Methods

Study Sites

This investigation evaluated microhabitats of cascades above and below diversions in 4 streams known as the Na Wai Eha located along the West Maui mountains: Waikapu Stream, Iao Stream, Waiehu Stream and Waihe'e River. Within each stream, a site was identified as a 500 meter reach upstream and downstream of the highest diversion. The USGS established these sites for a hydrologic study and developed the selection criteria; they were chosen for their variation in habitat, hydrology, accessibility and riparia. Within each site, samples were randomly collected along an established 100 meter study reach. To determine the effect of stream size, these four streams were divided into "small" and "large" described by mean upstream discharge.

Invertebrate Collections

Benthic torrenticolous microhabitat communities were randomly sampled from available cascade habitats (n=6) according to methods described by Benbow et al. (1997, 2003, 2005). Amphibious communities were evaluated by defining an area ~60cm² immediately adjacent to the torrenticolous microhabitat (n=6). A toothbrush was used to dislodge organisms by gently brushing over an exposed, but wet, boulder surface until all individuals were sampled by visual inspection. Contents of both

samples were preserved in 70% ethanol prior to processing and identification. Samples were collected once in August 2007 and twice in May 2008 for a total of three collection dates across two years.

Physical Data Collection

Bank full and wetted width were measured, canopy cover was quantified with a densitometer and substrate size measured with a gravelometer (Hauer and Lamberti, 1996). Reach gradient and habitat quantification was assessed by measuring the area of each cascade, riffle, run and pool habitat within the 100 meter study reach. For gradient estimates, the averages of five to six measurements were taken along the horizontal length of the study reach, measuring the vertical drop per length measurement.

Data Analysis

Organisms were counted and identified to genus level where practical (Merritt and Cummins, 2008; Zimmerman, 1948, EcoAnalyst Reference). We also calculated habitat corrected densities to reflect reach scale densities. The mean number of organisms per m² in cascade habitats was multiplied by the total area of cascade habitat in each reach to obtain corrected values that represent the potential density of the entire reach. One-way and two-way ANOVAS with Bonferroni post tests for pairwise comparisons were performed using GraphPad Prism, version 4.0, to detect differences between upstream and downstream macroinvertebrate

density and diversity values. Simpson's Diversity Index was calculated to measure the biodiversity of each habitat and data were transformed (arc sine square root) to conform with assumptions of normality and equal variances. Nonmetric multidimensional scaling (NMDS), followed by multi-response permutation procedures (MRPP) was used to analyze changes in overall community structure (McCune and Grace, 2002). Data were log transformed prior to NMDS analysis and the Sorensen distance measure was used with a random starting configuration, and 250 runs with real data. Indicator species analysis was then conducted comparing taxa in the two microhabitats and between locations. This type of test is used to identify species that are significantly associated with one of the sampling treatments. Significance was determined by comparing results to a Monte Carlo test that included 4999 randomizations. All multivariate analysis was performed in PC-Ord (McCune and Mefford, 1999).

Results

Habitat Characteristics

The physical characteristics of each stream were altered by water removal that ranged from 84% to 99%, depending on the stream (Table 1a). Daily mean discharge in each stream was significantly reduced, which corresponded with wetted channel width below diversions. Further, estimated cascade area was highly variable both within and among streams (Table 1a). The larger streams had significantly lower cascade

habitat under reduced flow conditions; the high variability of the smaller streams and efficiency of diversion within these reaches precluded significant differences for Waikapu and Waiehu Streams (Table 1a).

Macroinvertebrate Density

Over the entire study period and pooling all streams, total mean macroinvertebrate density was reduced by 33.1% between upstream and downstream habitats. Analyzing the effects of water removal on densities for each stream found that only two streams had statistically reduced densities, probably because of few sampling dates over a large time scale (Figure 1a). However, when densities are corrected for available cascade habitat, there are large and highly significant reductions in all stream reaches with flow removal, but the absolute magnitude depended on stream size (Figure 1b). Two-way ANOVA found no significant main effects on density, but a significant interaction in torrenticolous microhabitats, making interpretation difficult. However, the opposite was true for the amphibious microhabitat (Table 2).

Macroinvertebrate Diversity

In post-hoc tests, diversity was consistently higher in reaches with uninterrupted flow for both microhabitats. There were also significant stream effects on amphibious diversity and density but none for torrenticolous habitats (Table 2).

Community Composition

A significant difference existed between endemic populations in the two microhabitats, regardless of location, with the amphibious microhabitat having a mean of 38.5% endemic insects, while the torrenticolous microhabitat had a mean of 6.34% (Figure 2). A total of 86% of torrenticolous samples but only 33% amphibious samples had either no endemic taxa, or if present, the endemic taxa comprised under 10% of total organisms collected (Table 3).

Endemic taxa comprised a larger percentage of total population in the amphibious habitat (Figure 3). This difference in community structure between microhabitats was found significantly different through visual NMDS overlays and subsequent MRPP analysis (Euclidian distance measure, $A=0.0169$, $p=0.0002$), (Figure 4). Additionally, Indicator Species Analysis gives weight to non-native chironomids in the torrenticolous microhabitat with an 83.7% indicator value ($p=0.0002$). The next two taxa that accounted for the highest percent of perfect indication in torrenticolous habitats (behind chironomidae) were the *Cheumatopsyche* and *Hydroptila* genera with 69.1% and 63.5%, respectively ($p=0.0002$ for both). Members of the Ephydriidae family in general and members of the Tipulidae family, *Limonia*, were indicators of the amphibious microhabitat, with 27.9% and 58.9% perfect indication respectively ($p=0.0002$ for both). These were the only two significant indicator taxa for the amphibious

microhabitat. NMDS failed to find a pattern in community structure of sampled insects based on watershed of study, or location.

Discussion

Each of the four streams experiences a significant decrease in discharge as a result of the water diversion (Table 1a). While the decreased water flow ranges from 84 to 99 percent removal, the actual amount of water removal ranges from 0.08 m³/second to 1.00 m³/second. The difference in water withdrawal between the large and small streams can explain some of the non-significant results generated in the small streams. For Lao Stream and Waihe'e River, the two larger study sites, there is a significant decrease in wetted width and available cascade habitat. These watersheds have diversions in place that are more efficient and remove an amount of water that is an order of magnitude larger than the amount removed in the smaller streams. Canopy cover is higher in the smaller streams, but is not significantly impacted by the presence of diversion (Table 1b).

The differing amounts of water removed in each watershed produce a stream to stream variation that causes pooling data across streams to yield non-significant results. The significant main effect of stream for the amphibious microhabitat and a significant interaction between stream and location in the torrenticolous microhabitat verifies this within stream variation (Table 2). Lao Stream has higher densities in the downstream

reaches compared to its upstream counterpart on each of the sampled dates. This can be explained by the hydrology of the stream. On the first sampling date, August 3, 2007, discharge was 3 m³/sec, double the average for that year, 1.52 m³/sec. This spate event likely transported organisms from the upstream to the downstream habitats, thus evening the disparity expected between the two. When freshets occur, upstream organisms are washed over the diversion and thus abundance values become more similar between the two locations. The next sampling date was August 8, 2007 and only upstream samples were taken, these were compared to downstream samples collected on August 16, 2007. While valuable for the information they provide about cascade communities, these samples cannot be compared to one another to determine the effect of diversion. The hydrology of Iao Stream (already flashy and inconsistent) was not comparable in the eight days between these samplings. Lastly, the increased downstream densities on May 9, 2008 occurred in the amphibious microhabitat alone, and were probably the result of a recent flood event that encouraged colonization in this freshly scoured boulder area.

Hawaiian streams are subject to a unique hydrogeology that creates springs and sinks along the entire stream reach, from mountain to ocean. In addition, Hawaiian streams have a highly variable flow and are characterized by frequent flood events that cause water levels to rise and

fall dramatically within the course of even a single day. The data presented here show that density values alone are not sufficient in making conclusions about the effect of water removal, in part due to the nature of stream hydrology in this area.

A similar study conducted by McIntosh, *et al.* found parallel (and also non-significant) trends between upstream and downstream densities (2008). This non-significance was attributed to low power to detect significant changes in densities, but when studying multiple streams across multiple dates, it quickly becomes impractical to attempt a more powerful study design. This issue can be resolved by quantifying the amount of available habitat, as was performed in this study. When individual sample densities are corrected for the amount of available habitat in the reach, significant decreases in density occur downstream of diversion for all streams (Figure 1). This quantification of habitat is important for the discovery of trends in regions where among stream variation exists and practicality limits a high replication of samples.

Upstream communities are more diverse than their downstream counterparts. In both the torrenticolous and amphibious habitats, there is a significant effect of location indicating that decreased flow as a result of diversion allows for fewer species to inhabit cascades and in less abundance. In a specialized system, like Hawaiian turbulent cascades, species are evolved under a unique set of conditions and changes in

environmental parameters can result in a decreased sub-set of the macroinvertebrate community that can exist outside of ideal conditions. This is especially true for endemic species, but both endemic and non-endemic taxa suffer the effects of water reduction. Additionally, while non-native species are not significantly reduced by the presence of a water diversion, the native taxa are significantly reduced, by 47.6% (Figure 2).

Diversity is increased significantly in torrenticolous habitats and it appears to be the low diversity of downstream, amphibious communities that is driving this relationship between microhabitats. The amphibious habitat is higher in endemic species density and in terms of overall abundance decreases due to diversion, the amphibious microhabitat experiences more severe effects (Figure 2). The sensitivity of this habitat is reflected in the individual stream diversity calculations.

Striking differences exist in the community composition of torrenticolous and amphibious samples (Figure 3). While the chironomidae family of diptera is dominant in both microhabitats, endemic organisms comprise a dominant portion of amphibious communities while there is a significant lack of these species in torrenticolous microhabitats. In turn, torrenticolous microhabitats show the presence of two introduced caddisflies, *Cheumatopsyche analis* and members of the *Hydroptila* genera taking over a dominant role in the community. In addition, the overall structure

of torrenticolous microhabitats is extremely similar to riffle habitat composition, suggesting that on an organismal level, riffles and torrenticolous habitats provide a similar environment. The implication of non-native taxa as superior competitors and their prevalence in the torrenticolous habitats of Hawaiian cascades is disconcerting for the biodiversity management of tropical streams.

Table 3 further explains the differences in endemic species presence in torrenticolous and amphibious microhabitats. While both habitats produced samples that contained no endemic taxa, the torrenticolous habitat had 35.5% in which endemics were completely absent and another 49.6% of its samples containing less than 10% endemic taxa. Totaled, this represents 85% of torrenticolous samples. These samples have little, if any endemic taxa present. In turn, these same parameters applied to amphibious samples result in only 33%.

Quantifying shifts in community composition, especially the presence and abundance of endemic species, was one of the objectives of this study and the implications of the data presented here can be important for future bioassessment work in West Maui. The NMDS ordination of these data explains cumulatively, 93.1% of the variation between samples, giving even more weight to these results (Figure 4). Utilizing a microhabitat overlay, it is possible to visualize the differences in community structure between the two microhabitats. Amphibious samples are tightly clustered

whereas torrenticolous samples are clustered, but in a looser configuration, reiterating the wider variation in this habitat. Multi-Response Permutation Procedures indicate that these two groups are statistically different from each other (Sorensen distance measure, groups defined by microhabitat, $A = 0.1645$ $p = 0.0000$). Additionally, an Indicator Species analysis was used to determine which taxa were contributing the most to the differences in community ordination. The taxa that significantly accounted for highest percent perfect indication reflect the same trends from community composition analysis: *Cheumatopsyche* and *Hydroptila* in torrenticolous habitats and endemic taxa, Ephydriidae and *Limonia* in the amphibious habitat.

It was expected that the NMDS results would produce no pattern for differences based on stream or upstream/downstream location. The significant differences between the physical stream characteristics and results of the two-way ANOVA indicate stream to stream variation that is strong enough to mask a trend based on location alone. However, there is a clear difference in macroinvertebrate community structure between the microhabitats that can be visually assessed with an analysis of community composition (Figure 3) and tested with multivariate statistics (Figure 4). This difference in community is important to understanding the reaction of stream life to disturbance, especially native stream life.

Previous tropical work has shown the possibility for detrimental effects when endemic taxa are lost and in particular when they are replaced with introduced species (Englund, 2002). This appears to be the case in the torrenticolous habitats. The nature of cascades is altered when discharge is significantly reduced, making downstream torrenticolous habitats less ideal for endemic species and more like the in-stream habitats open to invasion by introduced species.

The overall objective of this study was to identify and monitor native population assemblages by investigating cascade habitats and by comparing communities between four study streams, between upstream and downstream locations and between microhabitats. Cascades are present in a multitude of tropical habitats and are underutilized, as they can be valuable study sites. Polynesia is considered one of the hot spots of biodiversity and identifying habitats important for endemic life is the first step towards preserving and maintaining biodiversity. It is our hope that this study will give insight to water management practices in the Na Wai Eha and tropical streams worldwide.

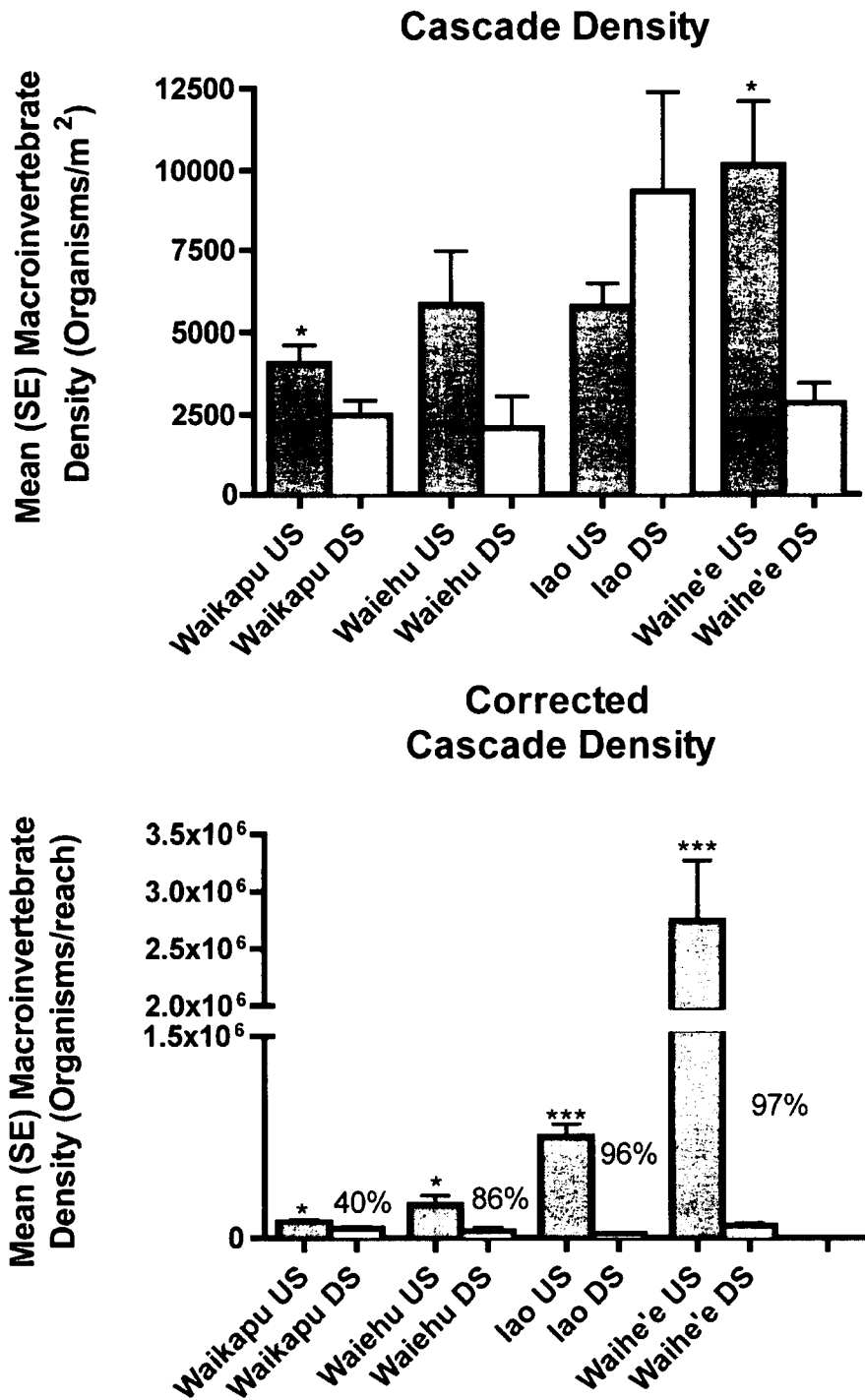


Figure 1: Mean (SE) invertebrate density for all cascade habitats sampled, pooled microhabitats and dates and mean (SE) cascade corrected densities among streams with percent reduction for all dates and microhabitats pooled.

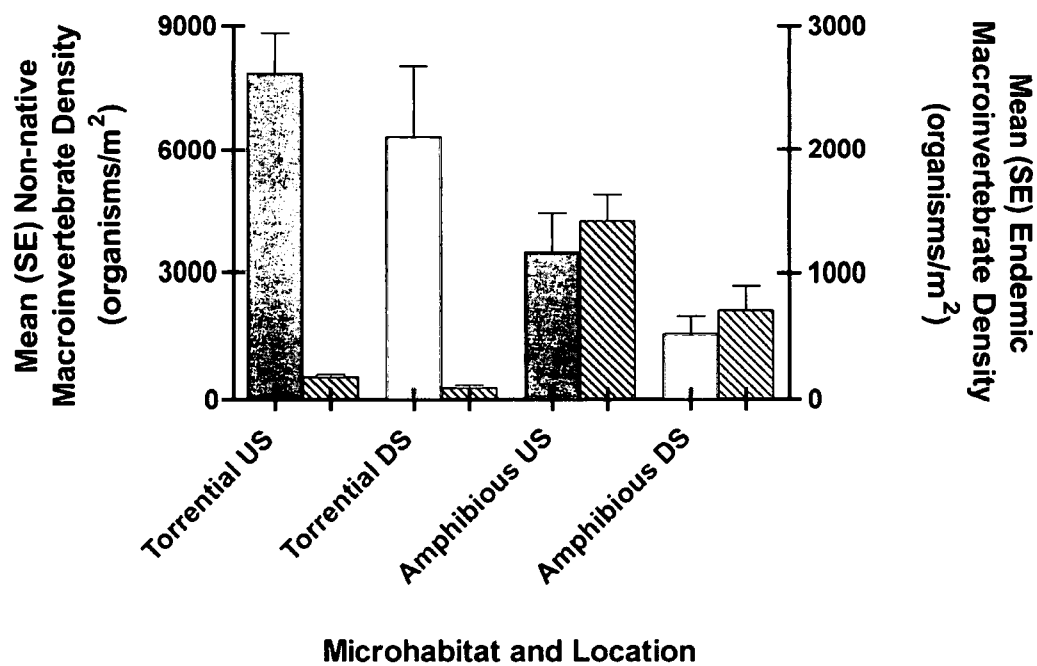


Figure 2: Mean (SE) macroinvertebrate densities for microhabitat and location, data pooled for three dates. Non-native macroinvertebrates are represented by solid bars and reference the left y axis, endemic macroinvertebrates are represented by the patterned bars and reference the right y axis.

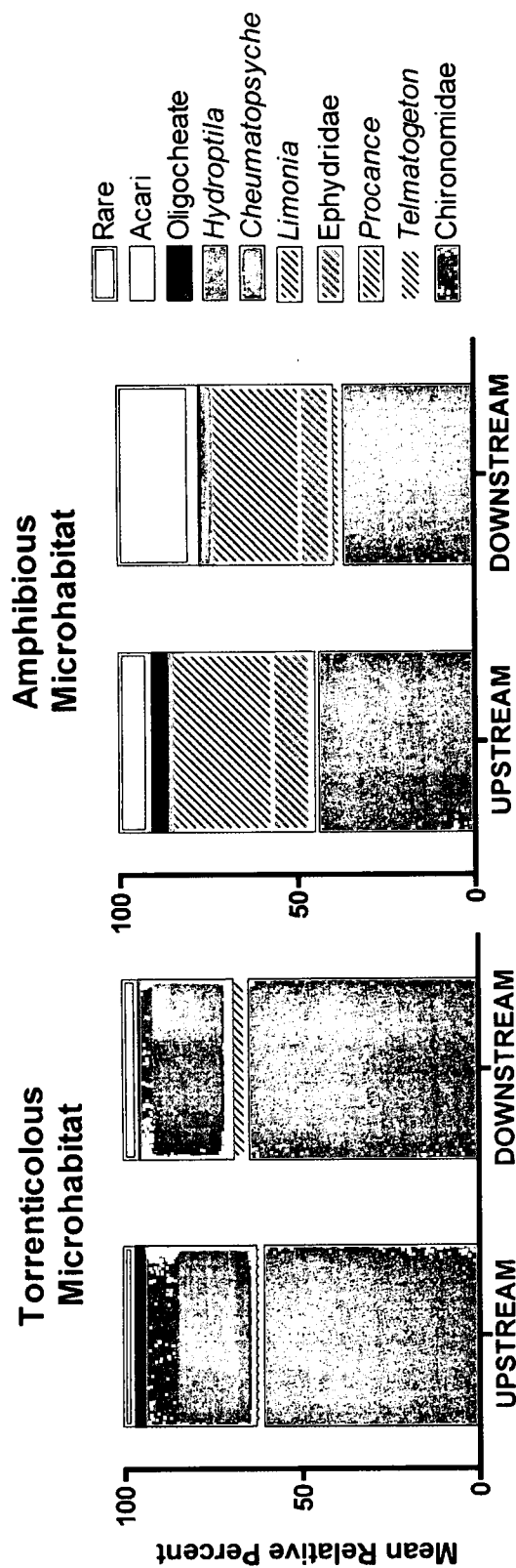


Figure 3: Community composition of Amphibious and Torrenticolous microhabitats in upstream and downstream locations for all streams pooled. Taxa represented with hatch marks are endemic. Taxa comprising less than 3% of total community were pooled and defined as rare.

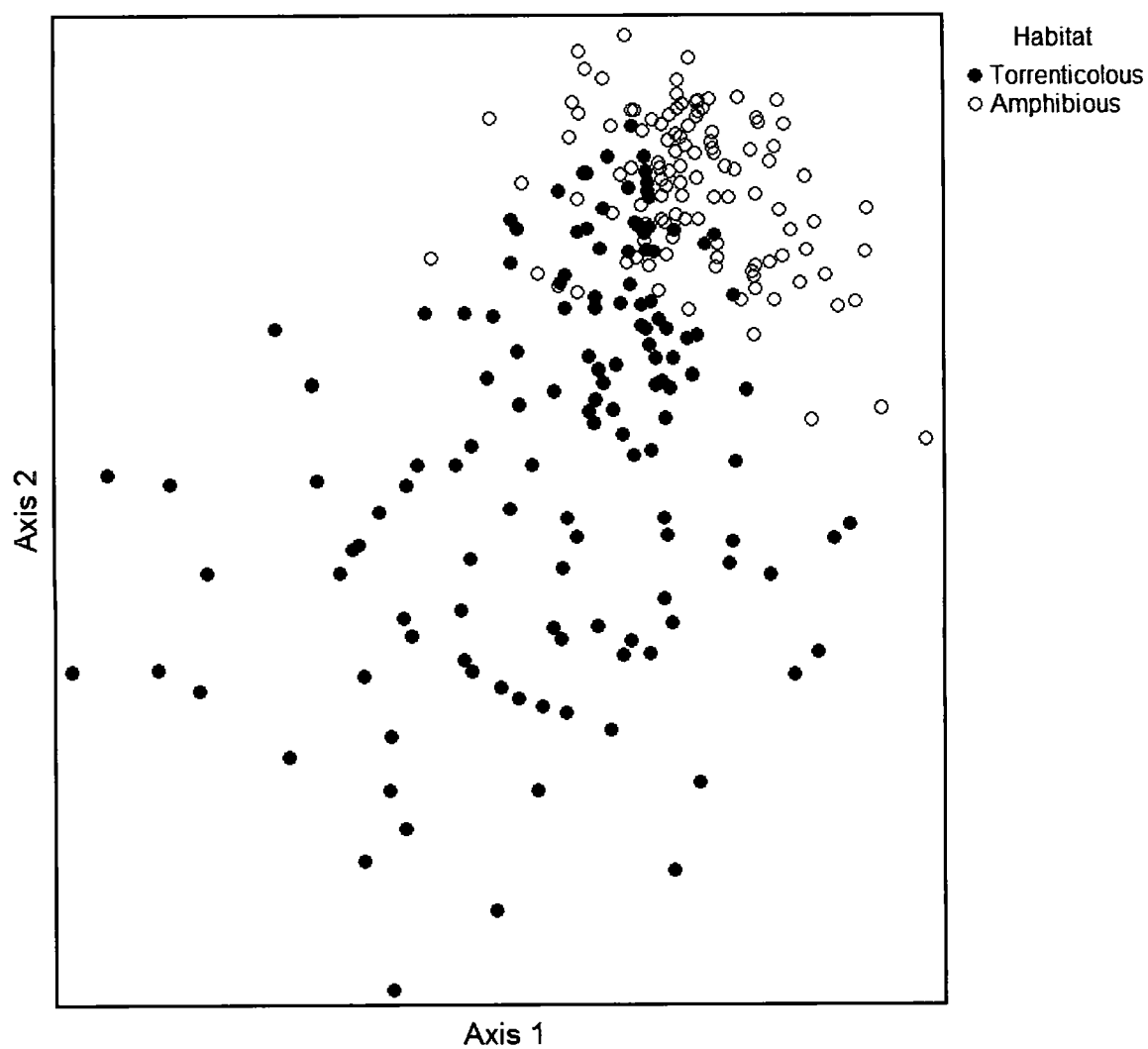


Figure 4: NMDS ordination with microhabitat overlay. Total stress = 17.54. Axis 1 explains 41.6% of the variation between samples and axis 2 explains 51.5%.

Table 1a: Mean discharge, total cascade habitat and mean total macroinvertebrate densities for each of the study reaches

Stream	Location	Mean Discharge (SD) (m^3/s)	Percent Change	t-test statistics	Total Cascade Habitat ($m^2/100m$ reach)	Percent Change	t-test statistics	Mean (SD) Total Cascade Invertebrate Density ($\#/m^2$)	Percent Change	t-test statistics
Waikapu	US	0.10 (0.03)	-84	$p<0.0001$, $t=7.529$, $df=7$	29	0.48	ns	117,698 (54,009)	-40	$p=0.0301$, $t=2.214$, $df=70$
	DS	0.02 (0.01)			29			71,061 (29,238)		
Waiehu	US	0.11 (0.01)	-95	$p=0.0006$, $t=15.48$, $df=3$	42	-41	ns	255,331 (223,928)	-86	$p=0.0314$, $t=2.207$, $df=56$
	DS	0.01 (0.00)			25			54,347 (60,493)		
Iao	US	0.66 (0.11)	-99	$p<0.0001$, $t=5.417$, $df=2$	131	-98	$p<0.001$, $t=4.944$, $df=21$	752,431 (107,634)	-96	$p<0.0001$, $t=7.871$, $df=67$
	DS	0.01 (0.00)			3			29,438 (6,908)		
Waihe'e	US	1.04 (0.26)	-97	$p<0.0001$, $t=13.09$, $df=8$	270	-88	$p<0.001$, $t=5.858$, $df=7$	2,743,600 (2,417,300)	-97	$p<0.0001$, $t=4.988$, $df=69$
	DS	0.04 (0.01)			31			91,510 (82,098)		

Table 1b: Mean wetted width, Percent canopy cover and substrate size for each of the study reaches.

Stream	Location	Mean (SD) Wetted Width (m)	Percent Change	t-test statistics	Mean (SD) Percentage Canopy Cover	Percent Change	t-test statistics	Mean (SD) Substrate Size (mm)	Percent Change	t-test statistics
Waikapu	US	4.65 (0.38)			97.6 (.63)			420 (1246)		
	DS	3.52 (0.23)	-24.30	ns	99.2 (.24)	1.61	ns	326 (381)	-22.38	ns
Waiehu	US	3.46 (0.44)			96.8 (.51)			471 (1530)		
	DS	3.07 (0.37)	-11.27	ns	97.2 (1.5)	0.41	ns	356 (394)	-24.42	ns
lao	US	11.59 (1.01)			34.3 (21)			337 (379)		
	DS	6.04 (0.39)	-47.89	p<0.001, t=6.024, df=7	38.1 (33)	9.97	ns	399 (404)	15.54	ns
Waihe'e	US	14.97 (1.28)			40.3 (13)			287 (384)		
	DS	7.99 (0.27)	-46.63	p<0.001, t=7.567, df=7	59 (18)	31.7	ns	540 (688)	46.85	p=0.01, t=3.63, df=7

Table 2: Two-way ANOVA statistics for testing total density and diversity versus microhabitat and extrapolated total densities for the entire 100 meter reach.

Habitat	Parameter	Source of Variation	Percent of Variation	P value	df	F
Torrenticolous	Total Density	Stream	4.93	0.0719	3	2.389
		Location	0.65	0.3341	1	0.9402
		Stream X Location	7.48	0.0149	3	3.625
		Stream	9.51	0.0029	3	4.901
		Location	4.07	0.0134	1	6.295
Amphibious	Diversity	Stream X Location	3.52	0.1477	3	1.815
		Stream	2.71	0.3598	3	1.081
		Location	2.36	0.0481	1	3.982
		Stream X Location	2.9	0.2982	3	1.239
		Stream	10.77	0.0008	3	5.968
100 m Reach	Total Density	Location	11.81	p<0.001	1	19.62
		Stream X Location	2.33	0.2799	3	1.292
		Stream	12.98	p< 0.0001	3	18.05
		Location	13.62	p< 0.0001	1	18.94
		Stream X Location	9.36	p< 0.0001	3	39.06

Table 3: Number and percentage of endemic taxa in each microhabitat for each of the study reaches pooled. Total number of samples for each reach is 135.

Microhabitat	Number of samples with zero endemics	% samples with zero endemics
Torrenticolous	48	35.56
Amphibious	35	25.93
Microhabitat	Number of samples in which endemics <10%	% samples in which endemics <10%
Torrenticolous	67	49.63
Amphibious	10	7.41
% samples with zero endemics	% samples in which endemics <10%	% Samples with zero or <10% endemics
35.56	49.63	85.19
25.93	7.41	33.33

FUTURE DIRECTIONS

Many interesting new questions are prompted with the conclusion of this study. One avenue for continuing this research would include aerial sampling of cascade habitats, in an attempt to quantify the emergence and breeding of adult insects. This information could aid in making conclusions about the effect of water diversion on riparia and terrestrial insect communities that are inherently linked to aquatic community well-being. Another project could investigate competitive interactions between endemic and introduced organisms and attempt to discover why amphibious habitats have become hotspots for endemic life. Amphibious microhabitats might be ideal because they are refugia for endemic species that are capable of living within their tolerance range there, whereas introduced species are not. An effective follow up to this work would investigate what aspects of the amphibious habitat are drawing endemic species to colonize and thrive and what role (if any) competition plays in this habitat choice.

Also mentioned in the introduction, tropical ecological work in general lacks the breadth of temperate studies and it would be of interest to conduct a cascade-based biomonitoring or bioassessment study in another high-gradient tropical stream located in another part of the world that is home to prominent endemic life. Cascade habitats are an understudied but valuable potential habitat for assessment of stream life and continued research into what cascades and their microhabitats can uncover is worthwhile in tropical, torrential streams.

Lastly, this work was completed against the backdrop of an environmental conflict involving water rights and resource control. Our hope is that the results presented here will enrich further discussion on the biological health and integrity of the Na Wai Eha and suggest management practices that will find a compromise between the need for water and a love of the natural world.

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APPENDIX A:
Macroinvertebrate Data

Date: 8/3/07		Stream Name: lao	Location: Upstream	Microhabitat: Torrenticolous			
		C1	C2	C3	C4	C5	C6
Odonata	Megalagrion sp.	0	0	0	0	0	0
Coleoptera	Dytiscidae fm.	0	0	0	0	0	0
Diptera-Chironomidae	Telmatogeton gr.	0	0	0	0	0	0
	Other	43	48	80	80	133	109
	Unknown	0	0	0	0	0	0
Diptera	Procance sp.	0	0	0	1	1	0
	Ephydriidae fm.	0	0	0	2	0	0
	Limonia sp.	0	0	0	4	2	0
	Pupae	9	7	10	13	9	18
Trichoptera	C. analis	0	3	1	6	9	1
	Hydroptila sp.	3	4	3	5	23	9
	Pupae	0	0	2	1	4	1
Lepidoptera	Hyposmocoma sp.	0	0	0	0	0	0
Annelida	Oligochaeta	0	0	0	0	0	0
Acarid	Oribatei	0	0	0	0	0	0
Crustacea	Atyoida bisulcata	0	0	0	0	0	0
Other Organisms	Prostoma sp.	0	0	0	0	0	0
	Turbellaria	0	0	0	0	0	0
Unknown		0	0	0	0	0	0
Adult		1	0	0	0	0	1
TOTAL		56	62	96	112	181	139
Diversity		0.3657	0.3876	0.2963	0.4739	0.4408	0.3573
Number of Endemics		0	0	0	7	3	0
Percent Endemic		0	0	0	6.25	1.6575	0

Date: 8/3/07 Stream Name: lao Location: Downstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5
Odonata	0	0	0	0	0
Coleoptera	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	0
	2	4	1	45	543
	0	0	0	0	0
	0	0	0	0	0
Diptera	0	0	0	0	0
	0	0	0	0	0
	0	0	0	1	0
	0	0	0	9	5
Trichoptera	0	3	4	10	578
	0	0	0	2	62
	0	0	0	0	3
Lepidoptera	0	0	0	0	0
Annelida	0	0	0	0	8
Acari	0	0	0	0	0
Crustacea	0	0	0	0	0
Other Organisms	0	0	0	0	0
	0	0	0	0	0
Unknown	0	0	0	0	0
Adult	0	0	0	0	0
TOTAL	2	7	5	67	1199
Diversity	0	0.5714	0.4000	0.5152	0.5602
Number of Endemics	0	0	0	1	0
Percent Endemic	0	0	0	1.4925	0

Date: 8/3/07 Stream Name: Iao Location: Upstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5
Odonata	0	0	0	0	0
Coleoptera	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	0
	24	0	4	1	46
	0	0	0	0	0
Diptera	1	1	0	0	2
	1	1	40	2	1
	2	6	1	8	2
	1	1	2	6	1
Trichoptera	0	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0
Lepidoptera	0	0	0	0	0
Annelida	0	0	0	0	1
Acar	0	0	0	0	0
Crustacea	0	0	0	0	0
Other Organisms	0	0	0	0	0
	0	0	0	0	0
Unknown	0	0	0	0	0
Adult	0	0	0	0	0
TOTAL	29	9	47	17	53
Diversity	0.3177	0.5833	0.2720	0.6765	0.2475
Number of Endemics	4	8	41	10	5
Percent Endemic	13.7931	88.8889	87.2340	58.8235	9.4340

Date: 8/8/07		Stream Name: lao	Location: Upstream		Microhabitat: Torrenticolous		
		C1	C2	C3	C4	C5	C6
Odonata	Megalagrion sp.	0	0	0	0	0	1
	Dytiscidae fm.	0	0	0	0	0	0
Diptera-Chironomidae	Telmatogeton gr.	0	0	0	0	0	0
	Other	71	151	96	128	62	66
	Unknown	0	1	0	0	0	0
Diptera	Procladius sp.	0	1	0	0	0	0
	Ephydriidae fm.	9	1	3	0	0	0
	Limonia sp.	0	0	1	0	0	0
	Pupae	2	8	10	5	1	6
Trichoptera	C. analis	14	0	69	8	22	2
	Hydroptila sp.	12	15	14	9	8	7
	Pupae	2	0	5	1	2	2
Lepidoptera	Hyposmocoma sp.	0	0	0	0	0	0
	Oligochaeta	6	2	2	0	3	20
Annelida	Oribatei	1	0	0	0	0	0
	Atyoida bisulcata	0	0	0	0	0	0
Other Organisms	Prostoma sp.	0	0	0	0	0	0
	Turbellaria	0	0	0	0	0	0
Unknown		0	0	0	0	0	0
Adult		0	2	1	3	0	0
TOTAL		117	181	201	154	98	104
Diversity		0.6029	0.2807	0.6454	0.2758	0.5468	0.5569
Number of Endemics		9	2	4	0	0	1
Percent Endemic		7.6923	1.1050	1.9900	0	0	0.9615

Date: 8/8/07 Stream Name: Iao Location: Upstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	0	0
	13	33	11	3	10	4
	0	0	0	0	0	0
Diptera	0	1	0	0	0	0
	39	54	13	0	2	11
	0	3	1	4	0	7
Trichoptera	1	1	6	1	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	0	0	1
Acarri	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	0	1	0	0
TOTAL	53	92	31	9	12	23
Diversity	0.4057	0.5313	0.6817	0.6786	0.3030	0.6759
Number of Endemics	39	58	14	4	2	18
Percent Endemic	73.5849	63.0435	45.1613	44.4444	16.6667	78.2609

Date: 8/16/07		Stream Name: lao	Location: Downstream			Microhabitat: Torrenticolous		
		C1	C2	C3	C4	C5	C6	
Odonata	Megalagrion sp.	0	0	0	0	0	0	
	Dytiscidae fm.	0	0	0	0	0	0	
Diptera-Chironomidae	Telmatogeton gr.	0	0	0	0	1	0	
	Other	510	439	59	156	24	8	
	Unknown	0	0	0	0	0	0	
Diptera	Procance sp.	0	0	0	0	0	0	
	Ephydriidae fm.	0	0	0	0	0	0	
	Limonia sp.	0	0	0	1	0	0	
	Pupae	1	15	1	4	5	0	
Trichoptera	C. analis	713	228	4	160	6	5	
	Hydroptila sp.	48	92	4	41	5	3	
	Pupae	1	14	1	7	0	1	
Lepidoptera	Hyposmocoma sp.	0	0	0	0	0	0	
	Oligochaeta	49	7	0	0	0	0	
Acari	Oribatei	0	1	0	0	0	0	
	Atyoida bisulcata	1	0	0	0	0	0	
Other Organisms	Prostoma sp.	0	0	0	0	0	0	
	Turbellaria	0	0	0	0	0	0	
Unknown		0	0	0	0	0	0	
	Adult	0	1	0	0	0	0	
	TOTAL	1323	797	69	369	41	17	
	Diversity	0.5587	0.6004	0.2656	0.6221	0.6207	0.6985	
	Number of Endemics	0	0	0	1	1	0	
	Percent Endemic	0	0	0	0.2710	2.4390	0	

Date: 8/16/07		Stream Name: lao	Location: Downstream			Microhabitat: Amphibious		
			C1	C2	C3	C4	C5	C6
Odonata	Megalagrion sp.		0	0	0	0	0	0
Coleoptera	Dytiscidae fm.		0	0	0	0	0	0
Diptera-Chironomidae	Telmatogeton gr.		0	0	0	0	1	0
	Other		9	1	0	0	0	0
	Unknown		0	0	0	0	0	0
Diptera	Procladius sp.		0	0	0	0	0	0
	Ephydriidae fm.		0	0	0	0	0	0
	Limonia sp.		3	0	0	2	0	0
	Pupae		1	0	0	0	0	0
Trichoptera	C. analis		0	15	0	0	0	0
	Hydropsyche sp.		0	0	0	0	0	0
	Pupae		0	0	0	0	0	0
Lepidoptera	Hypocnemis sp.		0	0	0	0	0	0
Annelida	Oligochaeta		0	1	0	0	0	0
Acari	Oribatei		0	0	0	0	0	0
Crustacea	Atyoida bisulcata		0	0	0	0	0	0
Other Organisms	Prostoma sp.		0	0	0	0	0	0
	Turbellaria		0	0	0	0	0	0
Unknown			0	0	0	0	0	0
Adult			0	0	0	0	0	0
TOTAL			13	17	0	2	1	0
Diversity			0.5000	0.2279	0	0	0	0
Number of Endemics			3	0	0	2	1	0
Percent Endemic			23.0769	0	0	100	100	0

Date: 5/9/08 Stream Name: Iao Location: Upstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	4	1	1	1	0	0
	57	47	21	96	21	51
	4	9	1	11	6	5
Diptera	0	1	0	0	0	0
	1	0	0	2	0	0
	0	0	0	0	1	0
	5	6	0	5	4	1
Trichoptera	2	106	0	0	0	5
	14	67	24	39	66	52
	5	10	5	16	5	8
Lepidoptera	0	0	0	0	0	0
Annelida	5	141	0	0	31	3
Acar	0	1	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	1	1	0	1	0
TOTAL	97	390	53	170	135	125
Diversity	0.6284	0.7519	0.6401	0.6180	0.6848	0.6578
Number of Endemics	5	2	1	3	1	0
Percent Endemic	5.1546	0.5128	1.8868	1.7647	0.7407	0

Date: 5/9/08 Stream Name: Iao Location: Downstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	3	4	1	1	0	5
	10	214	23	8	12	22
	0	5	4	0	2	2
Diptera	0	0	0	0	0	0
	0	1	0	0	0	0
	0	0	0	1	0	0
	1	2	4	2	0	3
Trichoptera	0	205	2	3	2	1
	2	386	1	1	0	1
	1	22	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	3	0	0	0	0
Acari	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	14	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	2	0	1	0	0
TOTAL	17	858	35	17	16	34
Diversity	0.6397	0.6766	0.5529	0.7333	0.4333	0.5633
Number of Endemics	3	5	1	2	0	5
Percent Endemic	17.6471	0.5828	2.8571	11.7647	0	14.7059

Date: 5/9/08 Stream Name: Iao Location: Upstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	22	2	16	2	0	5
	0	0	0	0	0	0
	2	1	2	2	0	1
Diptera	0	0	0	0	0	0
	2	0	0	0	3	0
	4	4	1	1	1	1
	0	0	1	0	0	0
Trichoptera	0	0	0	0	0	0
	3	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	1	0	0	0	0
Acar	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	33	8	20	5	4	7
Diversity	0.5417	0.7500	0.3632	0.8000	0.5000	0.5238
Number of Endemics	6	4	1	1	4	1
Percent Endemic	18.1818	50	5	20	100	14.2857

Date: 5/9/08 Stream Name: lao Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	2	0	1	3	0
	41	120	29	11	21	24
	8	12	3	0	2	1
Diptera	1	0	0	0	0	0
	0	3	0	0	0	0
	4	16	0	1	0	0
	0	1	0	0	0	1
Trichoptera	0	0	0	0	0	0
	11	3	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	1	0	0	0	0
Acari	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	1	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	66	158	32	13	26	26
Diversity	0.5630	0.4088	0.1754	0.2949	0.3415	0.1508
Number of Endemics	5	21	0	2	3	0
Percent Endemic	7.5758	13.2911	0	15.3846	11.5385	0

Date: 8/3/07 Stream Name: Iao Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5
Odonata					
Megalagrion sp.	0	0	0	0	0
Coleoptera					
Dytiscidae fm.	0	0	0	0	0
Diptera-Chironomidae					
Telmatogeton gr.	0	0	0	0	0
Other	6	0	24	2	0
Unknown	1	0	0	0	0
Diptera					
Procladius sp.	0	0	0	0	0
Ephydriidae fm.	0	0	0	0	0
Limonia sp.	0	0	0	1	2
Pupae	0	0	0	0	0
Trichoptera					
C. analis	0	0	15	0	0
Hydroptila sp.	0	0	0	1	0
Pupae	0	0	0	0	0
Lepidoptera					
Hypsimacoma sp.	0	0	0	0	0
Annelida					
Oligochaeta	0	0	0	0	0
Acari					
Oribatei	0	0	0	0	0
Crustacea					
Atyoida bisulcata	0	0	0	0	0
Other Organisms					
Prostoma sp.	0	0	0	0	0
Turbellaria	0	0	0	0	0
Unknown	0	0	0	0	0
Adult					
TOTAL	7	0	39	4	2
Diversity	0.2857	0	0.4858	0.8333	0
Number of Endemics	0	0	0	1	2
Percent Endemic	0	0	0	25	100

Date: 8/14/07 Stream Name: Waiehu Location: Upstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	2	1	4	9	5	5
Coleoptera	0	0	0	0	1	0
Diptera-Chironomidae	0	0	0	0	0	0
	3	36	42	241	64	291
	0	0	0	0	0	0
	0	0	0	0	0	0
Diptera	0	0	0	0	0	0
	0	0	0	0	3	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	4	2	5	0	0	1
Trichoptera	84	154	182	455	17	305
	1	23	9	98	17	160
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	20	7	8	9	5	5
Acari	0	0	0	0	10	3
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	1	0	0	1	0
Adult	3	0	1	4	2	2
TOTAL	117	224	251	816	125	772
Diversity	0.4277	0.4921	0.4406	0.5838	0.6860	0.6579
Number of Endemics	2	1	4	9	8	5
Percent Endemics	1.7094	0.4464	1.5936	1.1029	6.4	0.6477

Date: 8/14/07 Stream Name: Waiehu Location: Upstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5
Odonata					
Megalagrion sp.	0	0	0	0	0
Coleoptera					
Dytiscidae fm.	0	0	0	0	0
Diptera-Chironomidae					
Telmatogeton gr.	0	0	0	0	0
Other	0	12	0	0	0
Unknown	0	0	0	0	0
Diptera					
Procladius sp.	0	0	0	0	0
Ephydriidae fm.	0	0	0	0	0
Limonia sp.	2	0	0	0	0
Pupae	0	0	0	0	0
Trichoptera					
C. analis	1	13	0	0	0
Hydropsyche sp.	0	0	0	0	0
Pupae	0	0	0	1	0
Lepidoptera					
Hypsimorpha sp.	0	0	0	0	0
Annelida					
Oligochaeta	0	37	0	0	1
Acarid					
Oribatei	3	0	0	0	0
Crustacea					
Atyoida bisulcata	0	0	0	0	0
Other Organisms					
Prostoma sp.	0	0	0	0	0
Turbellaria	0	0	0	0	0
Unknown	2	0	0	0	4
Adult					
Adult	0	0	0	4	2
TOTAL	8	62	0	5	7
Diversity	0.8214	0.5717	0	0	0.4000
Number of Endemics	2	0	0	0	0
Percent Endemics	25	0	0	0	0

Date: 8/29/07		Stream Name: Waiehu	Location: Upstream			Microhabitat: Torrenticolous		
			C1	C2	C3	C4	C5	C6
Odonata	Megalagrion sp.		0	0	0	0	0	0
Coleoptera	Dytiscidae fm.		0	0	0	0	0	0
Diptera-Chironomidae	Telmatogeton gr.		1	4	0	2	0	0
	Other		43	16	54	23	5	40
	Unknown		0	0	0	0	0	0
Diptera	Procladius sp.		0	0	0	0	0	0
	Ephydriidae fm.		0	0	0	0	0	0
	Limonia sp.		0	0	0	1	0	0
	Pupae		4	4	5	3	0	4
Trichoptera	C. analis		0	0	3	0	3	0
	Hydropsyche sp.		0	1	6	1	1	2
	Pupae		0	0	2	0	0	0
Lepidoptera	Hypsimachia sp.		0	0	0	0	0	0
Annelida	Oligochaeta		1	0	10	0	0	0
Acari	Oribatei		0	0	0	0	0	1
Crustacea	Atyoida bisulcata		0	0	0	0	0	0
Other Organisms	Prostoma sp.		0	0	0	0	0	0
	Turbellaria		0	0	0	0	0	0
Unknown			0	0	0	1	0	1
Adult			0	0	0	1	1	0
TOTAL			49	25	80	32	10	48
Diversity			0.2270	0.5600	0.5237	0.4473	0.6389	0.3023
Number of Endemics			1	4	0	3	0	0
Percent Endemics			2.04	16	0	9.38	0	0

Date: 8/29/07 Stream Name: Waiehu Location: Downstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5
Odonata	0	0	0	0	0
Coleoptera	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	0
	2	5	13	7	1
	0	0	0	0	0
Diptera	0	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0
	1	0	0	1	0
Trichoptera	1	0	0	0	0
	1	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0
Lepidoptera	0	0	0	0	0
Annelida	0	0	0	0	0
Acari	0	0	0	0	0
Crustacea	0	0	0	0	0
Other Organisms	0	0	0	0	0
	0	0	0	0	0
Unknown	1	0	0	0	0
Adult	2	0	1	2	0
TOTAL	8	5	14	10	1
Diversity	0.9333	0	0	0.25	0
Number of Endemics	0	0	0	0	0
Percent Endemics	0	0	0	0	0

Date: 8/29/07 Stream Name: Waiehu Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	2	1	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Diptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	1	2	0	7
	0	0	0	0	0	0
Trichoptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	0	0	0
Acari	0	0	0	0	0	2
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	1	0
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	2	1	1	2	1	9
Diversity	0	0	0	0	0	0.3889
Number of Endemics	0	0	1	2	0	7
Percent Endemics	0	0	100	100	0	77.7778

Date: 8/29/07		Stream Name: Waiehu	Location: Upstream			Microhabitat: Amphibious		
			C1	C2	C3	C4	C5	C6
Odonata	Megalagrion sp.		0	0	0	0	0	0
Coleoptera	Dytiscidae fm.		0	0	0	0	0	0
Diptera-Chironomidae	Telmatogeton gr.		0	0	6	0	0	0
	Other		1	3	6	2	0	4
	Unknown		0	0	0	0	0	0
Diptera	Procnace sp.		0	0	1	0	0	0
	Ephydriidae fm.		0	0	0	0	0	0
	Limonia sp.		0	6	7	2	1	13
	Pupae		0	0	0	0	0	0
Trichoptera	C. analis		0	0	0	0	0	0
	Hydroptila sp.		0	0	0	0	0	0
	Pupae		0	0	0	0	0	0
Lepidoptera	Hypsimocoma sp.		0	0	0	0	0	0
Annelida	Oligochaeta		0	4	0	8	0	0
	Acani		0	0	0	0	0	0
Crustacea	Atyoida bisulcata		0	0	0	0	0	0
Other Organisms	Prostoma sp.		0	0	0	0	0	0
	Turbellaria		0	0	0	0	0	0
Unknown			0	2	0	0	0	0
Adult			0	1	0	1	0	0
TOTAL			1	16	20	13	1	17
Diversity			0	0.7619	0.5421	0.5455	0	0.3824
Number of Endemics			0	6	14	2	1	13
Percent Endemics			0	37.5	70	15.3846	100	76.4706

Date: 5/10/08 Stream Name: Waiehu Location: Downstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	1	0	13	1
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	2	0	4	1	9	7
	21	4	52	29	106	33
	2	0	7	12	17	2
Diptera	0	0	0	0	0	0
	1	0	0	0	0	0
	1	0	0	0	0	0
	2	0	9	6	4	4
Trichoptera	30	0	4	4	142	228
	0	0	0	0	4	3
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	1	0	3	0	53	3
Acani	0	0	0	0	9	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	3	0
TOTAL	60	4	80	52	360	281
Diversity	0.6339	0	0.5576	0.6282	0.7285	0.3280
Number of Endemics	4	0	5	1	22	8
Percent Endemics	6.6667	0	6.25	1.9231	6.1111	2.8470

Date: 5/10/08 Stream Name: Waiehu Location: Upstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	9	0	0	13	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	1	1	0	0	0	1
	83	97	61	15	66	20
	0	0	0	0	0	0
Diptera	0	0	0	0	1	0
	0	0	0	0	0	0
	0	1	1	0	3	0
	9	8	6	1	5	2
Trichoptera	1	114	1	0	120	3
	1	1	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	1	36	0	0	99	0
Acari	1	0	0	0	5	1
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	2	0	0	0	0
Adult	0	2	1	1	1	0
TOTAL	97	271	70	17	313	27
Diversity	0.2436	0.6702	0.2136	0.1250	0.7066	0.3903
Number of Endemics	1	11	1	0	17	1
Percent Endemics	1.0417	4.0590	1.4286	0	5.4313	3.7037

Date: 8/29/07 Stream Name: Waiehu Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	0	0
	0	0	0	1	0	0
	0	0	0	0	0	0
Diptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Trichoptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	0	0	0
Acari	1	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	1
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	1	0	0	1	0	1
Diversity	0	0	0	0	0	0
Number of Endemics	0	0	0	0	0	0
Percent Endemics	0	0	0	0	0	0

Date: 8/29/07 Stream Name: Waiehu Location: Upstream Microhabitat: Amphibious

Odonata	Megalagrion sp.	C1	C2	C3	C4	C5	C6
Coleoptera	Dytiscidae fm.	0	0	0	0	0	0
Diptera-Chironomidae	Telmatogeton gr.	1	0	0	0	0	0
	Other	10	3	3	2	4	0
	Unknown	0	0	0	0	0	0
Diptera	Procladius sp.	0	0	0	0	0	0
	Ephydriidae fm.	0	0	0	0	0	0
	Limonia sp.	0	3	6	10	1	1
	Pupae	0	0	0	1	0	0
Trichoptera	C. analis	0	0	0	0	0	0
	Hydroptila sp.	0	0	0	0	0	0
	Pupae	0	0	0	0	0	0
Lepidoptera	Hypsimacoma sp.	0	0	0	0	0	0
Annelida	Oligochaeta	0	0	0	0	0	0
Acari	Oribatei	0	0	0	0	0	0
Crustacea	Atyoida bisulcata	0	0	0	0	0	0
Other Organisms	Prostoma sp.	0	0	0	0	0	0
	Turbellaria	0	0	0	0	0	0
Unknown		0	0	0	0	0	0
Adult		0	0	0	0	0	0
TOTAL		11	6	9	13	5	1
Diversity		0.1818	0.6	0.5	0.4103	0.4	0
Number of Endemics		1	3	6	10	1	1
Percent Endemics		9.0909	50	66.6667	76.9231	20	100

Date: 8/6/07 Stream Name: Waikapu Location: Upstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	7	0	0	1	0	6
	14	10	15	15	5	56
	3	4	1	2	2	6
Diptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	4	2	1	3	0	5
Trichoptera	31	0	50	3	13	58
	3	3	0	2	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	0	0	2
Acari	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	1	0	1	0
TOTAL	62	19	68	26	21	133
Diversity	0.6885	0.6784	0.4162	0.6523	0.5762	0
Number of Endemics	7	0	0	1	0	6
Percent Endemics	11.2903	0	0	3.8462	0	5

Date: 8/6/07 Stream Name: Waikapu Location: Downstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	3	0	1	2	5	0
	27	90	31	6	44	10
	2	0	3	0	2	1
Diptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	2	0	0	0
	4	0	1	0	3	2
Trichoptera	0	119	23	3	0	111
	3	0	0	0	4	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	15	0	0	0	0
Acani	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	4	0	0	0	3
TOTAL	39	228	61	11	58	127
Diversity	0.5088	0.5543	0.6055	0.6545	0.4156	0.1934
Number of Endemics	3	0	3	2	5	0
Percent Endemics	7.6923	0	4.9180	18.1818	8.6207	0

Date: 8/6/07		Stream Name: Waikapu	Location: Upstream		Microhabitat: Amphibious		
		C1	C2	C3	C4	C5	C6
Odonata	Megalagrion sp.	0	0	0	0	0	0
	Dytiscidae fm.	0	0	0	0	0	0
Diptera-Chironomidae	Telmatogeton gr.	0	0	0	0	0	0
	Other	0	0	5	1	0	3
Diptera	Unknown	0	0	0	3	0	1
	Proclance sp.	0	0	0	0	0	0
	Ephyrididae fm.	0	0	0	1	0	0
	Limonia sp.	0	4	3	3	1	10
Trichoptera	Pupae	0	0	0	0	1	0
	C. analis	0	0	0	0	0	0
	Hydroptila sp.	0	0	0	0	0	0
	Pupae	0	0	0	0	0	0
Lepidoptera	Hyposmocoma sp.	0	0	0	0	0	0
	Oligochaeta	0	0	0	0	0	0
Acari	Oribatei	1	0	0	0	0	0
	Atyoida bisulcata	0	0	0	0	0	0
Other Organisms	Prostoma sp.	0	0	0	0	0	0
	Turbellaria	0	0	0	0	0	0
Unknown		0	0	0	0	0	0
Adult		0	0	0	1	0	0
	TOTAL	1	4	8	9	2	14
	Diversity	0	0	0.5357	0.8333	1	0
	Number of Endemics	0	4	3	4	1	10
	Percent Endemics	0	100	37.5	44.4444	50	71

Date: 8/6/07 Stream Name: Waikapu Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	1	0	0	0	0	1
	9	1	3	7	18	2
	2	0	4	0	1	1
Diptera	0	0	0	0	0	0
	0	0	0	1	0	1
	5	3	0	8	0	0
	2	0	0	1	0	0
Trichoptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	0	0	0
Acanthozoa	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	19	4	7	17	19	5
Diversity	0.7193	0.5	0.5714	0.6397	0.1053	0.9
Number of Endemics	6	3	0	9	0	2
Percent Endemics	31.5789	75	0	52.9412	0	40

Date: 8/22/07 Stream Name: Waikapu Location: Upstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	10	0	3	4	2	3
	179	55	24	51	18	69
	6	7	2	7	1	5
Diptera	0	0	0	0	0	2
	0	0	0	0	0	0
	0	1	0	0	0	0
	4	0	1	1	0	2
Trichoptera	62	10	5	14	73	49
	1	12	2	4	0	0
	3	23	0	3	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	2	1	2	4	0	1
Acari	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	1	0	0	0
TOTAL	267	109	40	88	94	131
Diversity	0.4962	0.6823	0.6256	0.6322	0.3635	0
Number of Endemics	10	1	3	4	2	5
Percent Endemics	3.7453	0.9174	7.5	4.5455	2.1277	3.8168

Date: 8/22/07 Stream Name: Waikapu Location: Downstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	1	5	0	1	3
	3	15	48	4	15	50
	0	1	8	0	1	3
Diptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	1	0	0	0	2
	0	0	5	0	1	5
Trichoptera	0	1	24	0	5	20
	0	0	12	0	0	1
	0	0	8	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	1	0	1	0
Acari	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	1	0	0	0
TOTAL	3	19	112	4	24	84
Diversity	0	0.3860	0.7468	0	0.5833	0.5892
Number of Endemics	0	2	5	0	1	5
Percent Endemics	0	10.5263	4.4643	0	4.1667	5.9524

Date: 8/22/07		Stream Name: Waikapu	Location: Upstream			Microhabitat: Amphibious		
		C1	C2	C3	C4	C5	C6	
Odonata	Megalagrion sp.	0	0	0	0	0	0	
Coleoptera	Dytiscidae fm.	0	0	0	0	0	0	
Diptera-Chironomidae	Telmatogeton gr.	0	0	0	0	1	0	
	Other	2	32	4	0	31	1	
	Unknown	3	9	2	0	5	0	
Diptera	Procladius sp.	0	1	0	0	0	0	
	Ephydriidae fm.	0	0	0	0	0	0	
	Limonium sp.	2	3	0	0	2	11	
	Pupae	0	0	0	0	0	0	
Trichoptera	C. analis	0	0	0	0	1	0	
	Hydroptila sp.	0	0	0	1	0	0	
	Pupae	0	0	0	0	0	0	
Lepidoptera	Hyposmocoma sp.	0	0	0	0	0	0	
Annelida	Oligochaeta	0	0	8	3	1	0	
Acar	Oribatei	0	0	0	0	0	0	
Crustacea	Atyoida bisulcata	0	0	0	0	0	0	
Other Organisms	Prostoma sp.	0	0	0	0	0	0	
	Turbellaria	0	0	0	0	0	0	
Unknown		0	0	4	1	0	0	
Adult		0	0	1	0	0	0	
TOTAL		7	45	19	5	41	12	
Diversity		0.7619	0.4596	0.7602	0.7	0.4195	0	
Number of Endemics		2	4	0	0	3	11	
Percent Endemics		28.5714	8.8889	0	0	7	92	

Date: 8/22/07 Stream Name: Waikapu Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Megalagrion sp.						
Coleoptera	0	0	0	0	0	0
Dytiscidae fm.						
Diptera-Chironomidae	0	0	2	0	0	0
Telmatogeton gr.						
Other	0	0	7	0	1	0
Unknown	0	0	3	0	0	0
Diptera	0	0	0	0	0	0
Procladius sp.						
Ephydriidae fm.	0	4	0	0	0	0
Limonia sp.	0	0	0	0	0	0
Pupae	0	0	0	0	0	0
Trichoptera	0	0	0	0	0	0
C. analis						
Hydropsyche sp.	1	0	0	0	0	0
Pupae	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Hypocyma sp.						
Annelida	0	0	0	0	0	0
Oligochaeta						
Acari	0	0	0	0	0	0
Oribatei						
Crustacea	0	0	0	0	0	0
Atyoida bisulcata						
Other Organisms	0	0	0	0	0	0
Procladius sp.						
Turbellaria	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	1	0	0	0	0	0
TOTAL	2	4	12	0	1	0
Diversity	0	0	0.6212	0	0	0
Number of Endemics	0	4	2	0	0	0
Percent Endemics	0	100	16.6667	0	0	0

Date: 5/12/08 Stream Name: Waikapu Location: Upstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	3	0	1	1	0	0
	39	74	37	41	13	21
	1	2	1	1	1	0
Diptera	0	0	1	0	0	0
	0	0	1	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	1	4	1	0	1
Trichoptera	1	50	140	130	0	3
	2	4	5	3	4	39
	2	0	3	0	1	7
Lepidoptera	0	0	0	0	0	0
Annelida	0	13	1	3	0	0
Acaril	0	0	0	4	0	0
Crustacea	0	1	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	3	0	1
Adult	0	1	1	0	0	1
TOTAL	48	145	195	187	19	73
Diversity	0.1833	0.5964	0.4635	0.4885	0.4	0.6249
Number of Endemics	3	0	3	1	0	0
Percent Endemics	5.7692	0	1.4851	0.5128	0	0

Date: 5/12/08 Stream Name: Waikapu Location: Downstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	1	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	0	0
	8	18	53	82	64	9
	0	0	0	1	1	0
Diptera	0	0	0	0	0	0
	0	0	2	0	0	0
	0	0	0	0	0	2
	0	1	2	8	10	1
Trichoptera	5	0	1	82	81	0
	2	0	5	9	4	0
	1	0	0	10	10	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	0	3	1
Acanthi	0	0	0	0	1	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	1	0	0	1	1	0
Adult	0	0	0	2	2	0
TOTAL	17	19	63	195	178	13
Diversity	0.6928	0.1053	0.2883	0.6299	0.6477	0.5256
Number of Endemics	0	0	2	0	1	2
Percent Endemics	0	0	3.1746	0	0.5618	15.3846

Date: 5/12/08		Stream Name: Waikapu	Location: Upstream		Microhabitat: Amphibious		
		C1	C2	C3	C4	C5	C6
Odonata	Megalagrion sp.	0	0	0	0	0	0
	Dytiscidae fm.	0	0	0	0	0	0
Diptera-Chironomidae	Telmatogeton gr.	0	0	0	0	0	0
	Other	21	12	12	1	7	5
	Unknown	0	0	0	0	0	0
Diptera	Procladius sp.	0	0	0	0	0	0
	Ephydriidae fm.	0	29	6	0	0	0
	Limonia sp.	3	16	14	8	10	22
	Pupae	1	3	2	0	1	1
Trichoptera	C. analis	0	0	0	0	0	0
	Hydroptila sp.	3	0	0	0	0	0
	Pupae	0	0	0	0	0	0
Lepidoptera	Hypsimacoma sp.	0	0	0	0	0	0
Annelida	Oligochaeta	2	0	1	0	0	0
	Oribatei	0	0	0	0	0	0
Crustacea	Atyoida bisulcata	0	0	0	0	0	0
	Procladius sp.	0	0	0	0	0	0
Other Organisms	Turbellaria	0	0	0	0	0	0
	Unknown	0	0	0	0	0	0
Adult		0	0	0	0	0	0
TOTAL		30	60	35	9	18	28
Diversity		0.5011	0.6552	0.7063	0.2222	0.5686	0.3941
Number of Endemics		3	45	20	8	10	22
Percent Endemics		10	76.2712	55.5556	88.8889	55.5556	75.8621

Date: 5/12/08 Stream Name: Waikapu Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	0	0
	0	0	1	9	0	8
	0	0	0	0	0	0
	0	0	0	0	0	0
Diptera	0	0	0	0	0	0
	0	0	0	0	0	0
	6	3	1	9	6	3
	0	0	1	2	1	0
Trichoptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	5	0	0
Acanthocephala	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	1	0	0	0	0	0
TOTAL	0	3	0	0	7	0
Diversity	0	0	1	0.7094	0.2857	0.4667
Number of Endemics	6	3	1	9	6	3
Percent Endemics	85.7143	100	33.3333	33.3333	85.7143	30

Date: 8/1/07 Stream Name: Waihe'e Location: Upstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	2	9	2	5	2	0
	95	5	20	86	83	23
	5	2	0	3	1	0
Diptera	3	1	0	4	7	0
	0	1	1	0	0	1
	0	0	0	0	0	0
	18	10	5	3	31	3
Trichoptera	25	0	0	100	25	1
	17	15	5	5	5	5
	3	3	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	3	0	0
Acari	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	168	46	33	209	154	33
Diversity	0.6385	0.8068	0.6004	0.6025	0.6435	0.4962
Number of Endemics	5	11	3	9	9	1
Percent Endemics	2.9762	23.9130	9.0909	4.3062	5.8442	3.0303

Date: 8/1/07 Stream Name: Waihe'e Location: Downstream Microhabitat: Torrenicolous

	C1	C2	C3	C4	C5
Odonata	0	0	0	0	0
Megalagrion sp.					
Coleoptera	0	0	0	0	0
Dytiscidae fm.					
Diptera-Chironomidae	1	0	1	0	0
Telmatogeton gr.					
Other	0	8	2	6	2
Unknown	0	0	0	0	0
Diptera	0	0	0	0	0
Procnace sp.					
Ephydriidae fm.	0	7	0	0	0
Limonia sp.	0	0	0	0	0
Pupae	0	1	0	1	1
Trichoptera	0	1	0	55	24
C. analis					
Hydroptila sp.	0	0	0	0	0
Pupae	0	0	0	0	0
Lepidoptera	0	0	0	0	0
Hypsmocoma sp.					
Annelida	0	0	0	0	0
Oligochaeta					
Acar	0	0	0	0	0
Oribatei					
Crustacea	0	0	0	0	0
Atyoida bisulcata					
Other Organisms	0	0	0	0	0
Prostoma sp.					
Turbellaria	0	0	0	0	0
Unknown	0	0	0	0	0
Adult	0	0	2	0	1
TOTAL	1	17	5	62	28
Diversity	0	0.6397	0.6667	0.2068	0.2108
Number of Endemics	1	7	1	0	0
Percent Endemics	100	41.1765	20	0	0

Date: 8/1/07 Stream Name: Waihe'e Location: Upstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	0	0	1	0	0
	0	16	20	10	1	1
	0	0	0	0	2	0
	0	0	0	0	0	0
Diptera	0	0	0	0	0	0
	0	6	4	1	2	4
	1	2	3	3	0	9
	0	5	5	1	1	1
Trichoptera	0	0	0	0	0	0
	0	0	0	2	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
	0	0	0	0	3	0
Annelida	0	0	0	0	0	0
Acar	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	1	29	32	18	9	15
Diversity	0	0.6404	0.5786	0.6797	0.8611	0.6
Number of Endemics	1	8	7	5	2	13
Percent Endemics	100	27.5862	21.8750	27.7778	22.2222	86.6667

Date: 8/1/07 Stream Name: Waihe'e Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	0	0
	3	0	0	0	0	0
	0	0	0	0	0	0
Diptera	0	0	0	0	0	0
	0	0	0	0	1	0
	30	3	0	4	3	3
	2	0	0	0	0	1
Trichoptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	0	0	0
Acar	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	35	3	0	4	4	4
Diversity	0.2622	0	0	0	0.5	0.5
Number of Endemics	30	3	0	4	4	3
Percent Endemics	85.7143	100	0	100	100	75

Date: 8/7/07 Stream Name: Waihe'e Location: Upstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	4	3	3	0	5	1
	41	112	71	19	133	54
	1	0	0	1	2	0
Diptera	5	3	2	3	7	2
	0	0	0	0	0	3
	1	0	0	0	1	1
	11	22	13	5	15	10
Trichoptera	6	0	113	0	11	106
	10	17	17	1	28	9
	0	0	0	0	3	0
Lepidoptera	0	0	0	0	0	0
Annelida	1	0	0	0	0	0
Acari	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	2	0
Adult	0	1	2	0	0	0
TOTAL	80	158	221	29	207	186
Diversity	0.6991	0.4619	0.6217	0.5468	0.5614	0.5884
Number of Endemics	10	6	5	3	13	7
Percent Endemics	12.5	3.7975	2.2624	10.3448	6.2802	3.7634

Date: 8/7/07 Stream Name: Waihe'e Location: Downstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	1	1
	6	9	2	4	3	14
	0	0	0	0	1	0
Diptera	0	0	0	0	0	0
	0	0	1	0	0	5
	0	0	0	0	0	0
	2	1	1	0	0	0
Trichoptera	0	0	1	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	0	0	0	0	0	0
Acaril	1	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	1	3	0	0	0
TOTAL	9	11	8	4	5	20
Diversity	0.5556	0.2	0.9	0	0.7	0.4684
Number of Endemics	0	0	1	0	1	6
Percent Endemics	0	0	12.5	0	20	30

Date: 5/23/08 Stream Name: Waihe'e Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	0	0	0	0	0	0
	23	30	24	13	25	4
	0	0	0	0	0	0
Diptera	0	0	0	0	0	0
	7	1	15	1	0	0
	1	15	1	0	1	16
	1	0	1	2	0	1
Trichoptera	0	0	0	1	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	1	0	0	7	0	0
Acar	0	0	0	1	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	1	2	0	1	0
Adult	1	0	0	0	0	0
TOTAL	34	47	43	25	27	21
Diversity	0.4811	0.5005	0.5770	0.6667	0.1453	0.3368
Number of Endemics	8	16	16	1	1	16
Percent Endemics	23.5294	34.0426	37.2093	4	3.7037	80

Date: 5/23/08 Stream Name: Waihe'e Location: Upstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	34	197	104	16	304	35
	0	0	0	0	0	0
	0	0	0	0	0	0
Diptera	0	0	0	0	0	2
	7	2	0	1	6	10
	13	1	0	18	1	3
	2	1	1	0	2	4
Trichoptera	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Annelida	1	2	0	0	24	0
Acar	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	1
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	57	203	105	35	337	55
Diversity	0.5858	0.0583	0.0190	0.5412	0.1814	0.5412
Number of Endemics	20	3	0	19	7	15
Percent Endemics	35.0877	1.4778	0	54.2857	2.0772	27.2727

Date: 5/23/08 Stream Name: Waihe'e Location: Downstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Megalagrion sp.						
Coleoptera	0	0	0	0	0	0
Dytiscidae fm.						
Diptera-Chironomidae	0	0	0	0	0	0
Telmatogeton gr.						
Other	61	75	24	175	149	27
	0	0	0	0	0	0
Unknown						
Diptera	0	0	0	1	1	0
Procladius sp.						
Ephydriidae fm.	0	0	6	0	1	0
Limonia sp.	0	0	0	0	0	0
Pupae	5	8	1	3	8	3
Trichoptera	0	0	0	125	0	2
C. analis						
Hydroptila sp.	0	0	1	16	0	0
Pupae	0	0	0	6	0	0
Lepidoptera	0	0	0	0	0	0
Hypsimacoma sp.						
Annelida	1	0	0	9	0	0
Oligochaeta						
Acari	0	0	0	2	0	0
Oribatei						
Crustacea	0	0	0	0	0	0
Atyoida bisulcata						
Other Organisms	0	0	0	0	0	0
Procladius sp.						
Turbellaria	0	0	0	0	0	0
Unknown	0	0	1	0	0	0
Adult	0	0	0	1	1	0
TOTAL	67	83	33	338	160	32
Diversity	0.1678	0.1763	0.4489	0.5911	0.1200	0.2843
Number of Endemics	0	0	6	1	2	0
Percent Endemics	0	0	18.1818	0.2959	1.25	0

Date: 5/23/08 Stream Name: Waihe'e Location: Upstream Microhabitat: Torrenticolous

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0
Diptera-Chironomidae	1	9	2	1	0	0
	57	144	423	291	212	431
	0	0	0	0	0	0
Diptera	1	4	0	1	0	0
	0	0	3	0	0	0
	0	0	1	0	0	0
	13	42	46	23	22	55
Trichoptera	1	0	6	19	10	30
	0	2	53	53	20	73
	0	0	2	2	1	10
Lepidoptera	0	0	1	0	0	0
Annelida	2	0	36	14	28	58
Acari	0	0	0	0	0	0
Crustacea	0	0	0	0	0	0
Other Organisms	0	0	0	0	0	0
	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	2	0	1	0	0	0
TOTAL	77	201	574	404	293	657
Diversity	0.3964	0.4428	0.4367	0.4584	0.4574	0.5410
Number of Endemics	2	13	6	2	0	0
Percent Endemics	2.5316	6.4677	1.0471	0.4950	0	0

Date: 8/7/07 Stream Name: Waihe'e Location: Downstream Microhabitat: Amphibious

	C1	C2	C3	C4	C5	C6
Odonata	0	0	0	0	0	0
Megalagrion sp.						
Coleoptera	0	0	0	0	0	0
Dytiscidae fm.						
Diptera-Chironomidae	0	0	0	0	0	0
Telmatogeton gr.						
Other	2	2	0	0	1	3
Unknown	0	0	0	0	1	0
Diptera	3	0	0	0	0	0
Procance sp.						
Ephyrididae fm.	5	1	0	1	3	59
Limonia sp.	1	0	0	0	0	0
Pupae	0	0	0	0	0	0
Trichoptera	0	0	0	0	0	0
C. analis						
Hydroptila sp.	0	0	0	0	0	0
Pupae	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0
Hypomocoma sp.						
Annelida	0	0	0	0	0	0
Oligochaeta						
Acari	0	0	0	0	0	0
Oribatei						
Crustacea	0	0	0	0	0	0
Atyoida bisulcata						
Other Organisms	0	0	0	0	0	0
Prostoma sp.						
Turbellaria	0	0	0	0	0	0
Unknown	0	0	0	0	0	0
Adult	0	0	0	0	0	0
TOTAL	11	3	0	1	5	62
Diversity	0.7455	0.6667	0	0	0.7	0.0936
Number of Endemics	9	1	0	1	3	59
Percent Endemics	81.8182	33.3333	0	100	60	95.1613

Date: 8/7/07		Stream Name: Waihe'e	Location: Upstream			Microhabitat: Amphibious		
			C1	C2	C3	C4	C5	C6
Odonata	Megalagrion sp.		0	0	0	0	0	0
Coleoptera	Dytiscidae fm.		0	0	0	0	0	0
Diptera-Chironomidae	Telmatogeton gr.		0	1	0	0	0	3
	Other		0	20	9	11	26	16
	Unknown		0	0	1	0	0	0
Diptera	Procladius sp.		0	1	0	3	1	2
	Ephydriidae fm.		1	11	0	0	10	15
	Limonia sp.		2	0	3	0	3	1
Trichoptera	Pupae		2	2	0	0	1	1
	C. analis		0	0	0	0	0	0
	Hydropsyche sp.		0	0	1	0	1	1
Lepidoptera	Pupae		0	0	0	0	0	0
	Hypocyma sp.		0	0	0	0	0	0
	Oligoneura		0	0	0	0	0	0
Acari	Oribatei		0	0	1	0	0	0
	Atyoida bisulcata		0	0	0	0	0	0
	Procladius sp.		0	0	0	0	0	0
Unknown	Turbellaria		0	0	0	0	0	0
			0	0	0	0	0	0
			0	0	0	0	0	0
Adult			0	0	0	0	0	0
TOTAL			5	35	15	14	42	39
Diversity			0.8	0.5866	0.6286	0.3626	0.5668	0.6910
Number of Endemics			3	13	3	3	14	21
Percent Endemics			60	37.1429	20	21.4286	33.3333	53.8462

Taxa	Waikapu US	Waikapu DS	Waiehu US	Waiehu DS	lao US	lao DS	Waihe'e US	Waihe'e DS
Chironomidae	24 (34)	18 (24)	36 (64)	12 (25)	44 (43)	70 (144)	87 (115)	20 (40)
Telmatogeton	1 (2)	1 (1)	1 (1)	1 (2)	0 (1)	1 (1)	2 (2)	0 (0)
Procanace	0 (0)	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	1 (2)	0 (1)
Ephydriidae	1 (5)	0 (1)	0 (1)	0 (0)	5 (13)	0 (1)	2 (4)	3 (10)
Limonia	3 (5)	1 (2)	2 (3)	0 (2)	2 (2)	1 (3)	2 (4)	2 (6)
Cheumatopsyche	19 (36)	13 (32)	42 (99)	18 (55)	7 (21)	57 (161)	13 (30)	6 (23)
Hydroptila	2 (7)	1 (3)	9 (31)	0 (1)	11 (18)	20 (68)	9 (17)	0 (3)
Oligochaete	1 (3)	1 (3)	7 (18)	3 (11)	6 (24)	2 (9)	5 (12)	1 (2)
Acari	0 (0)	0 (0)	1 (2)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)

Summary of mean (SD) densities of each taxa for the three sampling dates and two microhabitats pooled.

APPENDIX B:
Physical Data

Watershed	Date	Location	Number of Gravel Measurements	Size Range Category (mm)	Mean Size (mm)	Median Size (mm)	SD	D50 (50% are equal to or smaller than (mm))
Waikapu	5/12/08	US	131	2—10,069	420	64	1,246.3	130
Waikapu	5/12/08	DS	132	11—4,096	326	215	380.9	195
lao	5/13/08	US	282	2—2,048	337	250	379.4	160
lao	5/13/08	DS	147	11—2,048	399	260	403.5	300
Waiehu	5/10/08	US	126	8—10,068	471	90	1,529.6	90
Waiehu	5/10/08	DS	122	4—4,096	356	213	393.8	220
Waihee	5/22/08	US	349	2—4,096	287	180	383.6	135
Waihee	5/23/08	DS	148	6—4,096	540	300	687.8	325
Waikapu & Waiehu		US	257	2—10,069	445	128	1,389.9	100
Waikapu & Waiehu		DS	254	4—4,096	341	213	386.6	200
lao & Waihee		US	631	2—4,096	310	240	382.2	128
lao & Waihee		DS	295	6—4,096	469	300	567.8	256
Four Combined		US	888	2—10,069	349	180	815.5	128
Four Combined		DS	549	4—4,096	410	250	496.1	256

Results of gravelometer measurements for the four watersheds. Ten transects were measured for each reach.

Size Class	Size Range (mm)	Particle Size Category (mm)	Particle Size Log ₂ (mm)
Sand	<2	2	1.00
Very Fine Gravel	2—4	4	2.00
Fine Gravel	4—6	6	2.58
Fine Gravel	6—8	8	3.00
Medium Gravel	8—11	11	3.46
Medium Gravel	11—16	16	4.00
Coarse Gravel	16—22	22	4.46
Coarse Gravel	22—32	32	5.00
Very Coarse Gravel	32—45	45	5.49
Very Coarse Gravel	45—64	64	6.00
Small Cobble	64—90	90	6.49
Medium Cobble	90—128	128	7.00
Large Cobble	128—180	180	7.49
Very Large Cobble	180—256	256	8.00
Small Boulder	256—512	512	9.00
Medium Boulder	512—1024	1024	10.00
Large Boulder	1024—2048	2048	11.00
Large Boulder	2048—4096	4096	12.00
Very Large Boulder	4095—5461	5461	12.42
Very Large Boulder	5461—6997	6997	12.77
Very Large Boulder	6997—8533	8533	13.06
Very Large Boulder	8533—10069	10069	13.30

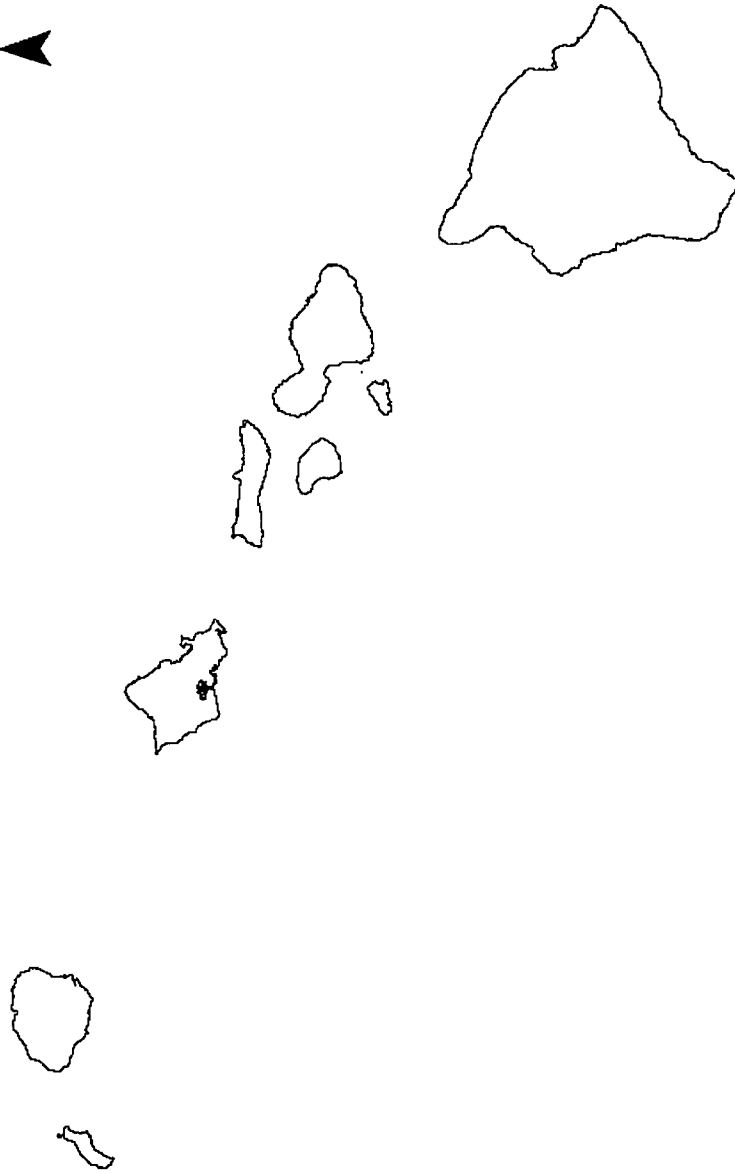
Classification of each of the size classes of gravel.

Watershed	Date	Location	Mean values (n=10) for density readings facing upstream (U), left descending bank (LDB), downstream (D) and right descending bank (RDB)				Percent Canopy Density n=40 Mean
			U	LDB	D	RDB	
Waikapu	5/11/08	US	97.3	98.2	96.9	98.1	97.6
Waikapu	5/11/08	DS	99.0	99.5	99.0	99.3	99.2
lao	5/13/08	US	25.8	58.7	10.4	42.4	34.3
lao	5/13/08	DS	16.4	26.0	23.2	86.6	38.1
Waiehu	5/10/08	US	96.2	97.3	96.5	97.1	96.8
Waiehu	5/10/08	DS	97.0	95.1	98.0	98.5	97.1
Waihee	5/22/08	US	33.3	52.3	25.8	50.0	40.4
Waihee	5/22/08	DS	54.6	81.1	37.4	62.8	59.0

Results for canopy cover measurements collected with a densiometer for each of the watersheds.

APPENDIX C:
Tables, Figures and Photos

The Hawaiian Islands



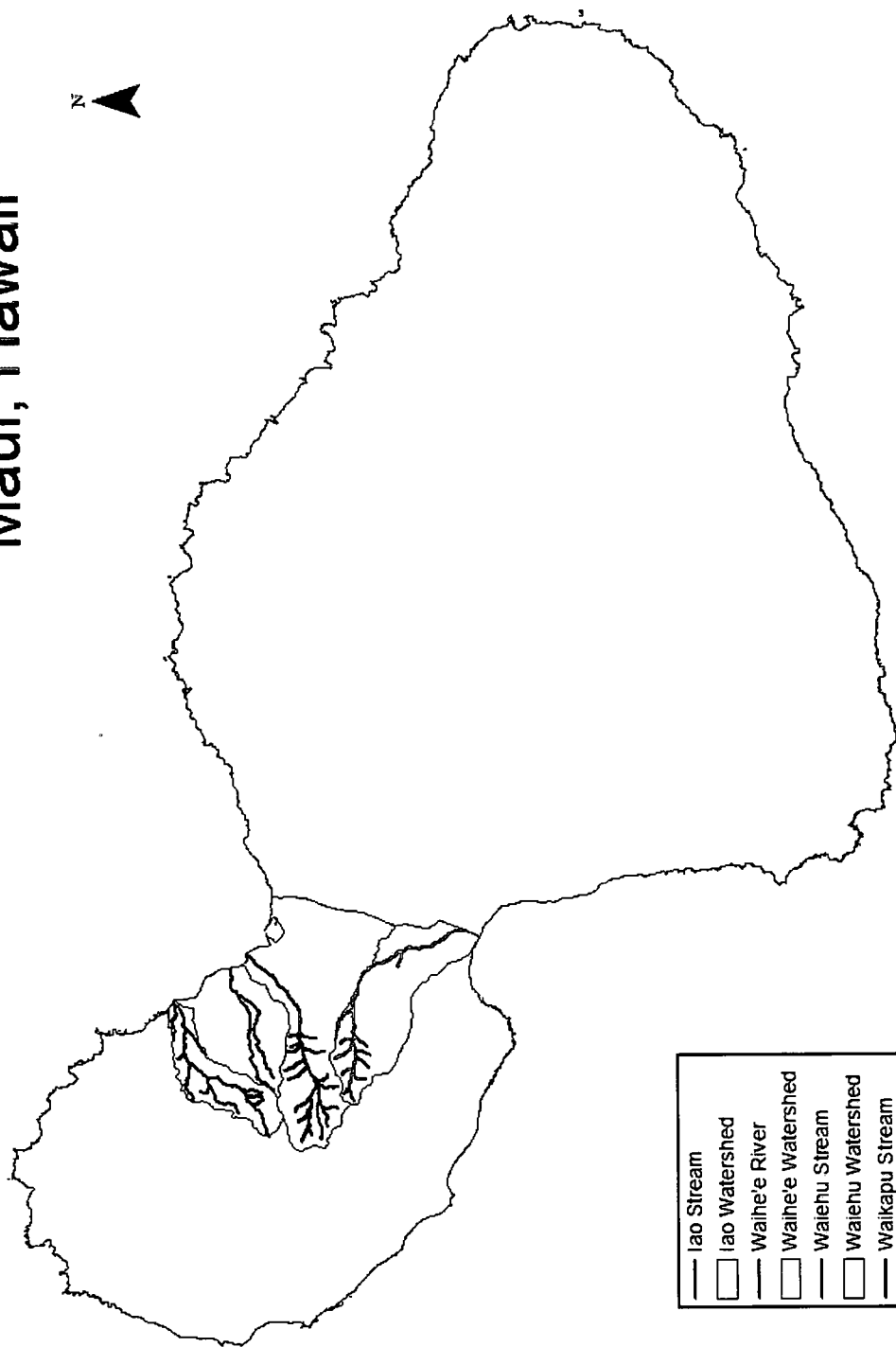
0 25 50 100 Kilometers

Maui, Hawaii



0 3.5 7 14 Kilometers

- Iao Stream
- ☐ Iao Watershed
- Waihe'e River
- ☐ Waihe'e Watershed
- Waiehu Stream
- ☐ Waiehu Watershed
- Waikapu Stream
- ☐ Waikapu Watershed



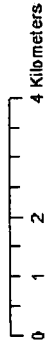
West Maui



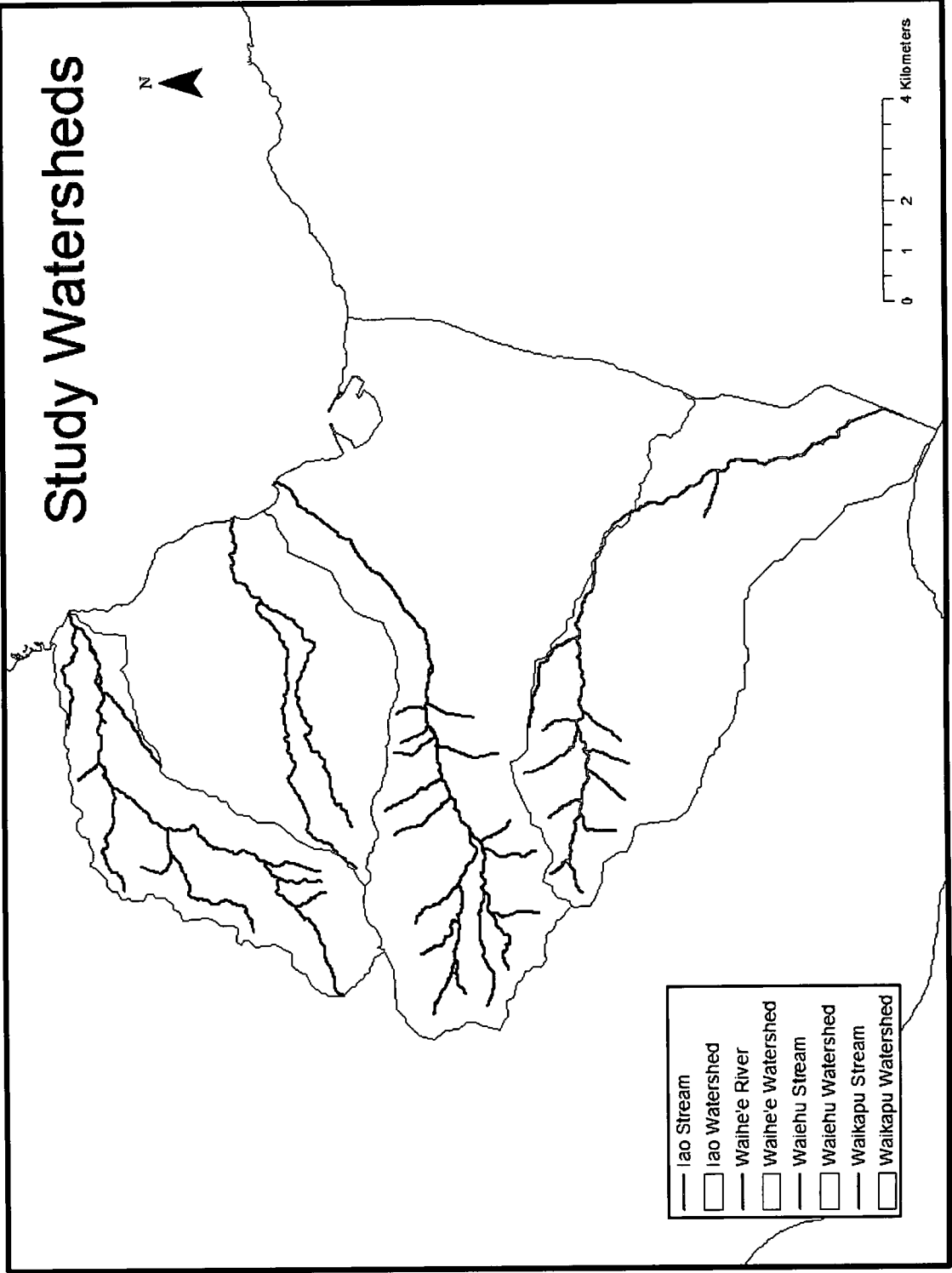
0 2 4 8 Kilometers

- | | |
|---|-------------------|
| — | Iao Stream |
| □ | Iao Watershed |
| — | Waihe'e River |
| □ | Waihe'e Watershed |
| — | Waiehu Stream |
| □ | Waiehu Watershed |
| — | Waikapu Stream |
| □ | Waikapu Watershed |

Study Watersheds



- | | |
|---|-------------------|
| — | Iao Stream |
| □ | Iao Watershed |
| — | Waie'e River |
| □ | Waie'e Watershed |
| — | Waiehu Stream |
| □ | Waiehu Watershed |
| — | Waikapu Stream |
| □ | Waikapu Watershed |

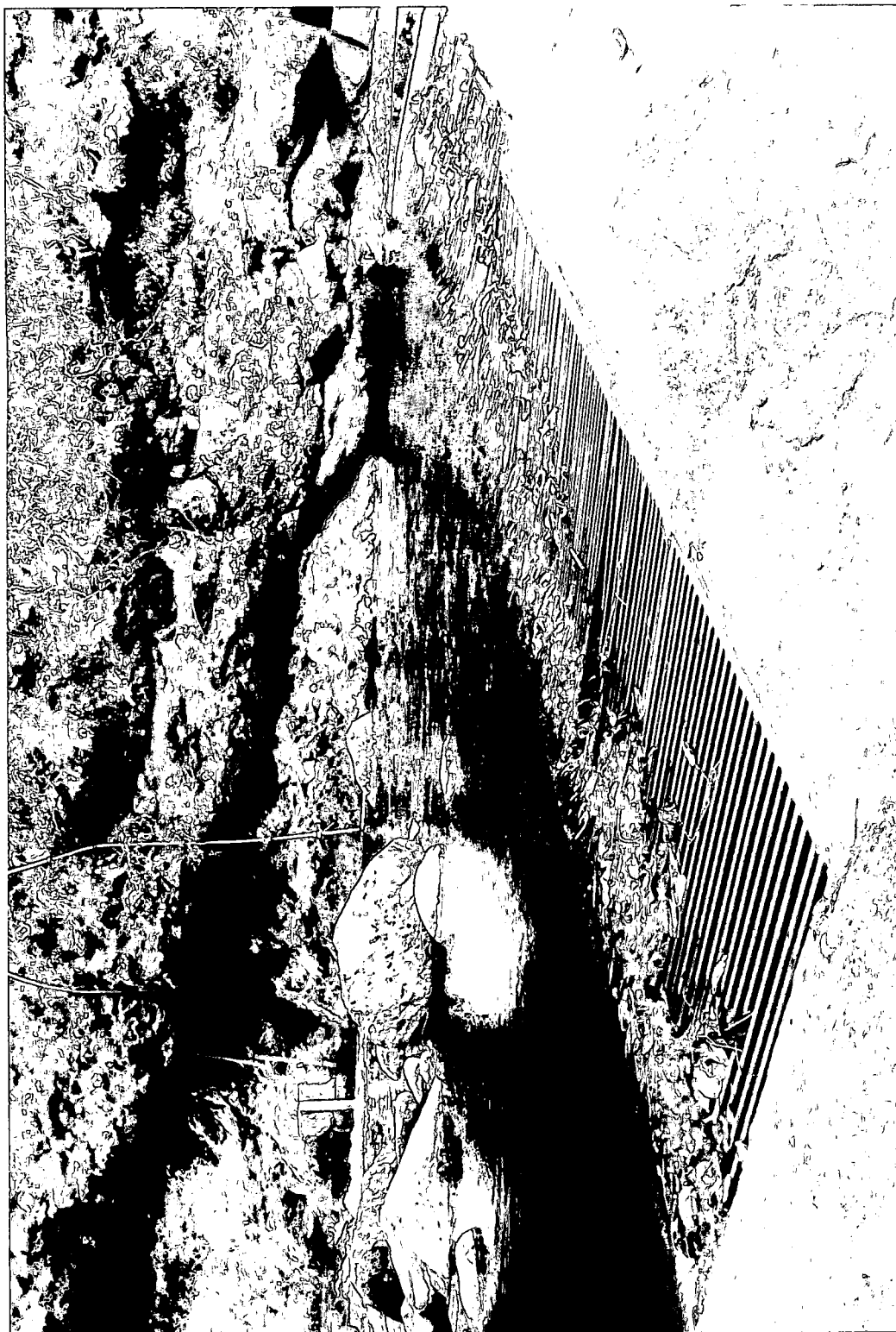




An upstream cascade at Iao Stream, May, 12 2008 .



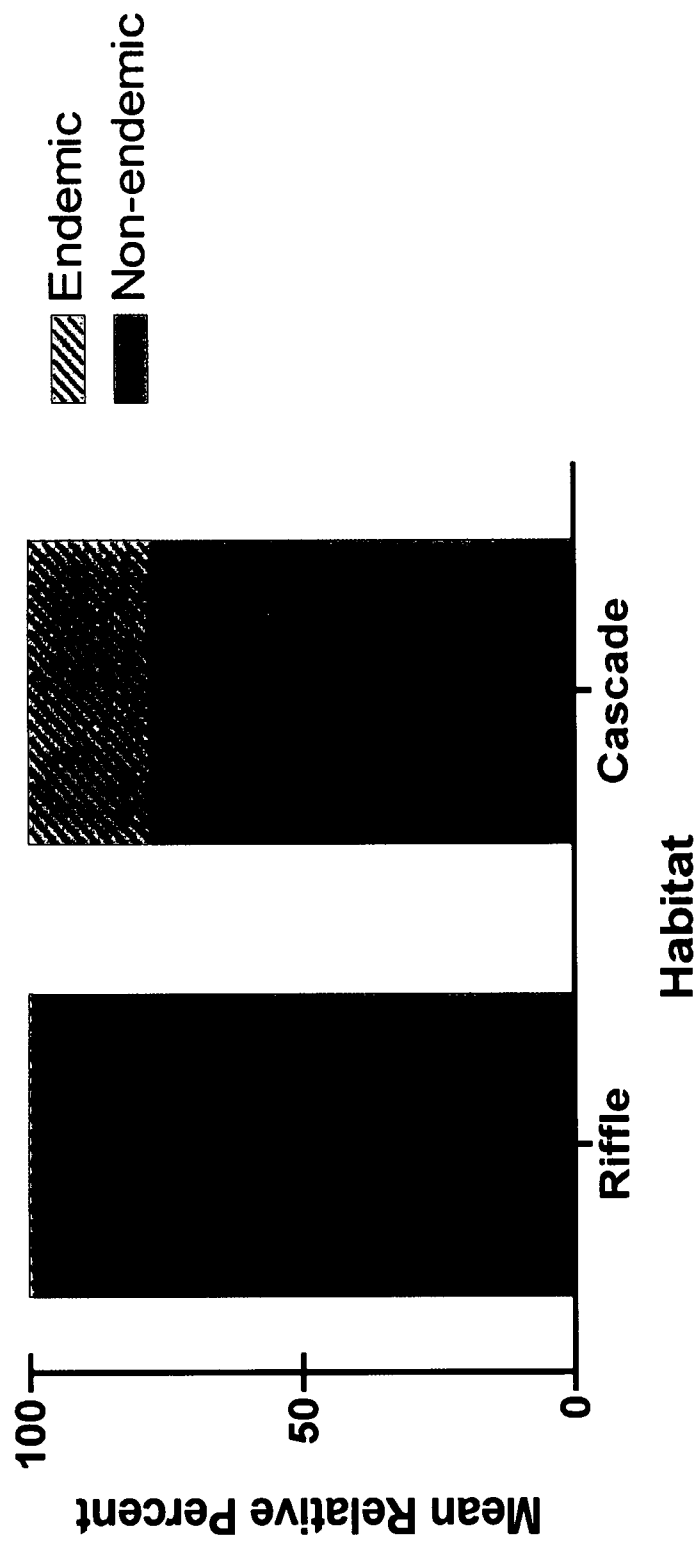
A downstream cascade at Lao Stream, May 12, 2008 .



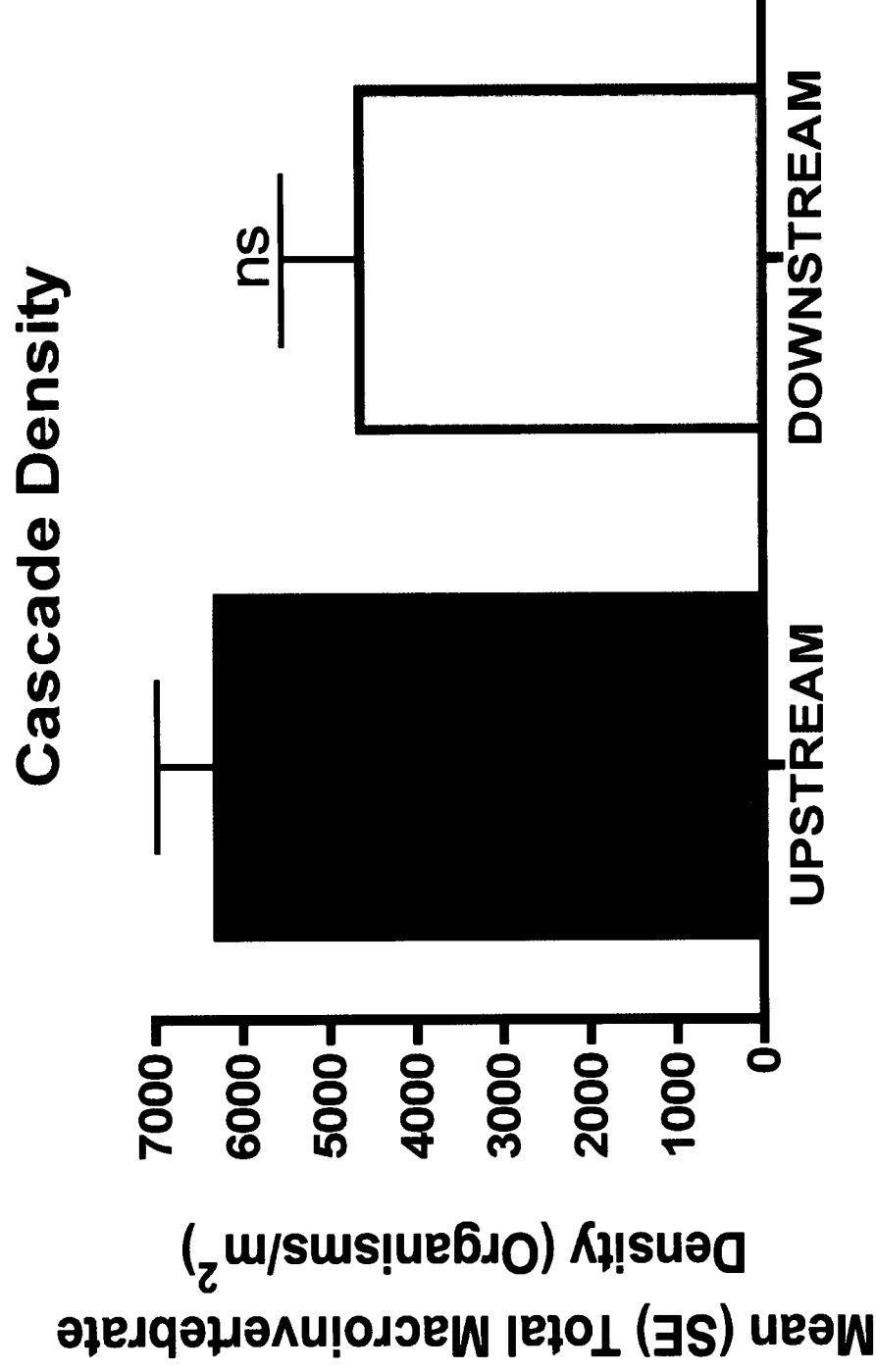
The first (highest) diversion at Iao Stream, May, 2008.



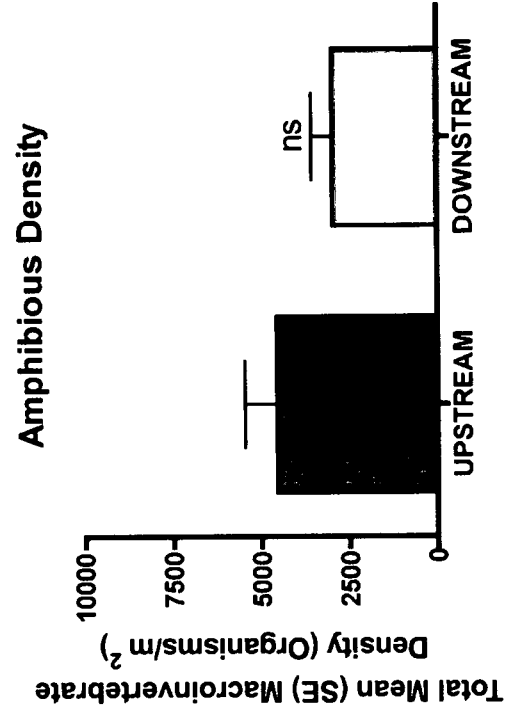
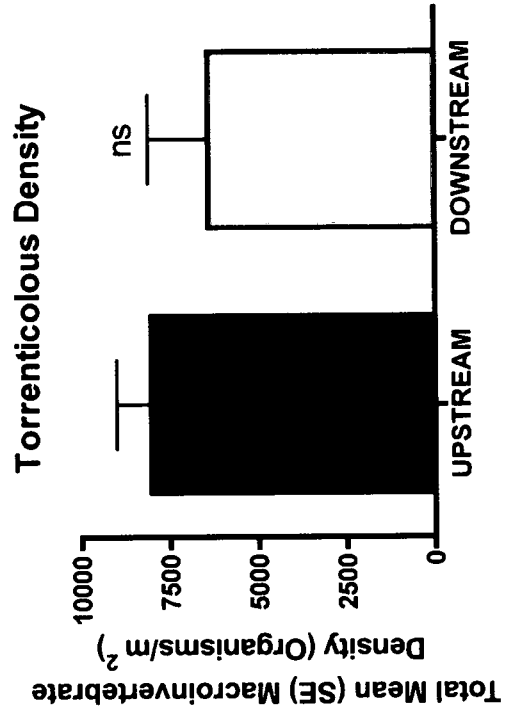
The first (highest) diversion at Waikapu Stream, May, 2008.



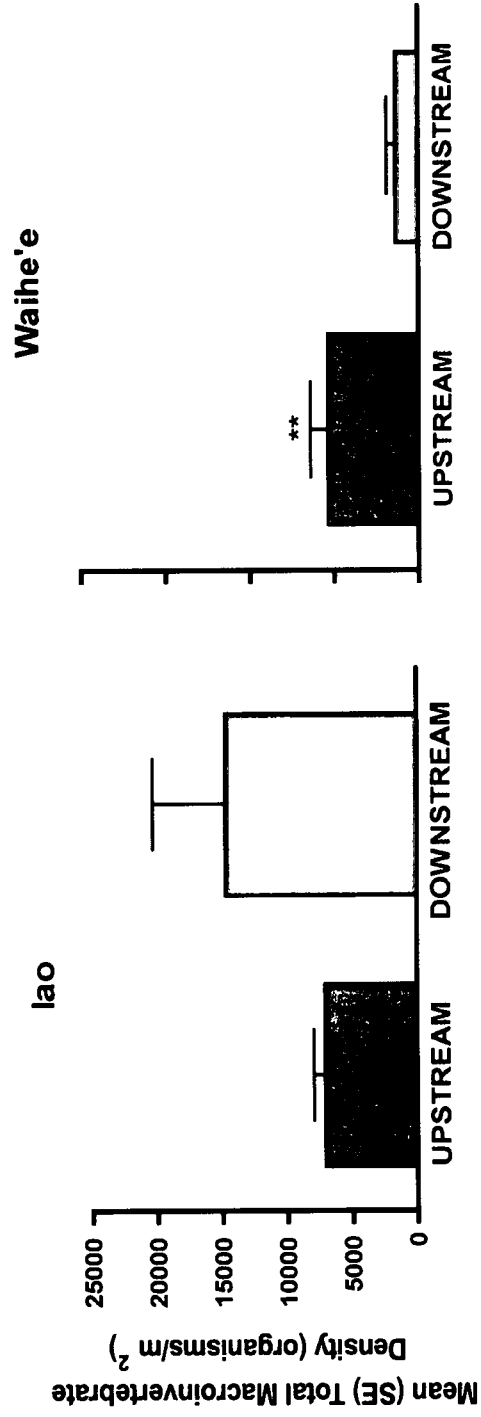
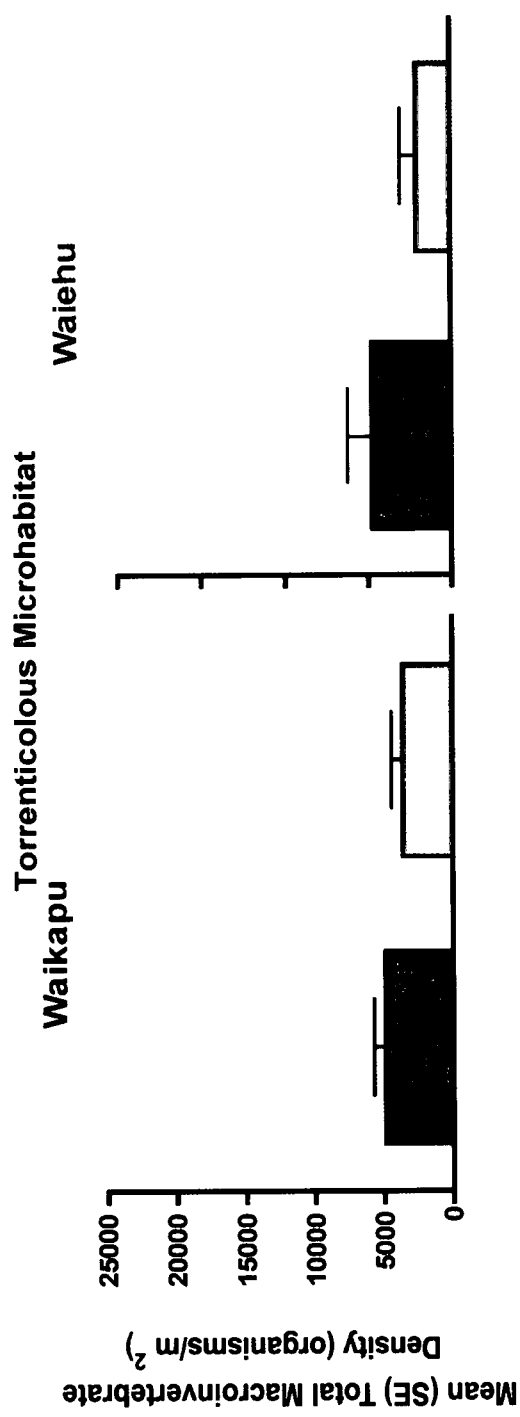
Mean relative percent of endemic and non-endemic macroinvertebrates in cascade and riffle habitats.
n=144 for riffles and n= 270 for cascades.



For all streams and dates and microhabitats pooled. $n=135$.

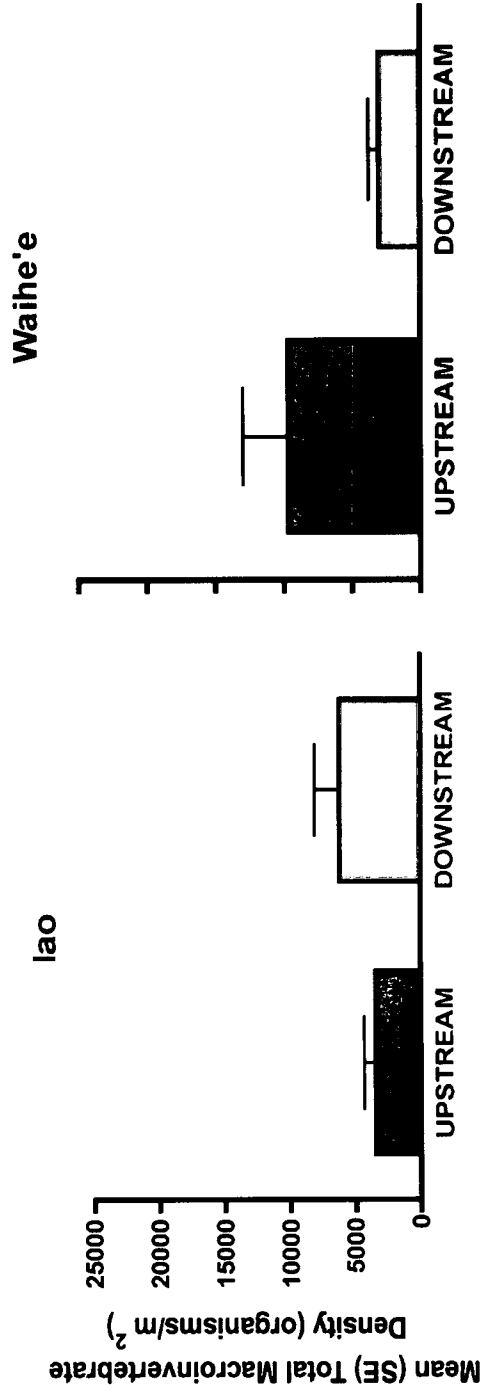
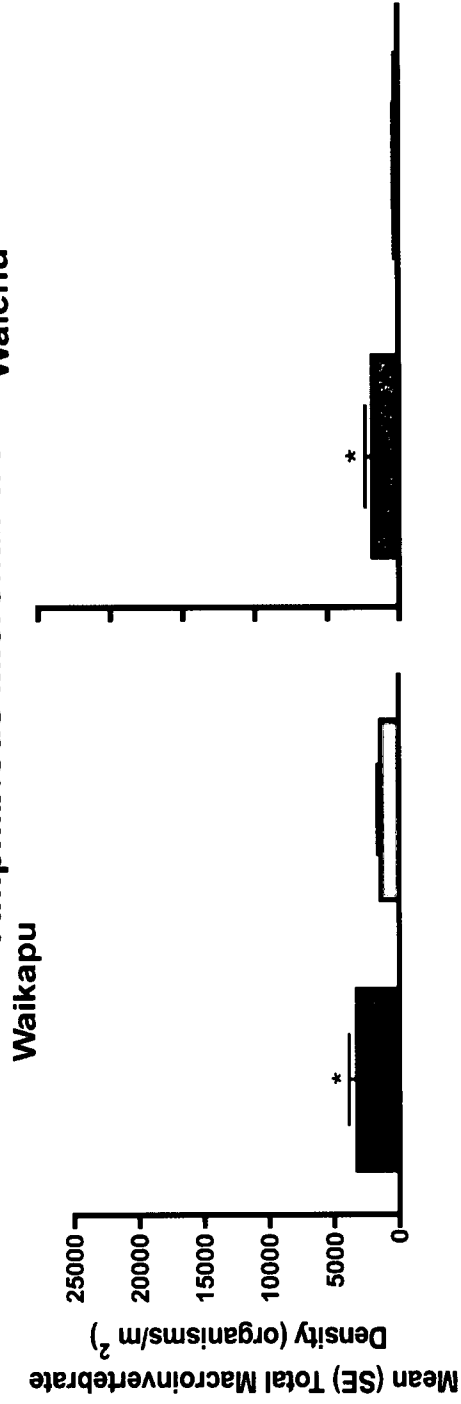


For all streams and dates pooled.



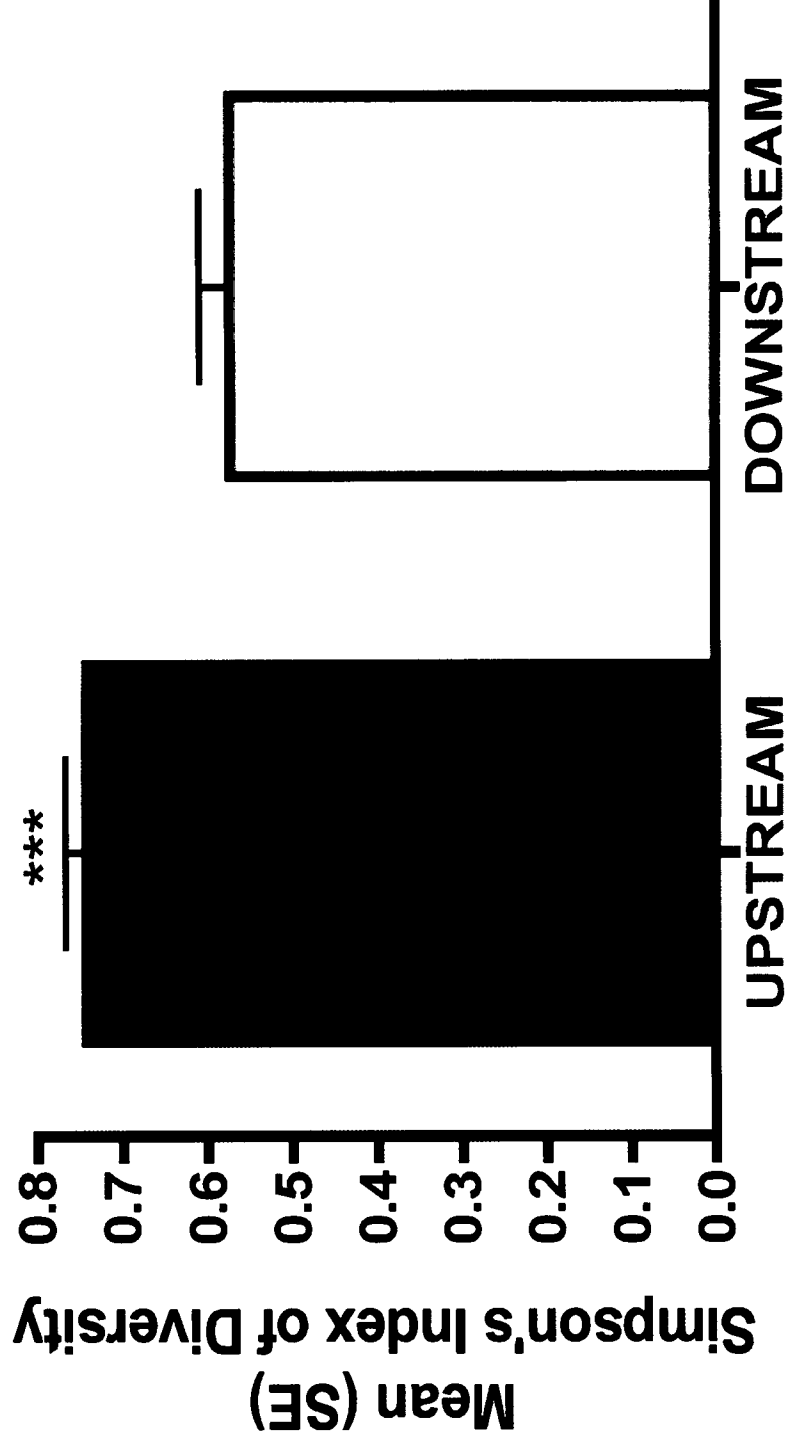
All dates pooled.

Amphibious Microhabitat

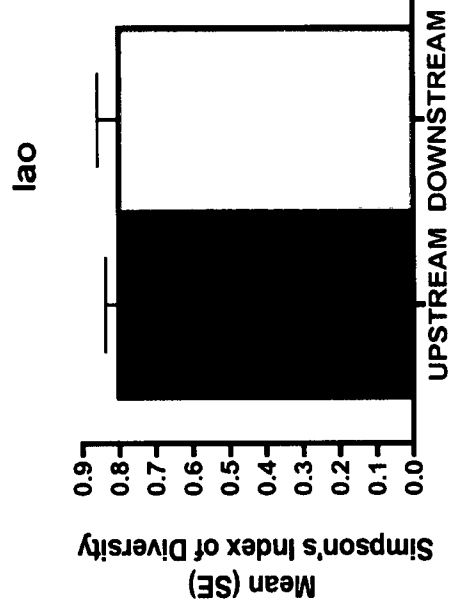
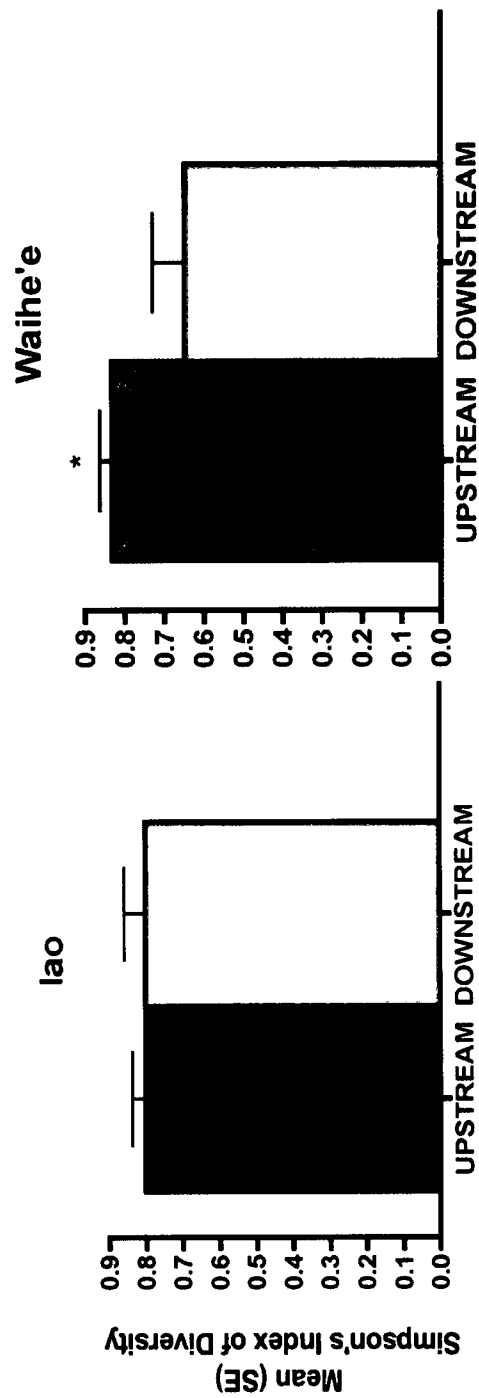
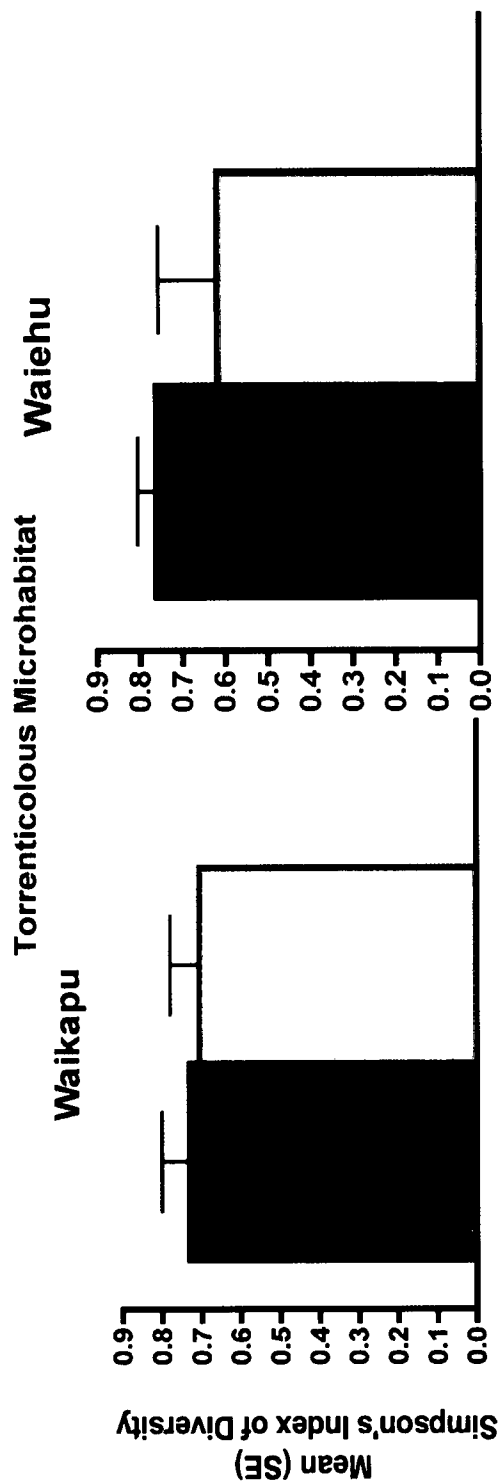


All dates pooled.

Cascade Diversity

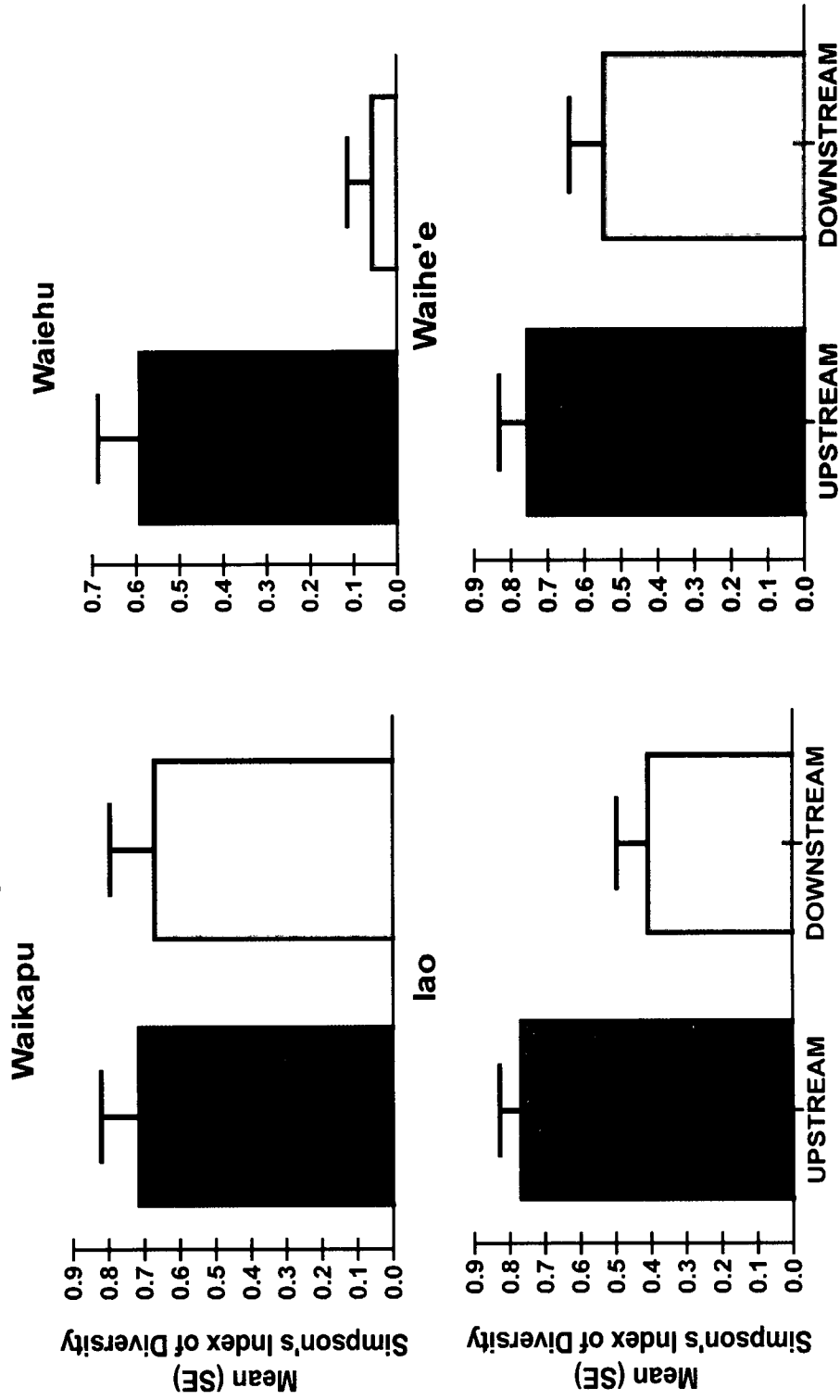


All streams, dates and microhabitats pooled.



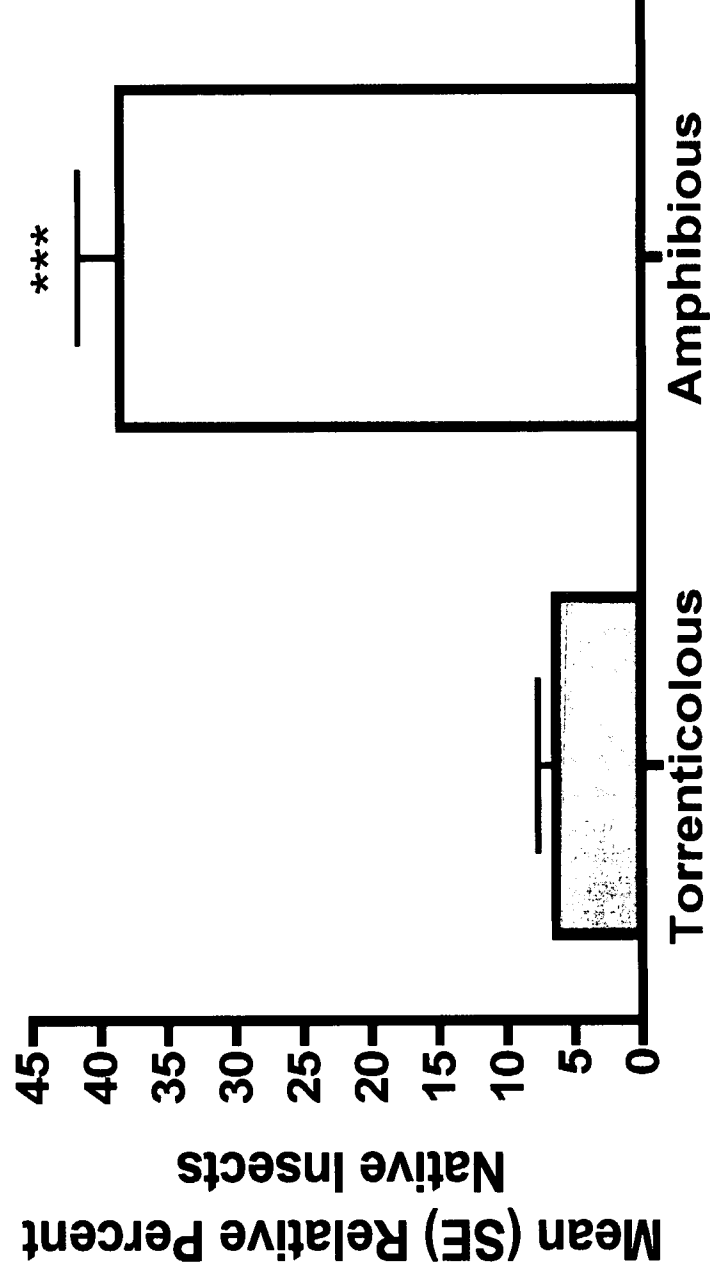
All dates pooled.

Amphibious Microhabitat

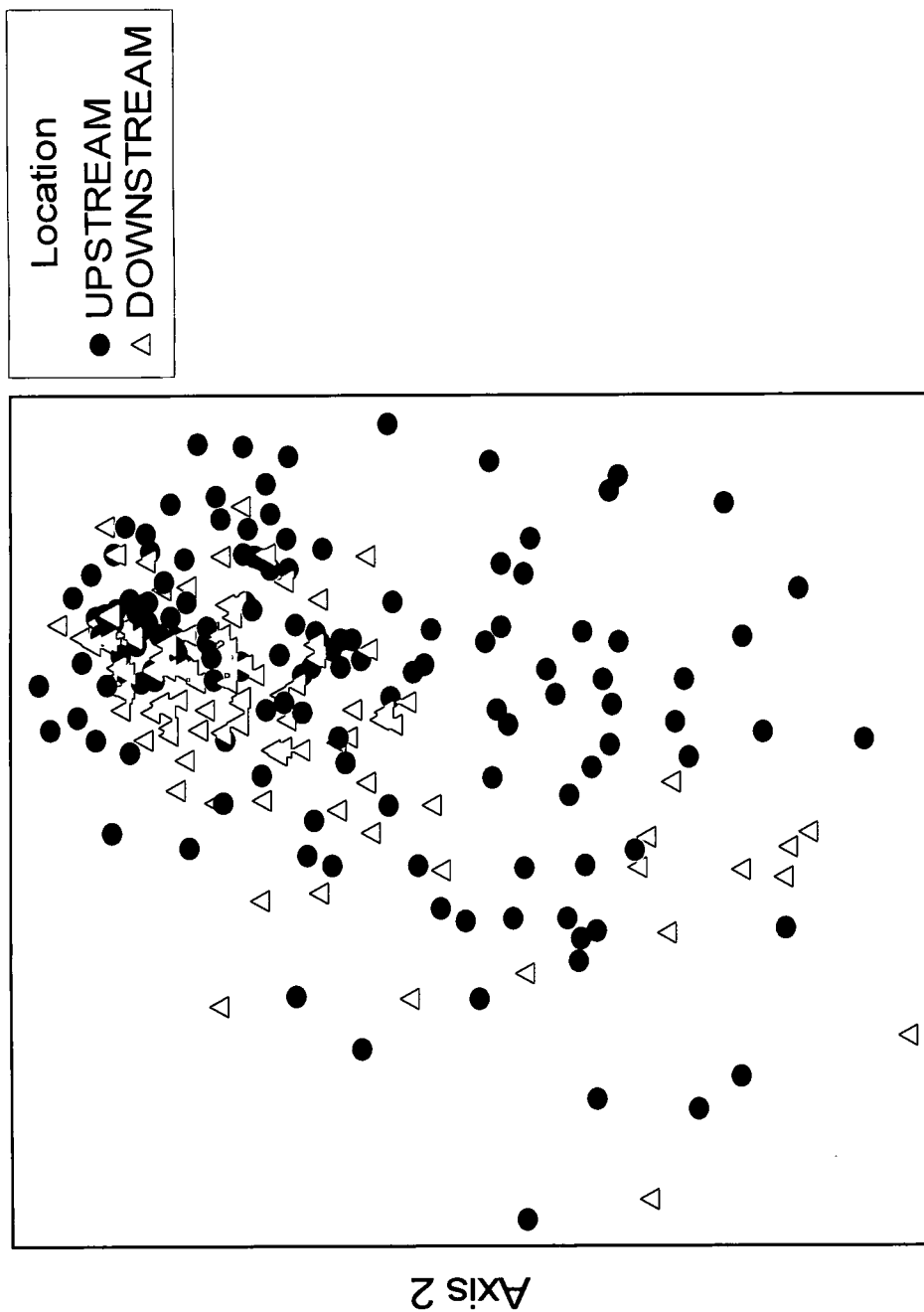


All dates pooled.

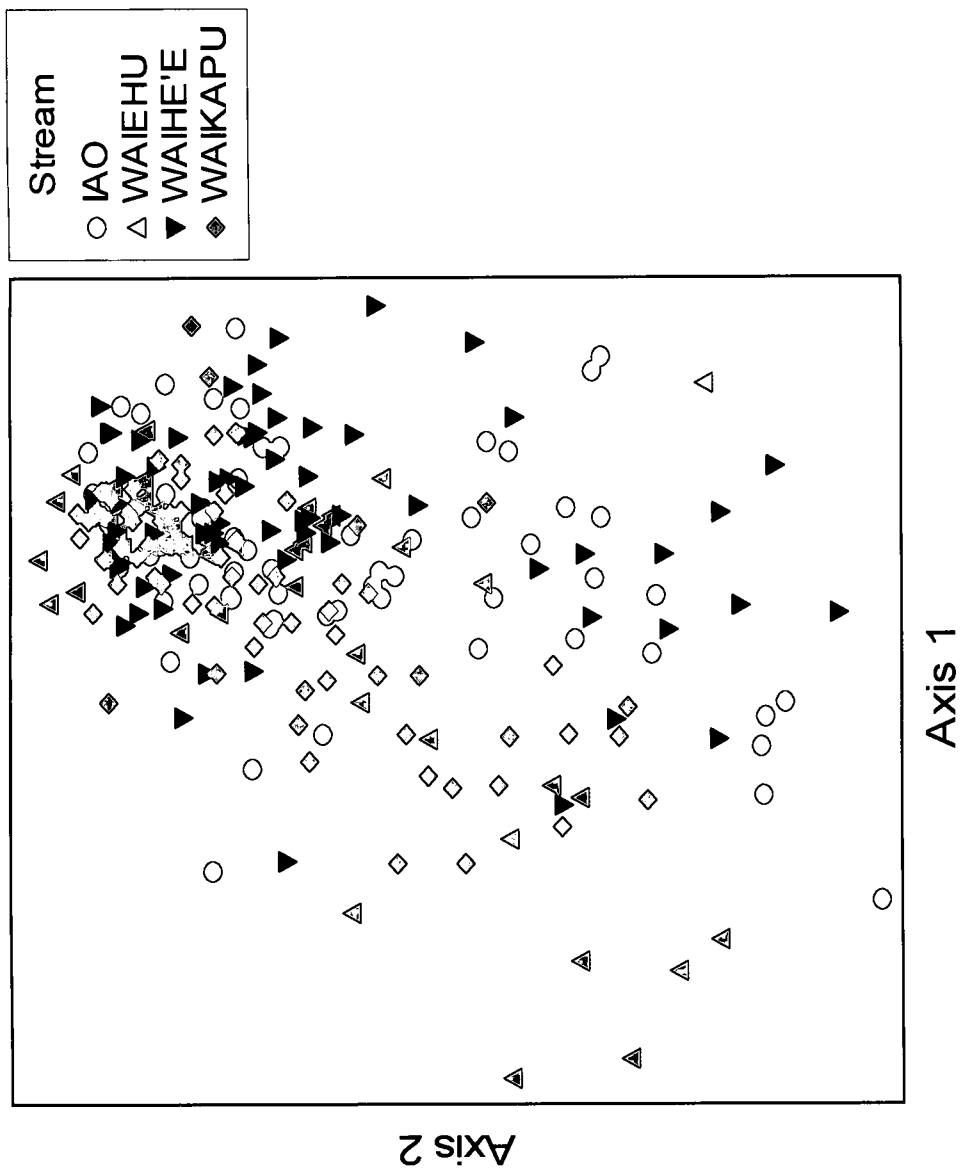
Percent Endemic Insects in two microhabitats



All streams, dates and locations pooled.

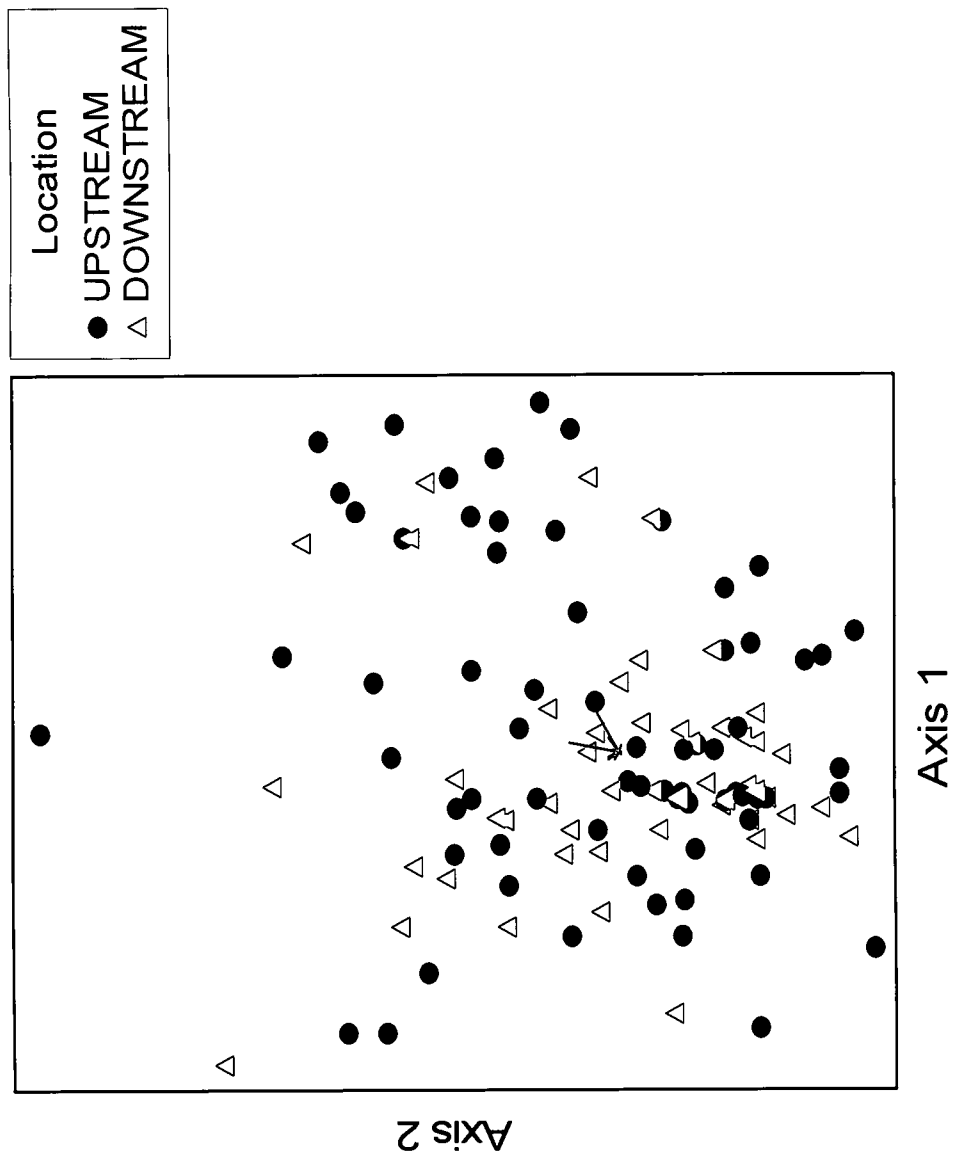


NMDS ordination with location overlay. Stress = 17.54.



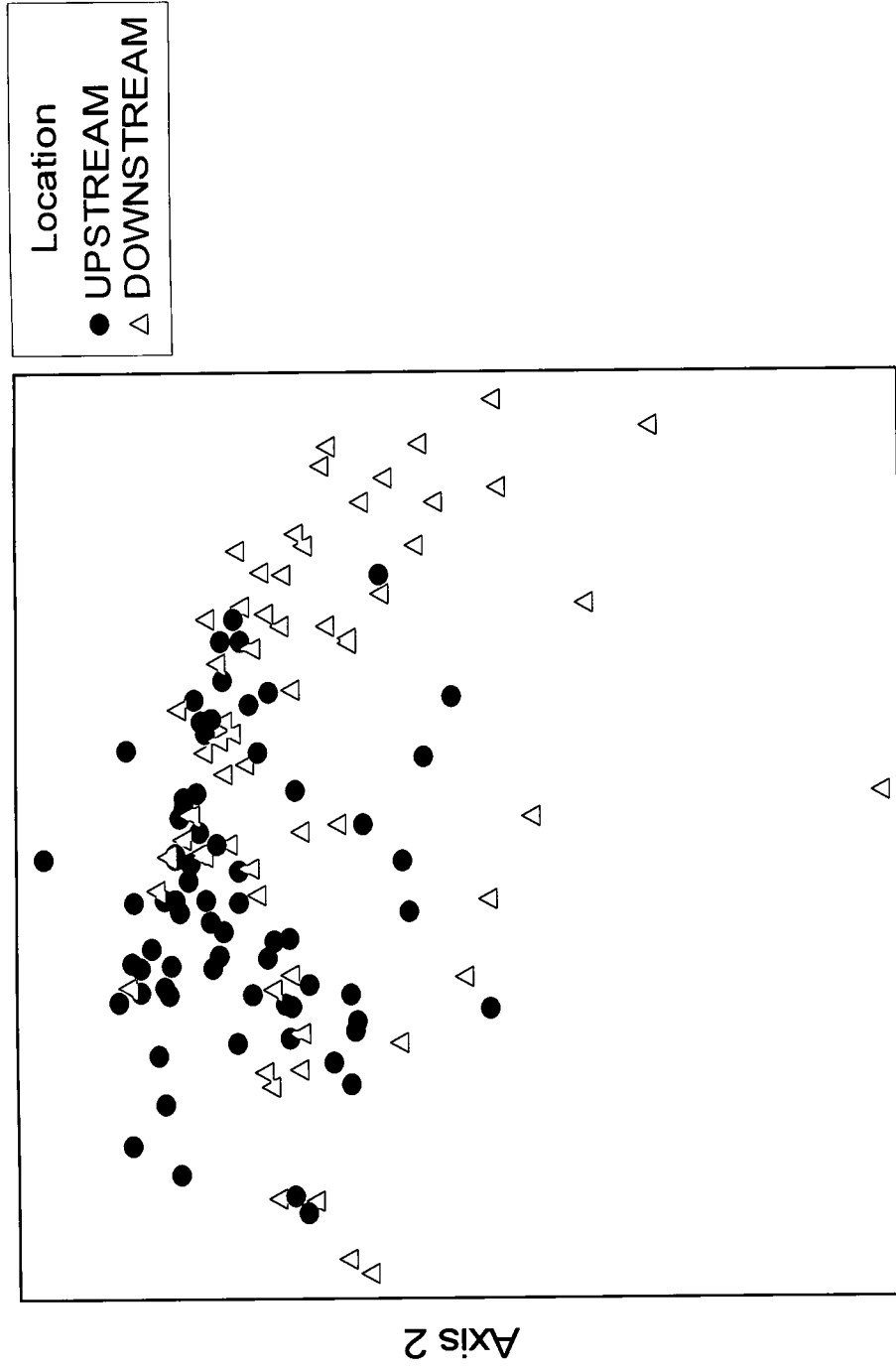
NMDS ordination with stream overlay. Stress = 17.54

Amphibious



NMDS ordination of amphibious samples with location overlay. Stress = 20.8

Torrenticolous



Axis 1

NOMDS ordination of torrenticolous samples with location overlay. Stress = 22.4

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