Biological Assessment of the Lower Hamakua Ditch on the Hawaiian Stream Fly (*Sigmatineurum meaohi*) and other aquatic insects

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EXECUTIVE SUMMARY

The Hawaii Biological Survey of the Bishop Museum conducted assessments on Koiawe, Alakahi, Kawainui, Waipio, and Waimanu Streams, Hawaii County, Hawaii. These assessments were conducted as part of the Lower Hamakua Ditch Environmental Impact Statement. The objectives of these assessments were to 1) describe baseline distribution and abundance of *Sigmatineurum meaohi* in Kawainui, Alakahi, and Koiawe Streams, streams potentially affected by the proposed project, 2) evaluate habitat quality *for Sigmatineurum meaohi*, and assess the observed distribution of this species under current stream flows, and 3) assess impacts that the ditch system may have on *Sigmatineurum meaohi*, 4) assess the aquatic insect fauna above and below the Lower Hamakua Ditch.

Any increase or resumption in diverted flows will adversely impact and reduce native aquatic insect habitat downstream of the ditch. Decreases in flow lead to a reduction in habitat availability and quality for native stream insects. Most native Hawaiian stream insects occupy the splash zone on rock faces in fast-water areas such as riffles and cascades. Other endemic insects are associated with rheocrene habitats (springs, seeps). This latter type of habitat is common where ground water emerges or where small amounts of water trickle down boulder faces, especially where rock overhangs are present. Some adverse impacts (through habitat reduction) may also occur in seep or rheocrene habitats created by water trickling down boulders in the main stream channel, but not in vertical seep faces located along cliff walls.

The results of this assessment and previous surveys indicate species diversity and abundance of native insects was greater above the Lower Hamakua Ditch than below during a drought period, and similar when the diversions were not effectively operating. Kawainui Stream was the stream most impacted by the diversion as it is the stream with the smallest gain of groundwater below the ditch. In 1996, Kawainui Stream below the diversion contained very little water and had almost no splash-zone habitat. Consequently, there was a corresponding paucity of native insects associated with this habitat. The native aquatic insect most affected by the diversions was the giant Hawaiian midge *Telmatogeton torrenticola*, a species nearly extirpated from Oahu and only found in the most pristine streams. Along with native *Megalagrion* damselflies and *Sigmatineurum meaohi*, this species is one of the best indicators of high quality aquatic habitats. *Telmatogeton torrenticola* was absent from Kawainui Stream below the diversion in 1996, but was abundant in the same area in 1998.

Sigmatineurum meaohi was found from 960 ft to 1240 ft elevation in Alakahi Stream, and 1020-1040 ft on Koiawe Stream. Intensive surveys for *S. meaohi* started at 640 ft

elevation in upper Waipio Stream, and continued upstream along three major tributaries to 1400 ft in Kawainui Stream. This species was uncommon, and found to be an obligate riffle/cascade splash-zone dweller. From the lack of captures below 960 ft, it is obvious this elevation is at the low end of the distributional range for this species. *Sigmatineurum meaohi* was most common in the 3-12 ft high riffle and cascade section of Alakahi Stream; an area that was surveyed from 960 to 1240 ft elevation. However, *Sigmatineurum meaohi* were not found in similarly-sized riffle habitats of a comparable and greater gradient in upper Waipio Stream (600-700 ft), indicating this species is found only at higher elevations.

Sigmatineurum meaohi was not found in Kawainui Stream to a surveyed elevation of 1400 ft, despite apparently suitable riffle habitat. However, it was noted that gradient in the area of Kawainui Stream appeared lower than that found in Koiawe and Alakahi Streams. The lower gradient found in the sampled area of Kawainui Stream may be the reason *Sigmatineurum meaohi* was not found here in 1996 or 1998. Helicopter overflights of Kawainui Stream indicated stream gradient increases above approximately 1800 ft elevation. This upper reach has numerous large and small waterfalls located upstream of the relatively lower gradient reach we sampled. Due to its preference for high gradient areas, it is highly likely that *Sigmatineurum meaohi* would be found in the upper reaches of Kawainui Stream.

Because the Lower Hamakua Ditch is located in the lowest elevational range of *Sigmatineurum meaohi*, adverse impacts to populations of this species because of the continued or renewed operation of the diversion are expected to be minimal. However, in 1996 some impacts were observed because of ditch operation, and this species was not found below the diversion. *Sigmatineurum meaohi* was not present when diversions have the most impact on stream fauna, as occurred during a drought period in Alakahi Stream below the Lower Hamakua Ditch.

Management of natural resources affected by the Lower Hamakua Ditch activities needs to be an iterative process of monitoring and management actions on a continuous basis. Observational monitoring and experimental monitoring will increase understanding of ecosystem dynamics and the effects of management actions. Monitoring will serve as a feedback mechanism to promote better integration of conservation efforts. As knowledge accumulates, management strategies will be adjusted, and management will become more effective at achieving the goal of conservation. Because of this adaptive benefit, monitoring of long-term ecosystem changes has been mandated as an integral component of conservation-oriented management on most federally funded and controlled projects.

INTRODUCTION

The Hawaii Biological Survey of the Bishop Museum was retained by the Natural Resources Conservation Service to assess populations of a newly discovered Hawaiian aquatic fly, *Sigmatineurum meaohi* (Evenhuis, 1997), in tributaries of Waipio Stream, Hawaii. These assessments were conducted as part of the Lower Hamakua Ditch Watershed Project Environmental Impact Statement (EIS). Previous studies (Englund & Filbert 1997) found the Lower Hamakua Ditch may have adverse impacts on populations of *Sigmatineurum meaohi*. However, as this species was unknown prior to the 1997 study, only very limited distributional and habitat data were available. This follow-up study allowed a further assessment of the habitat requirements and abundance of *S. meaohi*. Surveys were conducted in areas above and below the Lower Hamakua Ditch in Kawainui, Alakahi and Koiawe Streams, and in main Waipio Stream. Reconnaissance surveys were also conducted in adjacent Waimanu Stream to assess the abundance of this species in nearby watersheds, since little was known about the biology of *S. meaohi* prior to this study.

The objectives of these assessments were to 1) describe baseline distribution and abundance of *Sigmatineurum meaohi* in Kawainui, Alakahi, and Koiawe Streams and in main Waipio Stream, in areas potentially affected by the proposed project, 2) evaluate habitat quality for *Sigmatineurum meaohi*, and assess the observed distribution of this species under current stream flows, and 3) assess impacts that the ditch system may have on *Sigmatineurum meaohi*, 4) assess the aquatic insect fauna above and below the Lower Hamakua Ditch.

STUDY AREA

Three major tributaries of Waipio Stream, and a section of the upper Waipio Stream downstream of the confluence of Alakahi and Kawainui Streams were surveyed. This report contains descriptions only for areas previously not described in Englund & Filbert (1997), please refer to this report for a map of the study area. Water flow was much higher below the Lower Hamakua Ditch in 1998 than during surveys conducted in late 1996 and early 1997. This was because of two major factors; a wetter precipitation regime in the fall of 1998, and rocks and debris almost completely clogging the diversion intake grills at Koiawe, Alakahi, and Kawainui Streams.

WAIPIO STREAM (main channel)

Station 1 (640-700 ft elevation)

Station 1 began upstream of the confluence of Koiawe Stream and main Waipio Stream channel, and continued to the junction of Alakahi and Kawainui Streams. This station was accessed by hiking downstream from the confluence of Alakahi and Kawainui Streams. Stream gradient in this area was quite high, with large 5-10 ft boulders predominating in a bed of smaller boulders. A series of long riffle/rapids occurred here, with large stair-step cascades exposing areas of narrow, scoured bedrock chutes. Due to the high gradient of this reach, pools were generally less than six feet deep here. Riparian vegetation consisted almost entirely of the introduced common guava (*Psidium guajava*), with Job's tears (*Coix lachryma-jobi*), and kukui (*Aleurites moluccana*) also common.

KOIAWE STREAM

720-1040 ft elevation

This section was accessed by hiking on the old ditch trail to the Koiawe Stream crossing, and hiking up the streambed to the Lower Hamakua Ditch. Sampling for aquatic insects began immediately above the crossing at 720 ft elevation, and continued until above the diversion at approximately 1040 ft elevation. Quantitative net sweep sampling occurred below (940-960 ft) and above (1020-1040 ft) the diversion. Stream gradient was high, and the substrate and bank materials consisted mainly of large boulders. Riparian vegetation consisted of thick stands of white ginger (*Hedychium coronarium*). Habitat for aquatic organisms appeared excellent at this location, with numerous deep pools interspersed by riffles. High gradient cascades became more predominant above the diversion. Because the intake grates were completely filled with gravel, very little water was being diverted from Koiawe Stream during our sampling in December 1998.

ALAKAHI STREAM

720-1,240 ft elevation

Sampling in Alakahi Stream began approximately 150 yd upstream of the cement footbridge that crosses Alakahi Stream and continued upstream of the diversion to a large seep area located at approximately 1,240 ft elevation. This remarkably large seep, located on the north bank of the stream, was estimated to be at least 100 ft long and went 50 ft above the streambed. This rheocrene was apparently formed by a leaking dike compartment on the sheer (2000 ft +) cliff wall that formed the north stream bank.

Stream gradient was high, and stream substrate and bank materials consisted of large boulders and cobble. Riparian vegetation was mostly white ginger. Aquatic habitats and water quality were excellent; this reach has deep plunge pools and runs with abundant algae. Due to an increased flow regime (as compared to previous surveys) splash zones near riffles and cascades, a critical habitat for native insects, was extensive even below the diversion. Stream gradient was high throughout Alakahi Stream, and was comparable to the upper section of Koiawe Stream. Splash zone habitat, important to native torrenticulous insects, was abundant both above and below the diversion. A large grove of ‘awa (*Piper methysticum*) was located by the old concrete pillars just below the diversion. Riparian vegetation consisted mainly of white ginger, but silk oak (*Grevillea robusta*), mamaki (*Pipturus albidus*), ‘ohi’a (*Metrosideros polymorpha*), and kukui were also common.

A large landslide at the Lower Hamakua Ditch intake area has filled and partially covered the intakes and concrete dam. This landslide appeared to be fairly recent, and has occurred since January 1997. Consequently, very little, if any, water was being diverted from Alakahi Stream to the Lower Hamakua Ditch in December 1998.

KAWAINUI STREAM

980-1400 ft elevation

This station extended downstream about 150 yd from the Lower Hamakua Ditch. Stream flow and aquatic habitats appeared similar to that upstream of the diversion as most water was passing over the diversion intakes. This was in marked contrast to conditions observed in 1996, when Kawainui Stream was observed to have the most obvious impacts from diversions of all upper Waipio tributaries. In 1996, Kawainui Stream below the diversion was dry almost to the point of its confluence with Alakahi Stream, but in 1998 was flowing at what appeared to be apparently optimal conditions. Stream gradient in this reach was high, but may not be as high that of Koiawe and Alakahi Streams above their diversion points. Most sampled riffles in Kawainui Stream appeared to be of a lower gradient, and were a maximum of 3-6 ft high.

Kawainui Stream was assessed to an area above a large tributary (shown on the USGS quad) on the south side of Kawainui Stream. This tributary maintains a baseflow of barely a trickle; however, an enormous sand/gravel/boulder (at least 20-25 ft high) bar deposited into Kawainui Stream has been built up from this tributary by storm flows. This unique and very active geological feature is the largest boulder and gravel deposition bar observed by RAE in any Hawaiian stream. Riparian vegetation in the sampled area consisted mainly of white ginger lining the stream channel with

some areas of ‘ohi’a, various tree ferns, and mamaki. Seep walls and rheocrenes were not observed in the sampled elevations of 980-1400 ft.

During helicopter overflight observations it was apparent that the gradient picked up in Kawainui Stream above approximately 1800 ft elevation, an area we did not reach by hiking. From the helicopter, numerous large and small waterfalls were observed upstream of the long and relatively lower gradient area around the diversion. In the elevations we sampled (980-1400 ft), the Kawainui drainage is larger and longer than the other surveyed streams, and the canyon walls are not as close to the streambed. At higher elevations, a series of hanging waterfalls becomes the predominant feature, and seep habitats become more common.

Very little water was being diverted from Kawainui Stream into the Lower Hamakua Ditch in December 1998. This is because the intake grates were completely filled with gravel, and there was a generally wetter precipitation regime as compared to 1996.

WAIMANU STREAM

300-350 ft elevation

On 10 December 1998, the source of the main tributary to Waimanu Stream (Waihilau Stream on USGS quads) was sampled. This area is locally known as the ‘Keyhole’ due to the 3000 ft sheer valley walls forming a spectacular and nearly circular bowl, over which two main waterfalls plunge. The waterfalls start above the canyon rim at 3500 ft elevation, and descend to the bottom of the amphitheater at elevations ranging from 300 to 350 ft. In addition to these two major waterfalls, the entire amphitheater is virtually one large rheocrene or seep, with various amounts of water wetting most of the vertical cliff faces. Due to the wind blowing the 3000 ft cascading waterfalls, and the porous nature of the rocks, this entire area is one enormous seep eventually drained by the relatively small Waihilau Stream.

This area was sampled by starting at the bottom of the amphitheater walls at 300 ft and walking upslope along the completely vertical seep (cliff face) walls to approximately 350 ft elevation. Water draining off the cliff face walls created a small stream at the base of canyon that ran along the canyon walls, finally draining into one main stream. Waihilau Stream is formed below this amphitheater, and is a medium-sized stream that actually provides the majority of flow to Waimanu Stream. Riparian vegetation in the amphitheater consisted of mainly grasses and ti (*Cordyline fruticosa*), with kukui growing in areas away from falling boulders. Numerous fresh impact craters from falling boulders were observed at the base of the cliff walls here, and many freshly smashed kukui trees were evident. Due to recent storm flows, freshly fallen ‘ohi’a that had been washed from above the rim were observed at the

base of cliff walls in the amphitheater. The elevation we surveyed (300-350 ft) is generally too low for ‘ohi’a, and none was seen growing at this elevation.

METHODS

GENERAL METHODS

Assessments of Waipio Stream, three of its major tributaries, and portions of Waimanu Stream were conducted from 7-11 December 1998. With the exception of one day of rain in Alakahi Stream, sampling took place during a period of dry and sunny weather, but just after a large rainstorm and a period of increased precipitation.

Composition of the riparian vegetation and stream substrate was evaluated at each sampling station. Habitat condition for native aquatic organisms was evaluated both within sampling stations and throughout the sections of stream that we hiked. Altitude was determined by using a combination of USGS topographic quad maps and a hand-held Casio altimeter. Stream names were taken from USGS topographic quads. Mike Richardson of the U.S. Fish & Wildlife Service assisted in fieldwork and aquatic insect collections for these surveys.

AQUATIC INSECT SAMPLING

Aquatic insect sampling was conducted identically to that of Englund & Filbert (1997). Collections of both immature and adult specimens were conducted with aerial nets, dip nets and benthic samples. Visual observations of aquatic insects were also conducted as we hiked upstream among sampling stations. Sampling effort was focused on habitat suitable for native insects: splash zones around riffles and cascades, and wet rock faces associated with springs and seeps, waterfalls, and benthic sampling. All aquatic habitats were sampled, however. Two types of aerial aquatic insect sampling were used for this assessment: quantitative and general collections. General collections were conducted in prime native aquatic insect habitats, with numerous aerial net sweeps taken around riffle splash-zones, cascades, seeps, and waterfall areas. The primary objective of general collections was to assess the abundance and distribution of *Sigmatineurum*.

Secondarily, the influence of the Lower Hamakua Ditch on all species of aquatic insects was assessed through quantitative net sweeps and general aquatic insect sampling. Quantitative net sweeps allowed for general comparisons to be made between different streams, and also between the 1996 surveys. For quantitative sampling, the number of insect species collected per 25-30 aerial-net sweeps in randomly selected riffles was determined (Englund & Filbert 1997). Each aquatic insect species in the 25-30 net swings was counted, therefore a species could be

counted more than once if captured during a replicate net-sweep at another station. One net-swing consisted of an approximate 6 ft long back-and-forth sweep above a stream riffle or cascade. Adjusting the number of species collected by recording sampling effort allows for a comparison of aquatic insect diversity among sampling stations and streams. The sampling of damselflies and dragonflies (Odonata) was also emphasized. Dragonfly and damselfly species were observed, but not usually captured during aerial-net sweeps and are therefore not usually included in the catch rates.

Repeated benthic sampling was conducted at each sampling station by one person holding an aquatic dip net, while another person disturbed rocks upstream of the net. All insect specimens were stored in 75 percent ethanol and subsequently transported to the Bishop Museum Entomology laboratory for curation and identification. Voucher specimens are currently housed in the Bishop Museum collection.

RESULTS

WAIPIO STREAM (640-700 ft)

Insect Sampling Effort

Quantitative net sweep sampling effort for aquatic insects is shown in Table 1. Eighty-five quantitative aerial insect net samples were taken in riffles and their associated splash zones. Additionally, two people (Englund and Richardson) spent an entire day conducting general collections at this station sampling riffles for *Sigmatineurum*.

Aquatic Insect Species Composition and Distribution

Sigmatineurum were not observed or collected in the upper most section of Waipio Stream, despite intense sampling efforts and apparently suitable habitat in the form of very large riffles found here. Numerous uncounted aerial-net sampling by two collectors were taken in the favored riffle habitats of *Sigmatineurum meaohi*. Riffles in this area were of equal or higher gradient as compared to areas of Koiawe or Alakahi Streams. No seep habitats were observed in this section of Waipio Stream.

The number of insect species per quantitative aerial-net sweep is shown in Table 1. Adjusting the number of species by collecting effort allows for a rough comparison among sampling stations. The number of aquatic insect species captured in 1998 per aerial net sweep was 0.15 native species/net sweep, with no introduced species collected during quantitative sampling at this station (Table 1). In 1996, the catch rate was 0.08 native species/net sweep in the same area of Waipio Stream (Table 2).

Native species comprised 77% of the identifiable aquatic insect fauna in Waipio Stream (Table 4). Ten native, three introduced, and one species of unknown origin were found at Waipio Stream. The relative abundance of native species was high compared to many other Hawaiian Streams at similar elevations. Numerically, *Procanace constricta* was by far the most common species, while *Telmatogeton torrenticola* was the second most abundant species. The preponderance of native species, and the presence of *Telmatogeton torrenticola*, indicates excellent habitat quality in this section of Waipio Stream.

KOIAWE STREAM (660-1040 ft)

Sampling Effort

Sampling effort in Koiawe Stream consisted of a total of 160 quantitative aerial net sweeps, with 55 taken below the diversion and 105 collected above the diversion (Table 1). Additionally, numerous net sweeps for *Sigmatineurum* in riffle areas were taken during the upstream hike to access the Lower Hamakua Ditch intake. Insect sampling effort was primarily applied to known habitats of *Sigmatineurum* such as riffle splash-zones. Large rheocrene or seep habitats were not observed in the elevations of Koiawe Stream surveyed.

Aquatic Insect Species Composition and Distribution

Native species dominated the insect fauna in Koiawe Stream (Table 5). Below the diversion (from 720-1000 ft), twelve native and one introduced species of aquatic insects were collected during general and quantitative sampling. Above the diversion (1020-1040 ft), 10 native and 1 introduced species of aquatic insects were collected. The common endemic species *Saldula exulans* would likely have been collected above the diversion if more time were available. This dry-rock inhabiting species normally requires special collecting techniques, as it is not normally captured during aerial or benthic sweeps. The ratio of native to introduced insect species below and above the diversion was nearly identical, at a very high 92-91%, respectively (Table 5). The giant Hawaiian midge, *Telmatogeton torrenticola*, was found at both sites, indicating excellent aquatic habitat conditions for native insect species.

The number of insect species per aerial-net sweep is shown in Table 1. In the 1996 drought year, catch rate of native species (Table 2) was higher above the Lower Hamakua Ditch where somewhat greater flow and steeper gradient likely result in habitat conditions more conducive to native insects. In 1998, the number of native species/net sweep both above and below the diversion was at least double the 1996 catch rate in these areas (Tables 1 and 2). Introduced aquatic insects were not captured during quantitative net sweeps in 1998. Numerically, *Procanace constricta*

was by far the most common species, while *Scatella clavipes* and *S. cilipes* were the next most abundant species.

Table 1. Aquatic insect sampling effort catch rates (species/net sweep) in upper Waipio Stream and tributaries, and Waimanu Stream, Hawaii County in a wet period in December 1998 (See Englund & Filbert 1997 for sampling stations).

Stream	Elevation (ft)	Habitat	Net Sweeps	Native Species/Net Sweep	Introduced Species/Net Sweep	Total Species
Waimanu	300	Seep	50	0.14	0	0.14
Waipio	700	Riffle	85	0.15	0.0	0.15
Koiawe (below diversion)	940-960	Riffle	55	0.15	0.0	0.15
Koiawe	1020-1040	Riffle	105	0.19	0.0	0.19
Alakahi (below diversion)	960-980	Riffle	50	0.20	0.0	0.20
Alakahi	1100-1220	Riffle	75	0.24	0.0	0.24
Kawainui (below diversion)	980	Riffle	50	0.20	0.02	0.22
Kawainui	1300-1400	Riffle	115	0.17	0.0	0.17

Table 2. Aquatic insect sampling effort catch rates (species/net sweep) in upper Waipio Stream and tributaries, and Waimanu Stream, Hawaii County during a drought period in October 1996 (From Englund & Filbert 1997).

Stream	Elevation (ft)	Habitat	Net Sweeps	Native Species/Net Sweep	Introduced Species/Net Sweep	Total Species
Waipio	420	Riffle	93	0.08	0.03	0.11
Koiawe (below diversion)	720	Riffle	94	0.04	0.03	0.07
Koiawe	1020-1040	Riffle	72	0.07	0.01	0.08
Alakahi (below diversion)	800	Riffle	108	0.04	0.02	0.06
Alakahi	1100-1220	Riffle	90	0.09	0.03	0.12
Kawainui (below diversion)	1025	Riffle	74	0.03	0.0	0.03
Kawainui	1080-1400	Riffle	153	0.11	0.01	0.12

In 1998, *Sigmatineurum meaohi* were found in riffle habitats in Koiawe Stream above the Lower Hamakua Ditch. This species was always found in conjunction with the native giant Hawaiian midge, *Telmatogeton torrenticola*, a species known only from areas of high stream gradient and water quality. *Sigmatineurum meaohi* was not easily collected as only three individuals were captured in Koiawe Stream (Table 3).

ALAKAHI STREAM

Sampling Effort

Sampling effort in Alakahi Stream consisted of a total of 125 quantitative aerial net sweeps, with 50 taken below the diversion and 75 collected above the diversion (Table 1). Numerous net sweeps were also taken in riffle areas for *Sigmatineurum* during the hike upstream to access the Lower Hamakua Ditch intake. Insect sampling effort was primarily applied to known habitats of *Sigmatineurum* such as riffle splash zones. A large rheocrene (seep habitat) was observed and sampled at 1240 ft on Alakahi Stream (See STUDY AREA for description).

Species Composition and Distribution

Native species dominated the insect fauna in Alakahi Stream (Table 6). Below the diversion (from 720-1020 ft), ten native and one introduced species of aquatic insect were collected during general and quantitative sampling. Above the diversion (1020-1240 ft), 12 native and 1 introduced species of aquatic insects were collected. Rains and raising water somewhat reduced sampling time at this stream. Similar to Koiawe Stream, the ratio of native to introduced insect species below and above the diversion on Alakahi Stream was nearly identical, at a very high 90-92%, respectively (Table 6). The giant Hawaiian midge, *Telmatogeton torrenticola*, was found both above and below the diversion, indicating excellent aquatic habitat conditions for native insect species.

The number of insect species per aerial-net sweep is shown in Table 1. In the 1996 drought year, catch rate of native species (Table 2) was higher above the Lower Hamakua Ditch where increased flow and steeper gradient likely resulted in habitat conditions more conducive to native insects. In 1998, the number of native species/net sweep both above and below the diversion was at least double the 1996 catch rate in these areas (Tables 1 and 2). An increase in the aquatic insect catch rate from the 1996 survey was observed above the Lower Hamakua Ditch in 1998. Remarkably, in 1998 introduced aquatic insects were not captured during quantitative net sweeps above or below the Lower Hamakua Ditch. In 1998, the catch rate of native species was higher above the Lower Hamakua Ditch than in 1996, and this area of Alakahi Stream had the highest catch rate for native species of all areas assessed for this report. Numerically, *Procanace constricta* was by far the most common species, with up to 121 individuals collected per 25 net sweeps. *Scatella clavipes* was the second most abundant species captured during quantitative sampling.

In contrast to 1996, *Sigmatineurum meaohi* were found in riffle habitats both above and below the Lower Hamakua Ditch. As in 1996, few individuals were captured, with

a total of five *Sigmatineurum meaohi* collected in Alakahi Stream in 1998 (Table 3). In Alakahi Stream, *Sigmatineurum meaohi* adults were captured in splash zones created by 3 to 12-foot high cascades. Collections were made in open, sunny areas of the stream channel by running the net through the turbulent water of the cascade face.

A new species of *Sigmatineurum*, different from the new species found by Englund & Filbert (1997), was first collected on a seep immediately above Alakahi Stream at 1240 ft elevation, upstream of the Lower Hamakua Ditch. A thin layer of water draining from a crack in the sheer (ca. 2000 ft high) rock wall formed this huge seep. No other seeps were observed in surveyed areas of Alakahi Stream. Five individual *Sigmatineurum* new sp. were captured during aerial netting of the large seep habitat taken about 5 ft above the streambed. Adults of the new species were captured by scraping the net along the bottom of this large seep, which contained a thin layer of green filamentous algae. *Sigmatineurum meaohi* was captured immediately adjacent to this seep in a high-gradient riffle running adjacent to the seep wall. An apparently similar type of thin, green filamentous algae grows along the splash zone of riffles were *S. meaohi* was captured.

KAWAINUI STREAM

Sampling Effort

Sampling effort in Kawainui Stream consisted of a total of 165 quantitative aerial net sweeps, with 50 net sweeps taken below and 115 collected above the diversion (Table 1). Numerous net sweeps were also taken in riffle areas for *Sigmatineurum* during the hike upstream to above the major tributary on the south bank at 1400 ft elevation. Insect sampling effort was primarily applied to known habitats of *Sigmatineurum* such as riffle splash zones. No large rheocrenes (seep habitat) were observed or sampled on Kawainui Stream (See STUDY AREA for description).

Species Composition and Distribution

Sigmatineurum were not observed or collected in Kawainui Stream between 960-1400 ft elevation, despite intense sampling efforts. As in other areas, numerous uncounted aerial-net sampling by two observers (Englund and Richardson) were taken in the favored riffle habitats of *Sigmatineurum meaohi*.

The number of insect species per aerial-net sweep is shown in Table 1. In 1996, when Kawainui Stream was completely diverted, the insect catch rate (Table 2) was much higher (0.12) above the Lower Hamakua Ditch as compared to below (0.03). In 1998, the number of native and total species/net sweep both above and below the diversion was higher than the 1996 catch rates (Tables 1 and 2). The most

noticeable difference from the 1996 sampling was a slightly higher insect catch rate below the Lower Hamakua Ditch as compared to above. In 1998, both native and total species were caught at a rate of 0.22 species/net swing below the diversion, while a total 0.17 species/net swing were captured above the diversion. The ratio of native to introduced insect species below and above the diversion on Kawainui Stream was similar and ranged from 80-86%, respectively (Table 7).

The giant Hawaiian midge, *Telmatogeton torrenticola*, was found both above and below the diversion, indicating excellent aquatic habitat conditions for native insect species. As in all other sampled Waipio Valley tributaries, *Procanace constricta* was by far the most common species, with up to 108 individuals collected per 25 net sweeps. *Scatella clavipes* in the family Ephydridae was also the second most abundant species captured during quantitative sampling, with up to 39 individuals captured per 25 net sweeps. The most notable change from the 1996 survey was the preponderance of native species, and the similarity in the 1998 surveys of species diversity above and below the Lower Hamakua Ditch.

WAIMANU STREAM

Sampling Effort

Insect sampling effort was applied mainly to seeps formed at the bottom of the sheer vertical surfaces of the nearly 3000 ft rim of Waimanu Canyon, and riffles in Waihilau Stream. Fifty quantitative aerial insect net samples were taken along the seep walls of the canyon the associated splash zones. General aerial net collections were collected in riffle areas of Waihilau Stream, and numerous benthic samples were taken at the base of the seeps and Waimanu Canyon waterfalls and in Waihilau Stream.

Species Composition and Distribution

The surveyed area of Waimanu Stream (Waihilau tributary) aquatic habitats revealed one of the most intact low-elevation aquatic insect faunas in the Hawaiian Islands. Only one introduced species of aquatic insect was found during both general collections and quantitative aerial netting. Between 300-350 ft elevation, Waimanu Stream was found to have a 94% native aquatic insect fauna. The number of insect species per quantitative aerial-net sweep is shown in Table 1. The number of aquatic insect species captured in 1998 per aerial net sweep was 0.14 native species/net sweep, with no introduced species collected during quantitative sampling in the Waimanu watershed (Table 1). Only one introduced aquatic insect species was found during benthic sampling, the ubiquitous caddisfly (*Cheumatopsyche pettiti*).

A new species of *Sigmatineurum* first collected on a seep wall in Alakahi Stream was also collected in the Waimanu Stream 'keyhole' area of Waihilau tributary. No *Sigmatineurum meaohi* were collected in Waimanu Stream, although the *Sigmatineurum* new sp. were quite common, with a total of 85 specimens collected here. The *Sigmatineurum* new sp. was common nearly everywhere at the base of the amphitheater cliff walls; especially in areas of thin, filamentous algae, and even in some areas of just slightly wetted rock faces, and was very common in misty areas where shorter green algae appeared to predominate. Coarser and thicker moss covering many areas of the cliff-walls, especially near areas of heavy flowing water, was the one microhabitat not particularly preferred by the new *Sigmatineurum*. The brilliant green color of this large and spectacular species is likely no accident, as it easily blends in with algae on rock walls. Unlike *S. meaohi*, the new *Sigmatineurum* species was easy to collect and find in Waimanu Stream. Adults were visually observed and almost swarm-like, with up to 10-15 individuals observed on small sections of the seep walls at one time.

Sigmatineurum spp. CAPTURE AND DISTRIBUTIONAL DATA

The *Sigmatineurum* new sp. species should be considered common due to the large amount of seep faces in Waimanu Stream and upper Waipio Valley tributaries. A total of 90 specimens were collected from two widely separated areas (Table 3). Observations from helicopter overflights indicated there are many more inaccessible seeps in Waipio Valley tributaries likely containing this species. Two large seeps were sampled (Alakahi and Waimanu Streams), in a wide range of elevations (300 – 1240 ft) and both contained relatively high densities of the new *Sigmatineurum* new sp.

Sigmatineurum meaohi was found in low numbers for the first time in Koiawe Stream just above the Lower Hamakua Ditch intakes (Table 3). In 1998, this species was also found above and below the Lower Hamakua Ditch in Alakahi Stream. This contrasts with the 1996 surveys, where it was only found above the diversion.

Table 3. Numbers of *Sigmatineurum meaohi* and *Sigmatineurum* n. sp. captured in Waipio Stream and tributaries, and Waimanu Stream, Hawaii County in October 1996 and December 1998 (n/a = area not sampled).

Stream	Elevation (ft)	Habitat	*S. meaohi*		*Sigmatineurum* n. sp.
			1996	1998	1998
Waimanu	300-350	Waterfall Seep	n/a	0	85
Waipio	600-700	Riffle/Splash Zone	0	0	0
Koiawe (below diversion)	940-960	Riffle/Splash Zone	0	0	0
Koiawe	1020-1040	Riffle/Splash Zone	0	3	0
Alakahi (below diversion)	960-980	Riffle/Splash Zone	0	1	0
Alakahi	1100-1220	Riffle/Splash Zone	7	4	0
Alakahi	1240	Seep	n/a	0	5
Kawainui (below diversion)	980	Riffle/Splash Zone	0	0	0
Kawainui	1100-1400	Riffle/Splash Zone	0	0	0

DISCUSSION

Dry vs. Wet Year Sampling (1996 vs. 1998)

Prior to this study, little was known about the habitat use, distribution, abundance, and the influence of the Lower Hamakua Ditch on a species of *Sigmatineurum* first discovered in 1996. The results of intensive surveys in upper Waipio Valley indicated *Sigmatineurum meaohi* was only found in very high gradient riffle/cascade habitats above 960 ft elevation. In 1996, this species was only found in Alakahi Stream above the diversion, but in 1998 was found below the diversion. This is probably because a major landslide recently covered the Alakahi Stream diversion intake, and very little, if any, water was being diverted. Another population in Koiawe Stream only occurred above the Lower Hamakua Ditch intakes.

Data collected in 1998 after a period of increased precipitation allowed us to contrast conditions under different flow scenarios. Because of fortuitous timing, the 1998 supplemental aquatic insect study in Waipio Stream and tributaries allowed for comparisons between a drought period in 1996, and a wetter precipitation regime in 1998. In 1996, Kawainui Stream was virtually dewatered by the Lower Hamakua Ditch to its confluence with Waipio Stream, while Koiawe and Alakahi Streams exhibited lesser (but still significant) degrees of dewatering. In December 1998, the diversion appeared to be almost completely ineffective due to large landslides and sediment filling in the diversion intakes at Koiawe, Alakahi, and Kawainui Streams. Consequently, water flow in the streams below the Lower Hamakua Ditch appeared to be little affected by the diversion.

Using identical methods and surveying the same areas as in 1996, we obtained a much higher catch rate in 1998 for aquatic insect species throughout all areas of the upper Waipio watershed (Figure 1). This was likely due to the wetter precipitation regime providing greater amounts of aquatic habitats in 1998. Species diversity above and below the Lower Hamakua Ditch was compared in Figure 2, and shows the diversion impacts on native aquatic insects. The major impact of varying flow regime was exhibited in Kawainui Stream, with a large difference in species diversity between 1996-1998. In 1996, the diverted Kawainui Stream contained virtually no aquatic insects (see Figure 3), while catch rates above the diversion were the highest of any station sampled on Waipio Stream (Englund & Filbert 1997). In 1998, there were no major differences in insect diversity above and below the diversion because Kawainui Stream was largely undiverted (Figure 2). The diversion appears to be influencing the distribution of *S. meaohi*, as this species was not found in the dewatered section of Alakahi Stream in 1996, but was found in the same area in 1998.

Significant Findings in 1998

Another undescribed species of *Sigmatineurum* was first collected in seep habitat on Alakahi Stream during this assessment. As we had no microscopes in the field, this species at first was thought to be *S. meaohi*, and led sampling effort to be directed to large seep habitats. Upon return to the Bishop Museum, it was found to be another completely new *Sigmatineurum* species. *Sigmatineurum meaohi* was found to be much more cryptic and difficult to capture than the newly discovered species. RAE has never observed *S. meaohi* in the field, except in a net after capture. This is despite intensive visual observations around riffle areas conducted during both the 1996 and 1998 surveys. The paucity of captures and observational data for *S. meaohi* was likely due to its inhabiting very turbulent white-water areas of riffles and cascade splash-zones. This habitat preference makes both capture and visual observations difficult. In contrast, the new *Sigmatineurum* species, first captured on a large seep in Alakahi Stream, was easily visually observed and captured. In the amphitheater seep area of Waimanu Stream, the *Sigmatineurum* new sp. was the most common aquatic insect captured during sampling. As many as 20 individual *Sigmatineurum* new sp. were collected during standardized 25 net sweep sampling, while only 5-10 individual aquatic flies in the Ephydridae or Canacidae family (of 2-4 different species) were captured.

Summary of Important Findings

Three new species of aquatic insect were discovered during the 1998 surveys. These include another new *Sigmatineurum* species, and two other new and undescribed aquatic insect species. An undescribed species of cranefly, *Limonia* sp. was collected in several Waipio drainages. Although it is a possible new introduction,

most *Limonia* in Hawaii are native (Nishida 1997). An unidentified and new species of aquatic ephydrid fly in the genus *Scatella* was also collected on seep habitat in Waimanu Stream. The cranefly and undescribed species of *Scatella* will most likely be identified as a native species due to the preponderance of native fauna in the areas where these species collected.

Additionally, a range extension and additional specimens were collected for the aquatic fly *Scatella* [formerly *Apulvillus*] *femoralis*. This ephydrid fly was previously known from only a single male specimen collected on Maui in 1954 (Hardy & Delfinado 1980). Prior to these surveys, little was known about the habitat requirements of *Scatella femoralis*, and 24 individuals of both sexes were collected in seep habitats in Alakahi

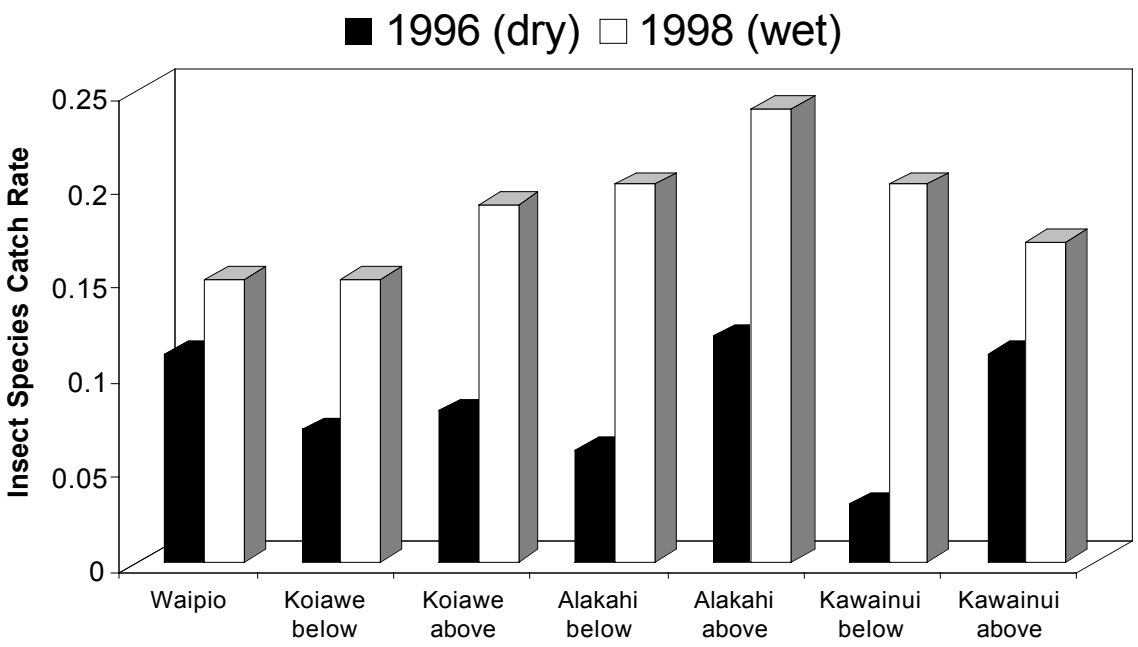

Figure 1. Aquatic insect species catch rate at the same stations in upper Waipio Valley streams during dry (1996) and wet (1998) sampling periods.

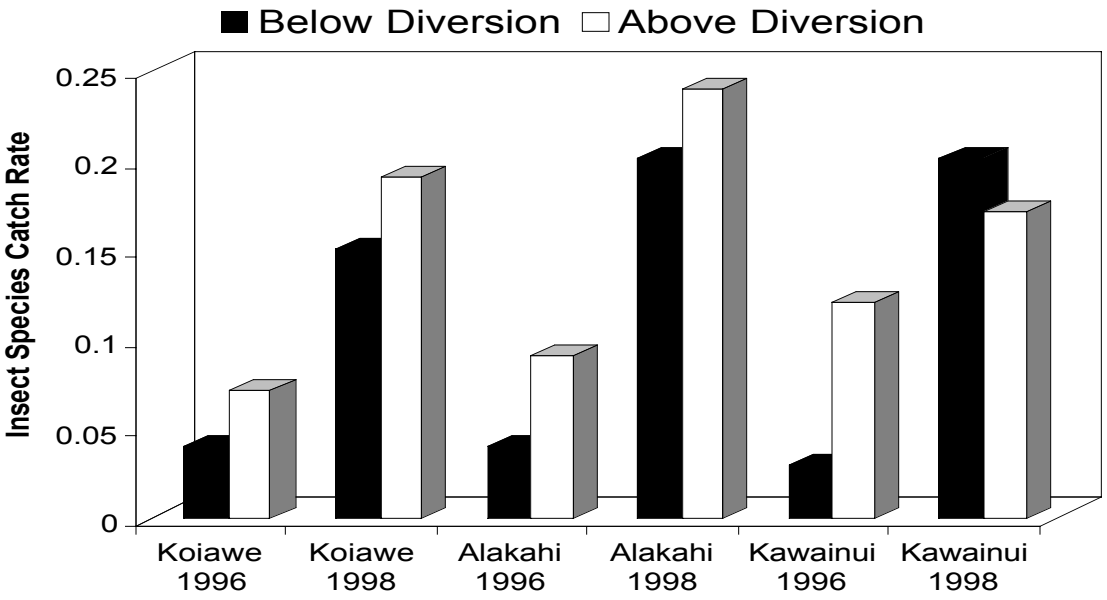

Figure 2. Aquatic insect species catch rate below and above the Lower Hamakua Ditch during a drought (1996) and a period of no diversion and increased precipitation (1998).

and Waimanu Streams. *Scatella femoralis* was collected in conjunction with the new species of *Sigmatineurum*, see [RESULTS Section] for Alakahi and Waimanu Streams for a detailed habitat description. Although *Scatella femoralis* is an extremely rare species, its preference for large seep walls, along with that of the new *Sigmatineurum* sp. and the unidentified *Scatella* sp., ensures that the Lower Hamakua Ditch has no influence on these aquatic insects. Too little is known about habitat preferences of the new cranefly (*Limonia* sp.) to make any statement on the effect of the Lower Hamakua Ditch on this species.

ENVIRONMENTAL CONSEQUENCES: NATIVE AQUATIC INSECTS

Two types of impacts to native stream organisms could result from renewed or continued operation of the Lower Hamakua Ditch: 1) reduction in base flow leading to a loss of habitat for stream animals; and 2) disruption of migratory routes of amphidromous animals. The second topic is not in the scope of this supplemental study, as disruption of migratory routes would not affect aquatic insects.

Because the Lower Hamakua Ditch has been in operation for over 80 years, continued operation will not result in new or additional impacts to the upper Waipio Stream and tributaries. However, continued operation or complete refurbishment of the ditch system would continue to affect native stream organisms. None of the following impacts are new, but have been occurring since the ditch was built.

Operation of the Lower Hamakua Ditch at or above current capacity will result in continued negative effects on native insects downstream of the diversion. Unlike native amphidromous animals, insects complete their life cycles completely within the stream. The diversion does not impose a barrier to migration for native Hawaiian stream insects, as their longitudinal movement occurs primarily during the aerial adult stage. Instead, native stream insects are adversely affected by reductions in flow and habitat. Therefore, negative effects of the Lower Hamakua Ditch on the native insect fauna only occur downstream of the ditch. Flow reductions due to the Upper Hamakua Ditch undoubtedly have some effect on insects above the Lower Hamakua Ditch, but that issue is beyond the scope of this study.

Impacts on *Sigmatineurum*

Sigmatineurum meaohi was found from 960 ft to 1240 ft elevation in Alakahi Stream, and 1020-1040 ft on Koiawe Stream. Intensive surveys for *S. meaohi* started at 640 ft elevation in upper Waipio Stream, and continued upstream along three major tributaries to 1400 ft in Kawainui Stream. This species was uncommon, and found to be an obligate very high gradient riffle/cascade splash-zone dweller. From the lack of captures below 960 ft, it is obvious this elevation is at the low end of the distributional

range for this species. *Sigmatineurum meaohi* was most common in the 3-12 ft high riffle and cascade section of Alakahi Stream; an area that was surveyed from 960 to 1240 ft elevation. However, *S. meaohi* were not found in similarly-sized riffle habitats of a comparable or greater gradient in upper Waipio Stream (600-700 ft), indicating this species occurs at higher elevations.

Sigmatineurum meaohi was not found in Kawainui Stream to a surveyed elevation of 1400 ft, despite apparently suitable riffle habitat. However, it was noted that gradient in the area of Kawainui Stream appeared lower than that found in Koiawe and Alakahi Stream. The lower gradient observed in the sampled area of Kawainui Stream may be the primary reason *S. meaohi* was not found here in 1996 or 1998. Helicopter overflights of Kawainui Stream indicated that stream gradient increases above approximately 1800 ft elevation. This upper reach has numerous large and small waterfalls located upstream of the relatively lower gradient reach we sampled. Due to its preference for high gradient areas, it is highly likely that *S. meaohi* would be found in the upper reaches of Kawainui Stream.

Because the Lower Hamakua Ditch is located in the lowest elevational range of *S. meaohi*, adverse impacts to populations of this species because of the continued or renewed operation of the diversion are expected to be minimal. However, in 1996 some impacts were observed because of ditch operation, and this species was not found below the diversion. *Sigmatineurum meaohi* was not present when diversions have the most impact on stream fauna, as occurred during a drought period in Alakahi Stream below the Lower Hamakua Ditch.

Prior to this survey, the lowest elevations that *Sigmatineurum* were captured was 600 ft (Evenhuis & Polhemus 1994), although most captures in recent years were at substantially higher elevations. The elevational distribution of most other species in the *Sigmatineurum* genus ranges from 2800 to 4000 ft (Evenhuis & Polhemus 1994, Englund et al. 1998). With the discovery of a new species *Sigmatineurum* on seep habitats between 300-1240 ft, in Waimanu and Alakahi Streams, the elevational distribution for this genus has been significantly lowered. The Lower Hamakua Ditch should not impact the new *Sigmatineurum* species because seep habitats were observed only above the diversion, and Waimanu Stream is not diverted or influenced by either the Lower or Upper Hamakua Ditch.

Impacts To Other Native Aquatic Insects

Any increase or resumption in diverted flows will adversely impact and reduce native aquatic insect habitat downstream of the ditch. Decreases in flow lead to a reduction in habitat availability and quality for native stream insects. Most native Hawaiian stream insects occupy the splash zone on rock faces in fast-water areas such as riffles and cascades (Howarth & Polhemus 1991, Englund et al. 1998). Other

endemic insects are associated with rheocrene habitats (springs, seeps). This latter type of habitat is common where ground water emerges or where small amounts of water trickle down boulder faces, especially where rock overhangs are present. Some adverse impacts (through habitat reduction) may also occur in seep or rheocrene habitats created by water trickling down boulders in the main stream channel, but not in vertical seep faces located along cliff walls.

The results of this assessment and previous surveys (Englund & Filbert 1997) indicate species diversity and abundance of native insects was greater above the Lower Hamakua Ditch than below during a drought period, and similar when the diversions were not effectively operating. Kawainui Stream was the stream most impacted by the diversion as it is the stream with the smallest gain of groundwater below the ditch. In 1996, Kawainui Stream below the diversion contained very little water and had almost no splash-zone habitat. Consequently, there was a corresponding paucity of native insects associated with this habitat. The native aquatic insect most affected by the diversions was the giant Hawaiian midge *Telmatogeton torrenticola*, a species nearly extirpated from Oahu and only found in the most pristine streams. Along with native *Megalagrion* damselflies and *Sigmatineurum meaohi*, this species is one of the best indicators of high quality aquatic habitats. *Telmatogeton torrenticola* was absent from Kawainui Stream below the diversion in 1996, but was abundant in the same area in 1998.

SUGGESTED MONITORING

Mitigation measures such as managed flow releases from the Lower Hamakua Ditch intake areas could be implemented to reduce the present impact of the Lower Hamakua Ditch on native stream organisms. The fact that we have discovered three to four previously unknown species of aquatic insects in the 1998 survey points out how little is really known about these systems. However, any mitigation measures aimed at ameliorating effects of the ditch should be monitored for effectiveness. For example, the effectiveness of mitigation could be assessed by measuring the differences in aquatic insect diversity and abundance over time, and at different mitigation flow rates.

Environmental monitoring is the investigation of the changes in environmental functions, attributes and characteristics that happen over time. Monitoring provides the information necessary for adaptive management of natural systems, biogeographical areas, and their biotic components. The knowledge gained through a properly designed monitoring program can provide land managers with inferences about ecological changes and the impacts of management strategies on natural resources.

Management of natural resources affected by the Lower Hamakua Ditch activities needs to be an iterative process of monitoring and management actions on a continuous basis. Observational monitoring and experimental monitoring will increase understanding of ecosystem dynamics and the effects of management actions. Monitoring will serve as a feedback mechanism to promote better integration of conservation efforts. As knowledge accumulates, management strategies will be adjusted, and management will become more effective at achieving the goal of conservation. Because of this adaptive benefit, monitoring of long-term ecosystem changes has been mandated as an integral component of conservation-oriented management on most federally funded and controlled projects.

The need for continuing inventory and monitoring of aquatic insects affected by the Lower Hamakua Ditch is clear. Less clear is how to go about it. Inventory and monitoring are complex, and often esoteric, endeavors. Proper application requires expertise in statistical ecology, biometrics, econometrics, digital data management, and geographic information systems, as well as typical ecology disciplines such as wildlife biology, entomology, and botany.

Inventory and monitoring planning is an intricate undertaking, and can be broken down into seven Tasks:

1. Prepare clear statements of the questions of interest.
2. Design the sampling systems
3. Develop sampling protocols for data collection
4. Prepare the data management systems, including GIS
5. Plan the analysis and interpretation systems
6. Develop a reporting system
7. Develop a monitoring sustainability plan

Each of these seven steps must be undertaken and completed to develop a successful monitoring plan. Furthermore, the steps must be undertaken in a comprehensive manner. Planning decisions made in any one-stage affect decisions at all the other stages.

The ultimate goal of monitoring is to aid in good stewardship and conservation of the natural world. A Long-Term Environmental Monitoring Program (LTEMP) should be designed and implemented to collect the best scientific information available and ensure effective management of the Lower Hamakua Ditch.

Table 4. Native and introduced aquatic insects collected in quantitative, general, and benthic sampling in the main Waipio Stream, Hawaii in December 1998.

Taxon	Waipio 640-700 ft	Geographic Status
Insects		
Damselflies/dragonflies (Odonata)		
Blackburn's Hawaiian Damselfly (*Megalagrion blackburni*)	X	Endemic
Dragonfly (*Pantala flavescens*)	X	Indigenous
Dragonfly (*Anax strenuus*)	X	Endemic
Dragonfly (*Orthemis ferruginea*)	X	Introduced
True flies (Diptera)		
Canacidae		
Procanace constricta	X	Endemic
Chironomidae		
Telmatogeton torrenticola	X	Endemic
Dolichopodidae		
Dolichopus exsul	X	Introduced
Ephydridae		
Scatella clavipes	X	Endemic
Scatella cilipes	X	Endemic
Psychodidae sp.	X	Unknown
Tipulidae		
Limonia jacoba	X	Endemic
True bugs (Heteroptera)		
Saldidae		
Saldula exulans	X	Endemic
Butterflies and Moths (Lepidoptera)		
Cosmopterigidae-*Hyposmocoma* sp.	X	Endemic
Caddisflies (Trichoptera)		
Cheumatopsyche pettiti	X	Introduced
Total Species (% Known Native)[1]:	14 (77%)	

[1]The unknown Psychodidae sp. was not included in % native calculation

Table 5. Native and introduced aquatic insects collected in quantitative, general, and benthic sampling in Koiawe Stream, Hawaii in December 1998.

Taxon	Below Diversion 720-1000 ft	Above Diversion 1020-1040 ft	Geographic Status
Insects			
Damselflies/dragonflies (Odonata)			
Blackburn's Hawaiian Damselfly (*Megalagrion blackburni*)	X	X	Endemic
Dragonfly (*Anax strenuus*)	X	X	Endemic
True flies (Diptera)			
Canacidae			
Procanace constricta	X	X	Endemic
Chironomidae			
Telmatogeton torrenticola	X	X	Endemic
Dolichopodidae			
Sigmatineurum meaohi	X	X	Endemic
Ephydridae			
Scatella clavipes	X	X	Endemic
Scatella cilipes	X	X	Endemic
Scatella hawaiiensis	X		
Scatella warreni	X	X	Endemic
Tipulidae			
Limonia new sp.	X	X	Endemic?
Limonia jacoba		X	Endemic
Limonia stygipennis	X		Endemic
True bugs (Heteroptera)			
Saldidae			
Saldula exulans	X		Endemic
Caddisflies (Trichoptera)			
Cheumatopsyche pettiti	X	X	Introduced
Total Species (% Native):	13 (92%)	11 (91%)	

Table 6. Native and introduced aquatic insects collected in quantitative, general, and benthic sampling in Alakahi Stream, Hawaii in December 1998.

Taxon	Below Diversion 720-1020 ft	Above Diversion 1030-1240 ft	Geographic Status
Insects			
Damselflies/dragonflies (Odonata)			
Blackburn's Hawaiian Damselfly (*Megalagrion blackburni*)	X	X	Endemic
Dragonfly (*Anax strenuus*)	X	X	Endemic
True flies (Diptera)			
Canacidae			
Procanace constricta	X	X	Endemic
Chironomidae			
Telmatogeton torrenticola	X	X	Endemic
Dolichopodidae			
Sigmatineurum meaohi	X	X	Endemic
Sigmatineurum new sp.		X	Endemic
Ephydridae			
Scatella femoralis[1]		X	
Scatella clavipes	X	X	Endemic
Scatella cilipes	X	X	Endemic
Scatella warreni		X	Endemic
Tipulidae			
Limonia new sp.	X		Endemic?
Limonia jacoba	X	X	Endemic
True bugs (Heteroptera)			
Saldidae			
Saldula exulans		X	Endemic
Caddisflies (Trichoptera)			
Cheumatopsyche pettiti	X	X	Introduced
Total Species (% Native):	10 (90%)	13 (92%)	

[1]Reported as *Apulvillus femoralis* in Hardy and Delfinado (1980)

Table 7. Native and introduced aquatic insects collected in quantitative, general, and benthic sampling in Kawainui Stream, Hawaii in December 1998.

Taxon	Below Diversion 960-1030 ft	Above Diversion 1037- 1400 ft	Geographic Status
Insects			
Damselflies/dragonflies (Odonata)			
Blackburn's Hawaiian Damselfly (*Megalagrion blackburni*)	X	X	Endemic
Beautiful Hawaiian Damselfly (*Megalagrion calliphya*)		X	Endemic
Dragonfly (*Pantala flavescens*)	X	X	Indigenous
Dragonfly (*Anax strenuus*)	X	X	Endemic
True flies (Diptera)			
Canacidae			
Procanace constricta	X	X	Endemic
Chironomidae			
Cricotopus bicinctus	X		Introduced
Telmatogeton torrenticola	X	X	Endemic
Ephydridae			
Scatella clavipes	X	X	Endemic
Scatella cilipes	X	X	Endemic
Scatella warreni		X	Endemic
Tipulidae			
Limonia sp.		X	unknown
Limonia jacoba	X	X	Endemic
Limonia perkinsi		X	Introduced
True bugs (Heteroptera)			
Saldidae			
Saldula exulans		X	Endemic
Caddisflies (Trichoptera)			
Cheumatopsyche pettiti	X	X	Introduced
Total Species (% Native):	10 (80%)	14 (86%)	

Table 8. Native and introduced aquatic insects collected in quantitative, general, and benthic sampling in Waimanu Stream (Waihilau tributary), Hawaii in December 1998.

Taxon	Waimanu (Waihilau) 300-350 ft	Geographic Status
Insects		
Damselflies/dragonflies (Odonata)		
Blackburn's Hawaiian Damselfly (*Megalagrion blackburni*)	X	Endemic
Hawaiian Upland Damselfly (*Megalagrion hawaiiense*)	X	Endemic
Dragonfly (*Anax strenuus*)	X	Endemic
True flies (Diptera)		
Canacidae		
Procanace acuminata	X	Endemic
Procanace constricta	X	Endemic
Dolichopodidae		
Sigmatineurum new sp.	X	Endemic
Ephydridae		
Scatella clavipes	X	Endemic
Scatella cilipes	X	Endemic
Scatella femoralis[1]	X	Endemic
Scatella hawaiiensis	X	Endemic
Scatella warreni	X	Endemic
Scatella new sp.	X	Endemic
Tipulidae		
Limonia new sp.	X	Endemic?
Limonia jacoba	X	Endemic
Limonia stygipennis	X	Endemic
Caddisflies (Trichoptera)		
Cheumatopsyche pettiti	X	Introduced
Total Species (% Native):	16 (94%)	

[1]Reported as *Apulvillus femoralis* in Hardy and Delfinado (1980)

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