ASSESSMENT OF THE SUITABILITY OF KOKEE STATE PARK STREAMS AS HABITAT FOR YEAR-ROUND CATCH AND RELEASE FISHING FOR RAINBOW TROUT WITHOUT ANNUAL STOCKING
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Hawaii Biological Survey, in collaboration with the Smithsonian Institution, conducted Phase I of a two-phase assessment of Kokee State Park streams as suitable habitat for rainbow trout year-round catch and release fishing. Phase I was conducted during the dry (summer) season in August 1997. A preliminary assessment of the amount and location of natural reproduction of rainbow trout (*Onchorhynchus mykiss*), food availability and density, and the influence of rainbow trout predation on native and introduced stream invertebrates was conducted in Kauaikinana, Kawaikoi, and Koaie Streams.

Eighteen rainbow trout stomachs were collected and examined from Koaie Stream. Length distributions for Koaie Stream indicate larger rainbow trout were found in Koaie Stream when compared to Kauaikinana Stream. The smallest fish caught around Koaie Camp was 12 in, while fish as small as approximately 5 in were caught and released on Koaie Stream by volunteer Trout Unlimited anglers during this study.

Natural reproduction was not observed for rainbow trout in Koaie Stream at Koaie Camp, but was observed below the large waterfalls at the USGS gaging station, at Station 6. Reproduction downstream of the falls may be due to a combination of emergent springs and possibly more available fine spawning gravel. Several colder springs emerged downstream of the waterfalls, and summer temperatures of 17.5 C at these springs contrasted with temperatures of 21 C near the USGS gaging station at Koaie Camp. The influence of groundwater at the springs was also apparent, as pH in the main channel was 6.8 as compared to 7.3 in the spring area. Regardless of the reason, natural reproduction was observed downstream of the falls. Small (< 5 in) fish were caught at Station 6, and the last stocking of Koaie Stream occurred in 1992.

Eight rainbow trout stomachs were collected and examined from Kauaikinana Stream. Smaller rainbow trout were found in Kauaikinana Stream as compared to Koaie Stream. Numerous fingerling sized (<2 in) rainbow trout were observed throughout Kauaikinana Stream. As rainbow trout were last stocked in Kauaikinana Stream in 1992 at the approximate 5 in size class, these fingerlings were obviously the result of natural reproduction.

The aquatic insect fauna in the three surveyed streams consists mainly of native aquatic insects. Because most native aquatic insects are splash-zone dwellers and not prone to drift it appears that rainbow trout are instead utilizing the available and abundant terrestrial insect drift.

The lack of drifting aquatic species is reflected in trout diet, as only 39% of the diet during the summer months was aquatic in nature, and of that 42% were native aquatic species. The unusual terrestrial feeding mode of rainbow trout on Kauai streams was also described by Needham and Welsh (1953). They found that rainbow trout diet in Kokee

Stream consisted of 34.7% (by number) terrestrial millipedes (Needham and Welsh 1953), as compared to the 40% we found in Koaie and Kauaikinana rainbow trout. The significant difference in rainbow trout diet analysis between this study and the Needham and Welsh study was the 33.8% (by number) of native *Megalagrion* damselflies in Kokee Stream rainbow trout. Phase I of this study found only one *Megalagrion* damselfly out of 485 identifiable prey items. This underscores the importance of obtaining rainbow trout diet data from Kokee Stream, as well as increasing our currently small sample size of 26 stomachs. Additionally, it is well known that rainbow trout undergo seasonal shifts in diet (Filbert and Hawkins 1995, Jenkins et al. 1970, Chaston 1969), and that shifts to other prey items such as native damselflies could potentially occur on a seasonal basis.

The primary objective of this study was to assess whether rainbow trout could maintain catch and release populations for recreational fishing in Kokee State Park streams without annual stocking. Phase I of this study enabled us to come to preliminary conclusions for the Koaie, Kawaikoi, and Kauaikinana Streams. Some basic needs of a self-sustaining fish population are proper environmental conditions such as water temperature and chemistry, an adequate forage base, and suitable spawning sites. Kawaikoi Stream does not appear to meet the conditions for a self-sustaining trout fishery, and would likely need to be stocked at least every two to three years. However, the forage base for rainbow trout in Kawaikoi Stream appears to be more than adequate for a stocked fishery. There appears to be no lack of forage for rainbow trout as they are mainly drift feeders. Kawaikoi Stream flows through a native ‘ohia dominated forest with high densities of terrestrial insects and millipedes. The high amount of terrestrial drift applies to both Kauaikinana and Koaie Stream as well. Kawaikoi Stream also had high densities ($8.2 \pm 2.6/ft^2$) of aquatic prey items such as caddisflies that accounted for 15.7% of the rainbow trout’s diet. Kauaikinana and Koaie Streams also have a more than adequate aquatic invertebrate forage base for rainbow trout survival.

Portions of Koaie Stream and Kauaikinana Stream upstream of the Mohihi Ditch are currently exhibiting the proper conditions allowing for a self-sustaining trout fishery. Natural reproduction was evident in both of these streams, with numerous 2-3 in fish observed in Kauaikinana Stream, and naturally reproduced 5-10 in rainbow trout observed and collected in Koaie Stream at Station 6. Assuming that catch and release regulations would be enforced, we conclude that Kauaikinana Stream, and Koaie Stream at Station 6 are suitable for year-round rainbow trout fishing without annual stocking.

INTRODUCTION

The Hawaii Biological Survey, in collaboration with the Smithsonian Institution, conducted Phase I of a two-phase assessment of Kokee State Park streams as suitable habitat for year-round rainbow trout catch and release fishing. Phase I was conducted during the dry (summer) season in August 1997. A preliminary assessment of the amount and location of natural reproduction of rainbow trout (*Onchorhynchus mykiss*), food availability and density, and the influence of rainbow trout predation on native and

introduced stream invertebrates was conducted in Kauaikinana, Kawaikoi, and Koaie Streams.

Rainbow trout had been stocked in Kokee area streams since 1920 (Needham and Welsh 1953), but stocking of streams with rainbow trout in Kokee State Park was discontinued in 1992 due to concerns of rainbow trout predation on native damselflies and other native aquatic insect species. Prior to this study, no published data existed regarding the impact of rainbow trout on native aquatic invertebrates in Kokee State Park streams. Native damselflies appear to be sensitive to the presence of introduced fish such as the green swordtail (*Xiphophorus helleri*) or the shortfin molly (*Poecilia mexicana*) in the family Poeciliidae (Polhemus and Asquith 1996). Prior to these first assessments there was only anecdotal evidence of rainbow trout predation on native damselfly populations. No published data existed as to whether rainbow trout predation negatively impacts Hawaiian damselflies or any other potential forage item.

To assess available rainbow trout forage, we surveyed the abundance and species composition of aquatic invertebrate populations in Kauaikinana, Kawaikoi, and Koaie Streams within Kokee State Park. Phase I also served as a preliminary investigation on the influence of rainbow trout predation on native endemic damselflies, and we assessed the predation effects on potentially sensitive native damselfly species. To evaluate rainbow trout diet, stomach contents were collected from rainbow trout on Kauaikinana and Koaie Streams in August 1997. Although stocked in the past, Kawaikoi Stream currently does not have any rainbow trout.

The objectives of this study are to 1) assess stream habitat including available food resources, and potential spawning areas in Kokee State Park streams for a wild rainbow trout catch and release fishery, 2) evaluate whether rainbow trout reproduction currently occurs and ascertain the holdover status of previously stocked rainbow trout, 3) assess whether predation by rainbow trout impacts the aquatic insect forage base in Kokee State Park, 4) evaluate seasonal rainbow trout diet in Kauaikinana Stream, and two other streams, and, 5) describe baseline distribution and abundance of endemic damselflies and other potentially sensitive native aquatic insects in Kokee State Park.

STUDY AREA

Encompassing the Alakai Swamp, Kokee State Park is located in northwestern Kauai. Situated on the Alakai plateau and running through the Alakai Swamp, Kokee State Park contains numerous streams that drain Mt. Waialeale, the wettest area on earth (Hazlett and Hyndman 1996). This area is heavily dissected by deep, erosion formed canyons thickly covered by mostly native vegetation along the stream corridors. Beginning near the western end of the Alakai Swamp, the aquatic biota of Koaie, Kawaikoi, and Kauaikinana Streams was assessed in August 1997.

The three streams assessed for Phase 1 of the study were relatively close to each other, and ranged in elevation from approximately 3400-3800 ft (Figure 1). Two stations were

sampled for each stream in this study. Kawaikoi and Koaie Streams appeared to have relatively similar base flows, while Kauaikinana Stream was smaller and had a lower base flow. Overall, stream flow was low and stable throughout Phase 1 of this study allowing for uniform aquatic insect sampling between streams. This in combination with the fact that all three streams lay at relatively similar elevations, meant the data from sampling stations on these streams were quite comparable.

Kauaikinana Stream

We assessed Kauaikinana Stream downstream from Camp 10 road to the diversion dam at Station 1, and approximately 0.5 mi upstream of Camp 10 road at Station 2. Kauaikinana is a small stream characterized by a relatively low baseflow. Kauaikinana Stream flows though a small, narrow, sinuate canyon covered with an uluhe (*Dicranopteris linearis*) fern understory overtopped by many large ‘ohi’a (*Metrosideros polymorpha*) growing on the stream banks. Although native plants dominated the forest a few meters away from the stream banks, alien plants dominated the riparian zone. In particular, a few alien plants such as raspberry (*Rubus argutus*), common guava (*Psidium guajava*), and Kahili ginger (*Hedychium gardnerianum*) were found growing almost exclusively near the more open stream bank areas.

Station 1 (3400 ft)

This station was located at the concrete diversion weir for the Mohihi Ditch system. Upstream of the concrete diversion weir stream flow appeared to be doubled by the Mohihi ditch for a short distance of about 150 ft. At the concrete weir Kauaikinana Stream flow disappears entirely into the Mohihi tunnel system. Above the influence of the Mohihi ditch, stream flow is quite low, with the stream generally ranging from 3.5 to 6 ft in width, except in areas of deep pools that
were 30 ft wide. Stream gradient in this area was moderate, with shallow (2-7 in deep) riffles formed by small boulders. Suitable sized rainbow trout spawning substrate was observed in many of the small riffles. More silt was found in this station than in other areas in this study.

Station 2 (3540 ft)

This station was located upstream of Camp 10 road. Water clarity increased upstream of Camp 10 road, with the stream gradient still moderate but slightly increasing, and the streambed becoming filled with large boulders. Above Camp 10 road the canyon is quite constricted in places, and is the smallest of the three streams assessed for this study. Seep habitat was not evident in areas of the stream with sheer gorge walls. There was ample side pool and side channel habitat.

Kawaikoi Stream

Kawaikoi Stream flows through a fairly open canyon covered by uluhe ferns and ‘ohi’a trees. Kawaikoi Stream is a relatively large stream, being quite similar in discharge and

size to Koaie Stream. We assessed Kawaikoi Stream at two stations above Camp 10 road: the first location was adjacent to the USGS gaging station at 3,420 ft, and the second station was on a tributary approximately 1 mile upstream from the USGS gaging station. Kawaikoi Stream had abundant isolated side pool and side channel habitats, but lacked seep or rheocrene habitats in the areas we surveyed.

Station 3 (3420 ft)

Station 3 was located in a moderate gradient area of Kawaikoi Stream, with short riffles interspersed between large, deep pools. Stream gradient was similar to Kauaikinana Stream, but somewhat less steep than Koaie Stream. Abundant large boulders provide evidence that streambed is regularly scoured by high flows. Water clarity was better than Koaie Stream, although the stream contained large quantities of green filamentous algae.

Station 4 (3580 ft)

This station was located along a tributary incised approximately 100 ft in a narrow gorge. A dense riparian vegetation corridor was formed along the stream by Kahili ginger and raspberry. Kawaikoi Stream becomes smaller above this tributary, and was similar in size at this point to Kauaikinana Stream. Stream habitat in consisted of shallow (1.5-3 ft) pools with many slow, clear side-pools. Several small springs also enter into this tributary. Abundant still water pool habitats were interspersed with many small 3-4 ft cascades.

Koaie Stream

Koaie Stream was accessed from the end of Camp 10 road and by hiking along the Mohihi-Waialae trail to Koaie Camp. Koaie Camp, at 3800 ft elevation, was used as an endangered bird research station during Phase 1 of this study, and was next to the metal shed at the USGS gaging station. The stream in this area lies approximately 300 ft below the rim of the Alakai Swamp plateau. Koaie Stream originates from runoff of the northeastern sections of the Alakai Swamp, resulting in deeply tannin stained water and lower pH compared to Kauaikinana Stream. Koaie Stream was the most remote of the three streams sampled for Phase I of this study.

Along the reach sampled, Koaie Stream had many small, side tributaries entering from the Alakai Swamp plateau. These tributaries emptied from small, semi-circular amphitheaters with sheer rock walls lined with moss. The abundant seep habitat in Koaie Stream stood in contrast to Kauaikinana and Kawaikoi Streams, which lacked this habitat at our sampling locations. Side pool and side channel areas were common at Koaie Stream, especially at Station 2, below the falls at the stream gage.

The nearly pristine native riparian vegetation found along Koaie Stream was quite unusual for a Hawaiian stream. The streambed was lined mostly with uluhe ferns and

‘ohi’a, with relatively small amounts of raspberry being the most noticeable introduced species. Aquatic insect and rainbow trout sampling occurred at two locations on Koaie Stream.

Station 5 (3800 ft)

The first sampling area began with a long series of riffles upstream of the USGS gaging station, which is called Koaie Camp on USGS quad maps. Koaie Stream in this area flowed through an incised canyon approximately 300 ft deep, and was characterized by low to moderate gradient riffles interspersed with large, deep, still pools. Substrate composition in the shallower run and riffle areas of Koaie Stream consisted of an even mix of larger gravels, small and large cobbles, and numerous small and large boulders. Finer gravel substrates suitable for rainbow trout spawning were not abundant in this area of Koaie Stream. Upstream of the USGS station, Koaie Stream could be accessed for 0.5 mi to the base of a waterfall approximately 50 ft high.

Station 6 (3650 ft)

The second sampling station was located below a large 75 ft waterfall, which was located approximately 1/4 mi downstream of the USGS gaging station at Koaie Camp. This area was accessed by hiking up the near vertical valley ridge on the north bank of Koaie Stream and then descending the cliff to the stream bottom below the falls. The steep ridge is overgrown with stands of uluhe 6-10 ft high, and should be considered hazardous. Due to the difficult and dangerous nature of this climb, this station will be accessed with helicopters in the future. Stream gradient and habitat was similar to that observed at Station 5. Several springs and rheocrenes (as defined by Polhemus et al. 1992) were observed entering the stream at this station. Koaie Stream flowed approximately 0.5 mi more before passing over another large, 75 ft impassable waterfall that blocked further downstream passage. This area also had plentiful seep and rheocrene habitat, and areas with gravel sized substrate were not uncommon.

METHODS

GENERAL METHODS

Field work for Phase 1 was conducted from 1-8 August 1997 during a period of low flow in Kauaikinana, Kawaikoi, and Koaie Streams. Sampling was conducted under unusually clear weather conditions. Representative sampling stations (see STUDY AREA) were established on each of these streams, and aquatic macrofauna (fish, crustaceans, mollusks, and amphibians) was assessed at each station. Sampling areas were somewhat dependent upon the constraints of vegetation and local terrain, and were established in streams containing rainbow trout with natural reproduction (Kauaikinana and Koaie Streams), and in a stream currently devoid of rainbow trout

(Kawaikoi). Snorkeling and above-water observation were not used to estimate fish density due to poor water visibility.

Composition of the riparian vegetation and stream substrate were evaluated at each sampling station. Habitat condition for native aquatic organisms was evaluated both within sampling stations and throughout the sections of stream that we hiked. Altitude at each sampling station was determined by using a combination of USGS topographic maps and a hand-held Casio altimeter. The altitude given at each sampling station (see STUDY AREA) was the starting altitude. Stream distances were measured with a planimeter on USGS quads. Field water quality measurements were made in Kawaikoi and Kauaikinana Streams, while pH and temperatures were collected in Koaie Stream.

Rainbow Trout Diet Analysis

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

Contents of each rainbow trout stomach were identified to the lowest possible level, and in many cases to genus and species. Species level identification was not possible for partially digested insects, or some insects such as Diptera (aquatic flies) as males are required for identification. Total prey item numbers in each trout stomach were recorded, and if contents were broken into pieces, head capsules were then counted to assess prey item numbers. The terrestrial or aquatic status of each prey item was determined for each identifiable prey item found in rainbow trout stomachs. The percent composition of rainbow trout diet was calculated by adding the total number of identifiable prey items and dividing by each prey item category. The proportion of introduced and native aquatic prey items in rainbow trout stomachs was calculated for the aquatic species where geographic status was known.

Identifications were conducted primarily by Ron Englund, David Preston, Dr. Alan Samuelson, Dr. Frank Howarth, Gordon Nisihida, and Dr. Sabina Swift of the Bishop Museum and Dr. Dan Polhemus of the Smithsonian Institution. Curtis Ewing of the University of Hawaii and Dr. Rowland Shelley of the North Carolina State Museum of Natural Sciences also provided beetle and millipede identifications. The processed stomach contents are stored in the Bishop Museum Entomology Department collection.

Field autopsies providing a health and condition profile based on Goede and Barton (1990) were also conducted for rainbow trout. This method provides an assessment of fish health, and allows for inferences to be made as to how a fish population is coping with its environment. Conversely, it also provides an indication as to environmental quality (Goede and Barton 1990). Factors such as fat levels, and condition of eyes and gills, physical fin damage, pseudobranch and thymus condition, and hind gut inflammation were examined during field autopsies of fish immediately after capture. Blood chemistry values such as hematocrit, leukocrit, and plasma protein were not measured. This is due to the remote location of the study areas, and the necessity of centrifuging freshly collected blood. Rainbow trout autopsy data were entered into the AUSUM computer program for a summary of the health assessments (Goede and Houghton 1993).

One of the most commonly used methods for assessing fish well-being is the condition factor (K) which measures the relationship between fish length and weight. Condition factors are normally expressed as weight/length^3 (Nielsen and Johnson 1983). To ease the problem of carrying so many decimals, K in this study was calculated according to Goede and Barton (1990):

$$K \times 10^5 = (W \times 10^5)/L^3$$

Aquatic Insect Sampling

Aquatic insect sampling was conducted according to Polhemus (1995) and Englund and Filbert (1997). Collections of both immature and adult specimens were conducted with aerial sweep netting, dip nets and Surber (benthic) samples. Visual observations of aquatic insects were also conducted while hiking 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 rock overhangs. In addition, the sampling of damselflies and dragonflies (Odonata) was emphasized. Six species of *Megalagrion* damselflies are currently held as candidate Threatened, Endangered, or Species of Concern on the Federal Register. Moreover, native Hawaiian damselflies give an indication of the relative 'health' of a stream system; they do not typically occur in highly disturbed areas. The number and species of native damselflies observed during hikes both upstream and downstream were also recorded, and damselfly catch (or observations) per unit of time was noted.

Randomly selected Surber samples were used to determine benthic aquatic insect densities in riffles. Benthic samples were collected in streams with (Kauaikinana, Koaie) and without (Kawaikoi) rainbow trout populations. All three streams contained many moderate gradient riffles with similarly sized substrate (3-10 in).

The number of insect species collected per aerial-net sweep of riffles was also determined (Englund and Filbert 1997). Adjusting the number of species by collecting effort allows for a rough comparison among sampling stations and streams. Dragonfly and damselfly species were observed but not usually captured during aerial-net sweeps and are therefore not usually included in the catch rates. However, some damselflies were captured during our quantitative aerial-net sweeps of riffle habitats. Those damselflies captured during aerial-net sweeps of riffles were included in the species catch/effort at those stations.

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

RESULTS AND DISCUSSION

KOAIE STREAM

Sampling Effort

Sample effort for Koaie Stream consisted of stomach collections and autopsies of 18 rainbow trout. The size and weight distribution for captured rainbow trout was also recorded. Ten benthic samples were taken in riffles, and 90 aerial insect net samples were taken in riffles and their associated splash zones (Tables 4 and 5). Damselfly observations/time (i.e. catch/effort rates) were also recorded for each damselfly species commonly observed (Table 6), and general collections were made for aquatic insects in a wide range of habitats.

Species Composition and Distribution

Aquatic Macrofauna

Native ‘o’opu were not observed in the section of Koaie Stream we sampled, and apparently do not make it to the elevations where this study was conducted. The native ‘opae kalaole (*Atyoida bisulcata*) was uncommon and only found in one trout stomach at Station 2, below the large falls downstream of the USGS gaging station. Rainbow trout were the only fish observed in Koaie Stream. Wrinkled frogs (*Rana rugosa*) were common, and were the only amphibians observed in Koaie Stream.

Aquatic Insects

Koaie Stream aquatic insect populations were assessed through the use of benthic sampling, aerial-net sweeps, and visual observations (Tables 1 and Tables 4-6). Eighty-nine percent of the aquatic insects collected in Koaie Stream were endemic to Hawaii. This was the highest percent native aquatic insect fauna of the three surveyed streams in Phase I of this study. Several other important aquatic invertebrate species such as ‘opae kalaole, *Telmatogeton* sp., and *Microvelia vagans* were not captured using the proceeding methods, but were found in trout stomachs collected from Koaie Stream (Table 7). The greatest number of native damselfly species were found in Koaie Stream, which was likely due to the diversity of aquatic habitats found there.

Koaie Stream had the greatest diversity of aquatic insect species of the three streams examined during Phase I of this study. Aerial net sweeps collected 0.17 native species/sweep, and a remarkable 0 introduced species/sweep. In comparison, pristine sections of upper Waipio Valley streams, such as Kawainui Stream in Hawaii County exhibited slightly lower catch rates of 0.15 native and 0 introduced species/sweep (Englund and Filbert 1997). The dearth of introduced aquatic insect species, and the high densities of native aquatic species indicate that Koaie Stream maintains one of the healthiest native insect faunas remaining in the Hawaiian Islands. Introduced aquatic insect species such as caddisflies (*Cheumatopscyhe pettiti*) were also commonly found during benthic sampling.

A significant finding of this study was the collection of large populations of the Kauai endemic Na Pali Hawaiian skating fly, *Sigmatineurum napali*, in both Koaie and Kawaikoi Streams. Collections were made in open, sunny areas of the stream channels by running the net through the turbulent water of the cascade or riffle face. The catch rate at Koaie Stream for this species was remarkably high, with more than 25 individual *Sigmatineurum napali* captured for every 20 aerial net-sweeps. Prior to this study only five individuals from Hanakoa and Hanakapaiai Streams had been collected (Evenhuis and Polhemus 1994) during extensive Kauai surveys. Populations of *Sigmatineurum* skating flies are generally quite small, and it can take an entire day of sampling to capture 10 individuals (Evenhuis and Polhemus 1994).

Koaie and Kawaikoi Streams appear to have a more robust population of *Sigmatineurum* than other areas sampled in the Hawaiian islands, including Alakahi Stream (1140 ft elevation) in upper Waipio Valley, Hawaii County (Englund and Filbert 1997). For comparison, the previously mentioned study collected seven adults during a total of 90 net sweeps in a 1-hour period in upper Alakahi Stream. Evenhuis and Polhemus (1994) found that adults of *Sigmatineurum* were tightly restricted to riparian microhabitats consisting of wet, shaded, vertical bedrock exposures next to small splashing waterfalls in areas of mesic forest. In Hanawi Stream, Maui, adults preferred vertical wet bedrock walls in the splash zone of small cascades (Englund and Polhemus 1993). *Sigmatineurum* appears to be an ecologically sensitive aquatic insect taxon susceptible to disturbances such as introduced species and water diversions; for instance, members of this genus and were not found below Hamakua ditch water diversions (Englund and Filbert 1997).

Visual observations or the number of individuals sighted/hour were conducted for the most common native stream damselfly, the Kauai mountain damselfly (*Megalagrion heterogamias*). During sunny weather, an average of 9.5 adult Kauai mountain damselflies/hour were observed by two knowledgeable observers (Table 6). Catch/effort rates for the Kauai mountain damselfly indicate this species was common at Koaie Stream. Although the utility of this method is still uncertain, it may allow for rough comparisons to be made between streams, and possibly among islands. Streams without any alien fish such as Waikolu Stream, Molokai had a catch/hour rate of 13.8 for Blackburn's Hawaiian damselfly (*Megalagrion blackburni*) during August , 1997 (Englund, unpublished database). The Molokai counts were conducted upstream of the highest water diversion (990 to 1200 ft elevation) in the naturally flowing portion of Waikolu Stream. The Blackburn's Hawaiian damselfly is found on Molokai, and is a riffle-dweller ecologically analogous to the Kauai Mountain damselfly.

Due to a greater variety of aquatic habitats, Koaie Stream was found to have the most diverse native damselfly population of the three streams sampled during this study. The frosty Hawaiian damselfly (*Megalagrion eudytum*) was found on waterfall faces and on the sides of the numerous seeps found in the many feeder tributaries entering Koaie Stream. These habitats were not observed in Kauaikinana and Kawaikoi Streams, which explains why frosty Hawaiian damselflies were not observed in those areas.

Two rare species of terrestrial beetles were also collected from the same rainbow trout in Koaie Stream. Most significant is an extremely rare elaterid beetle, *Eopenthes muticus*. This beetle was last collected in 1896 by Perkins, and only two specimens are known to exist. An alleculid beetle, *Pseudocistela kauaiensis*, also taken from the same trout, was last collected in 1937 by E.C. Zimmerman (Bishop Museum Collection). *Pseudocistela kauaiensis* is endemic to Maui and Kauai, and only 13 specimens are known.

Freshwater mollusks (for Koaie, Kawaikoi, Kauaikinana Streams)

Some native stream mollusks are not amphidromous but complete their life cycles within streams. These endemic freshwater snails are members of the family Lymnaeidae, and some of the snails found in the surveyed Kokee State Park streams are likely native lymnaeids. However, except for *Erinna newcombi*, (a candidate endangered species), and *Oligospira*, identification of native lymnaeids is difficult as many taxonomic issues remain unresolved (Cowie 1998). It is not currently possible to positively identify the snails that we found in Kokee State Park streams to species level (Cowie 1998). Thus the native or introduced status of the lymnaeids we collected during aquatic organism sampling or found in trout stomachs cannot be resolved. The candidate endangered *Erinna newcombi* was not observed or collected in any of the streams sampled, and is not likely found at these high elevations.

Rainbow Trout

Eighteen rainbow trout stomachs were collected and examined from Koaie Stream (Table 7). Length distributions for Koaie Stream (Figure 2) indicate larger rainbow trout were found here as compared to Kauaikinana Stream. The smallest fish caught around Koaie Camp was 12 in, while fish as small as approximately 5 in were caught and released by the TU anglers during this study at Station 6. Only collected and measured fish were included in the length distribution shown in Figure 2.

Natural reproduction was not observed for rainbow trout in Koaie Stream at Koaie Camp, but was observed below the large waterfalls at Station 6.
Reproduction downstream of the falls may be due to a combination of emergent springs and possibly more available fine spawning gravel. Several colder springs emerged downstream of the waterfalls, and temperatures of 17.5 C at these springs contrasted with temperatures of 21 C near the USGS gaging station at Koaie Camp (Table 8). The influence of groundwater at the springs was also apparent, as pH in the main channel was 6.8 as compared to 7.3 in the spring area. Regardless of the reason, natural reproduction was observed downstream of the falls. Small (< 5 in) fish were caught at Station 6, and the last stocking of Koaie Stream occurred in 1992.

Autopsy results for Koaie Stream determined through the AUSUM computer program are shown in Appendix 1. The autopsy results provide a baseline measure of the fish health for future studies, but will not provide definitive causal mechanisms if fish are found to be under stress (Goede and Barton 1990). Our results indicate an overall healthy condition for both stocked and naturally reproduced rainbow trout in Koaie Stream. One of the most important measures of trout health is the summary of combined percent indices (see Appendix I). For Koaie Stream rainbow trout, the normality index of 95% was well above the acceptable range of 90% (Goede 1996). The severity index was 0.7%, far below the acceptable range of <10%, while the feeding index of 78% was well above the acceptable range of 67% (Goede 1996). The feeding index is measured by bile color, and gives an approximation of how recently it has been since the fish have eaten (Goede and Barton 1990). The feeding index from Koaie Stream indicated 78% of the rainbow trout had eaten within a day.

Condition factor (K) expresses weight and length relationships within a fish population, usually expressed as weight/length^3. A decline in K often reflects a stress to a fish population that can either be related to normal events such as spawning or due to environmental events such as hatchery overcrowding or adverse environmental conditions (Goede and Barton 1990). The condition factor of Koaie Stream rainbow trout was 0.93, which is somewhat lower than the expected norm of 1.12 (Goede 1996), but is not a cause for concern. The slightly lower than expected K factor may be explained by the rainbow trout living in a stream with marginally acceptable stream temperatures, or it may just be the strain of trout stocked on Kauai has this type of weight/length relationship.

Mesentery fat levels averaged 1.6 on a scale of 4 having the mesentery completely covered in fat. These levels appear to fall within an acceptable range, and may be explained by number of variable factors. There is no normal value for mesentary fat

levels, as fish at different times of the year may be putting metabolic energy into reproduction or growth rather than storage (fat deposits). With a plentiful terrestrial and aquatic year-round food supply, it is conjectured that rainbow trout in Kauai streams may not need much of a fat reserve. Instead, fish may be putting energy into tissue growth and reproduction throughout the year.

KAWAIKOI STREAM

Sampling Effort

Rainbow trout were not captured in Kawaikoi Stream, although observations of two introduced fish species were made. Nine benthic samples were taken in riffles, and 90 aerial insect net samples were taken in riffles and their associated splash zones (Tables 4 and 5). Damselfly observations/time (i.e. catch/effort rates) were also recorded for each damselfly species commonly observed (Table 6), and general collections were made for aquatic insects in a wide range of habitats.

Species Composition and Distribution

Aquatic Macrofauna

Probably due to its proximity to an easily accessible road, more alien species of aquatic macrofauna were observed in Kawaikoi Stream then at other sampled locations. Two species of introduced fish were observed here, the dojo loach (*Misgurnus anguillicaudatus*), and green swordtails (*Xiphophorus helleri*). Green swordtails appeared to be restricted by a concrete weir at the USGS gaging station, and may only occur in areas downstream of the 3420 ft elevation. The introduced crayfish (*Procambarus clarki*), a likely bait introduction, was also common in Kawaikoi Stream.

Aquatic Insects

Kawaikoi Stream aquatic insect populations were assessed through the use of benthic sampling, aerial-net sweeps, and visual observations (Tables 2 and Tables 4-6). Seventy-five percent of the aquatic insects collected in Kawaikoi Stream were endemic to Hawaii, and this was the lowest percent native species of the three streams surveyed for this study. Aerial net sweeps collected 0.08 native species/sweep, and a 0.03 introduced species/sweep. Kawaikoi Stream should still be considered to have an excellent native aquatic insect fauna, even though a greater percentage of introduced aquatic insect species was found here as compared to Koaie or Kauaikinana Streams. Examples of the robust native endemic aquatic insect population include adult native damselflies almost to numerous for observers too count. Additionally, the previously mentioned Na Pali Hawaiian skating fly, rare elsewhere, was abundant at Kawaikoi Stream.

Introduced aquatic insect species such as a caddisflies (*Cheumatopscyhe pettiti*) were also commonly found during benthic sampling. There appeared to be no relationship between the presence of rainbow trout and densities of caddisflies among the sampled streams. Kawaikoi Stream had caddisfly densities of 8.2/ft^2, which was intermediate between rainbow trout containing Koaie and Kawaikoi Streams (Table 5).

Visual observations or the number sighted/hour were conducted for the most common native stream damselfly, the Kauai mountain damselfly (*Megalagrion heterogamias*). During sunny weather, an average of 24 adult Kauai mountain damselflies/hour were observed by two trained observers (Table 6). Catch/effort rates for the Kauai mountain damselfly indicate this species was abundant at Kawaikoi Stream. Although the utility of this method is still unclear, it may allow for rough comparisons to be made between streams, and possibly among islands. The scarlet Kauai damselfly (*Megalagrion vagabundum*) was also common enough to allow for quantitative visual counts. Approximately six scarlet Kauai damselflies/per hour were observed at Kawaikoi Stream.

Rainbow Trout

Rainbow trout were not observed here, although Kawaikoi Stream was stocked until 1992 (Dennis Shinno, Hawaii Division of Aquatic Resources, personal communication). Water visibility was good due to dry weather and low-flow conditions, and no rainbow trout were observed. A check of the catch record at Kokee State Park confirmed no angling success in Kawaikoi Stream this year during through first nine days of the trout season. Anglers also confirmed that rainbow trout have not been caught from this stream in several years. In the past, poaching has been a problem at Kawaikoi Stream (Dennis Shinno, HDAR, personal communication). This is probably due to the ease of fishing along a large, open stream channel with a maintained trail providing easy public access. Natural reproduction of rainbow trout in Kawaikoi Stream is probably hampered by high water temperatures. Water temperatures were 73 F, the highest measured in the three streams assessed in Phase I of this study.

KAUAIKINANA STREAM

Sampling Effort

Sample effort for Kauaikinana Stream consisted of stomach collections and autopsies of eight rainbow trout. The size and weight distribution for captured rainbow trout was also recorded (Figures 2 and 3). Four benthic samples were taken in riffles, and 110 aerial insect net samples were taken in riffles and their associated splash zones (Tables 4 and 5). Damselfly observations/time (i.e. catch/effort rates) were also recorded for each damselfly species commonly observed (Table 6), and general collections were made for aquatic insects in a wide range of habitats (Table 3).

Species Composition and Distribution

Aquatic Macrofauna

Native ‘o’opu were not observed in the sections of Kauaikinana Stream we sampled, and apparently do not make it to the elevations where this study was conducted. Rainbow trout and dojo loaches were the only fish observed in Koaie Stream. Wrinkled frogs (*Rana rugosa*) were common, and was the only amphibian observed in Kauaikinana Stream. The introduced crayfish (*Procambarus clarki*), a likely bait introduction, was also observed in Kauaikinana Stream.

Aquatic Insects

Kauaikinana Stream aquatic insect populations were assessed through the use of benthic sampling, aerial-net sweeps, and visual observations (Tables 2 and Tables 4-6). Eighty-five percent of the aquatic insects collected in Kauaikinana Stream were endemic to Hawaii. This indicates Kauaikinana Stream has a healthy and relatively unimpacted native aquatic insect population. Aerial net sweeps collected 0.11 native species/sweep, and a 0.02 introduced species/sweep. The catch rate of native aquatic insects is similar to that found in a pristine system such as Koaie Stream, and Kawainui Stream, on Hawaii island (Englund and Filbert 1997). Kauaikinana Stream has an excellent native aquatic insect fauna, even though a greater percentage of introduced aquatic insect species were found here as compared to Koaie or Kauaikinana Streams. Examples of the robust native endemic aquatic insect population include native damselflies being almost to numerous for observers too count here. The Na Pali Hawaiian skating fly was not observed in Kauaikinana Stream probably due to the small stream size and lack of high gradient riffle habitats.

Visual observations on the number of individuals sighted/hour were conducted for the most common native stream damselfly, the Kauai mountain damselfly. During sunny weather, an average of 60 adult Kauai Mountain Damselflies/hour were observed by two observers (Table 6). Although the utility of this method is still unclear, it indicates that Kauai mountain damselflies were abundant in Kauaikinana Stream during Phase I of this study.

Introduced aquatic insect species such as a caddisflies (*Cheumatopscyhe pettiti*) were also commonly found during benthic sampling. There appeared to be no relationship between the presence of rainbow trout and densities of caddisflies among the sampled streams. Kauaikinana Stream, with a large, naturally reproducing rainbow trout population, had the highest average densities of caddisflies at 12/ft^2 (Table 4) among the three sampled streams.

Rainbow Trout

Eight rainbow trout stomachs were collected and examined from Kauaikinana Stream (Table 7). Length distributions for Kauaikinana Stream (Figure 2) indicate smaller

rainbow trout were found here as compared to Koaie Stream. Only collected and measured fish were included in the length distribution shown in Figure 2. However, numerous fingerling sized (<2 in) rainbow trout were observed throughout Kauaikinana Stream. As rainbow trout were last stocked in Kauaikinana Stream in 1992 at the approximate 5 in size class (Dennis Shinno, HDAR personal communication), these fingerlings were obviously the result of natural reproduction.

Stream temperature was measured in area with warmer than normal stream temperatures, at the diversion weir pond. As the large diversion pond and the diverted water from the Mohihi ditch are likely warmer than the true stream temperature, this was probably an inappropriate area to measure temperatures. The 65 F stream water temperature (at the Kauaikinana road crossing) collected during July-August 1949 is undoubtedly more accurate (Needham and Welsh 1953). Kauaikinana Stream clearly originates from a groundwater spring source, as the measured pH was 7.9 as compared to 6.8 measured at Station 5 (USGS gaging station) on Koaie Stream. Greater surface water runoff from the Alakai swamp is the likely reason for the lower pH found in Koaie Stream.

Autopsy results for Kauaikinana Stream determined through the AUSUM computer program are shown in Appendix 1. See Koaie Stream RESULTS AND DISCUSSION - RAINBOW TROUT section for a discussion of the meaning of autopsy results. Unfortunately the sample size of eight fish collected in Kauaikinana is fairly small. However, the small sample size still allows valid inferences to be made as the autopsy and diet results from both Koaie and Kauaikinana Streams are similar.

Rainbow trout have been naturally reproducing in Kauaikinana Stream since at least 1949 (Needham and Welsh 1953). Thus, the autopsy results are interesting as they indicate that this population is currently quite healthy. Similar to Koaie Stream, we found a normality index of 97.5%, and a low severity index of 0.0. The feeding index indicated that 67% of the captured fish had eaten within a day, which is at the acceptable level (Goede 1996). The condition factor (K) for Kauaikinana Stream was 0.94, and mirrored the 0.93 K found for Koaie Stream rainbow trout. Mesentery fat levels averaged 1.4 (on a scale of 4.0 being completely fat), and were similar to 1.6 fat level found in Koaie Stream.

ECOLOGICAL REQUIREMENTS OF NATIVE DAMSELFLIES

Unlike amphidromous animals such as ‘o’opu and ‘opae, native aquatic damselflies and other native aquatic insects complete their life cycles entirely within streams or other freshwater ecosystems. Until recently, native endemic *Megalagrion* damselflies were once common in virtually every such ecosystem throughout the Hawaiian Islands, being found from areas of slightly brackish basal spring wetlands water near the ocean to upland springs, seeps, rheocrenes, and riverine habitats, exploiting a full range lotic and lentic habitats (Polhemus and Asquith 1996). In recent decades, however, a combination of alien species introductions, stream channelization and diversions, and

water quality degradation has caused significant reduction or local extirpation of many native damselfly populations throughout Hawaii (Polhemus and Asquith 1996). Since Hawaiian streams differ from larger continental stream systems in that longitudinal movement of native aquatic insects occurs primarily during their aerial adult stage, rather than as upstream migration or downstream drift, the local extirpation of species within Hawaiian watersheds can often be persistent.

Two primary ecological requirements for native damselflies are good water quality (clear, low turbidity water) and the absence of certain alien fish species such as Tilapia (*Sarotherodon melanotheron*) and members of the family Poeciliidae. In 1995, a remnant population of *Megalagrion xanthomelas* at Tripler Medical Center on Oahu was extirpated from its last 100 m of stream habitat by a heavy sediment load from a nearby construction site (Pangelinan 1997). Although subsequent re-introductions from nearby mitigation ponds have re-established this remnant population, this incident points out the susceptibility of native damselflies to ecological disturbances such as sedimentation.

As noted above, native damselflies are sensitive to the presence of introduced fish such as the green swordtail (*Xiphophorus helleri*) or the shortfin molly (*Poecilia mexicana*) in the family Poeciliidae (Englund and Filbert 1996, Polhemus and Asquith 1996). Extensive surveys on Oahu have determined that the distributions of introduced Poeciliidae, including green swordtails, mollies and guppies (*Poecilia reticulata*), show little or no overlap with *Megalagrion* damselflies (Englund and Filbert 1996), indicating a negative interaction between the two groups.

The following section provides a brief description of habitat requirements (see also Polhemus and Asquith 1996) for the native damselfly species found in Koaie, Kawaikoi, and Kauaikinana Streams during Phase I of this study. None of the native damselflies found in this survey are considered rare, and none are among the six species listed on the Federal Register as candidate Threatened or Endangered species.

Frosty Hawaiian Damselfly (*Megalagrion eudytum*)

Strictly found on sheer waterfall faces, or vertical moss covered seep faces, and observed during Phase I of this study only in along Koaie Stream. The breeding habitat needs appear to be sheer vertical drops of > 6 ft; small seeps or cascades do not appear to be suitable. This damselfly remains common throughout Kauai, and exhibits a wide elevational range being found near sea level (Filbert and Englund 1995) to at least 4,000 ft elevation in this study. Frosty Hawaiian damselflies were not recovered in any trout stomachs probably due to their habitat preference for sheer waterfall faces.

Kauai Mountain Damselfly (*Megalagrion heterogamias*)

The most abundant damselfly in Koaie, Kawaikoi, and Kauaikinana Streams. This immatures of this species dwell strictly in the main stream channel, in fast water run,

riffle, and cascade habitats, and adults were mainly observed flying around these areas. The Kauai mountain damselfly is the most conspicuous and common stream-dwelling damselfly on Kauai (Polhemus and Asquith). Rainbow trout did not appear to favor this species as a forage item. Only one Kauai mountain damselfly was recovered from 485 identifiable prey items found in 26 rainbow trout stomachs. Rainbow trout were primarily found in slower water habitats of the streams we assessed, and this damselfly species inhabitats higher velocity riffle and cascade habitats.

Scarlet Kauai Damselfly (*Megalagrion vagabundum*)

This damselfly was the second most common damselfly observed in August 1997, and was abundant in all three streams assessed for Phase I of this study. Adult scarlet Kauai damselflies were commonly observed around seeps and mossy areas, and occasionally slow-water stream areas. None were found in rainbow trout stomachs, probably because seep habitats are favored by the immatures (Polhemus and Asquith 1996).

Slender Kauai Damselfly (*Megalagrion oresitrophum*)

This damselfly was abundant in Koaie, Kawaikoi, and Kauaikinana Streams. Slender Kauai damselflies were mainly found in slack sidewater pools, and stream side-channel habitats. This species was also found in calm side tributaries away from the main channel of the stream. None were found in rainbow trout stomachs, which is somewhat surprising since there appears to be an obvious overlap in habitat use between rainbow trout and immature scarlet Kauai damselflies.

MANAGEMENT RECOMMENDATIONS

PRELIMINARY ASSESSMENT OF RAINBOW TROUT IMPACTS TO NATIVE AQUATIC INSECT SPECIES

Hawaiian streams are naturally devoid of three major insect orders that dominate the fauna and trout diet of continental streams (Howarth and Polhemus 1991). Naturally missing from Hawaiian streams are the orders Plecoptera (stoneflies), Ephemeroptera (mayflies), and Trichoptera (caddisflies). Caddisflies were introduced into Hawaii as early as 1940 (Zimmerman 1957), and currently at least three species occur in nearly all perennially flowing streams. Native aquatic insect drift in Hawaiian streams is also much different than in continental systems such as in the mainland United States. In Hawaii, the greatest diversity and densities of native aquatic insects is found in the riffle and splash zones areas.

Species diversity in benthic samples collected in riffles was very low when compared to diversity in aerial-net collections conducted in the splash zones of riffles and cascades, and on the mossy faces of waterfalls and seeps. For example, only five aquatic insect species were collected during benthic sampling conducted in the three surveyed

streams (Table 5). This contrasts with 19 aquatic insect species caught only in the riffle/cascade splash zone habitats in the streams assessed for Phase I of this study (Tables 1-3). An additional six species of aquatic insects were netted on or near seeps and rheocrenes. The native species inhabiting these splash zones have very specific habitat requirements, and as a result the immatures tend not to drift when compared to continental streams. The aquatic insect fauna in the three streams we assessed consists mainly of native aquatic insects. Because most native aquatic insects inhabit splash-zone areas and are not prone to drift, it appears that rainbow trout are instead utilizing the available and abundant terrestrial insect drift.

Dragonflies are the closest relatives of damselflies, and the endemic *Anax strenuus* was extremely abundant in all three streams. *Anax strenuus* has wingspan of up to 142 mm (5.63 in), and is larger than any dragonfly in North America (Williams 1936). Another endemic dragonfly, *Nesogonia blackburni*, was common around its preferred seep habitat in Koaie Stream, but was not found in rainbow trout stomachs. It is not surprising that *A. strenuus* formed five percent of rainbow trout diet, as they and rainbow trout both prefer the same slow-water pool habitat. Rainbow trout predation did not appear to be reducing *A. strenuus* in either Koaie or Kauaikinana Streams as they were common enough to catch by hand during this study. The circumtropical genus *Anax* appears to be much more resistant to fish predation as compared to the endemic damselfly genus *Megalagrion*. Ongoing Bishop Museum studies in severely altered Oahu wetlands and streams have found immatures and adults of both the native lowland (*A. junius*) and upland forms of *Anax* co-exist with high densities of introduced fish. Interestingly, these same areas do not contain any native damselflies.

The lack of drifting aquatic species is reflected in trout diet, as only 39% of the diet during the summer months was aquatic in nature, and of that 42% were native aquatic species (Figures 4 and 5). The unusual, highly terrestrial feeding mode of rainbow trout in Kauai streams was also described by Needham and Welsh (1953). They found that rainbow trout diet in Kokee Stream consisted of 34.7% (by number) terrestrial millipedes (Needham and Welsh 1953), as compared to the 40% we found in Koaie and Kauaikinana Stream rainbow trout. The significant difference in rainbow trout diet analysis between this study and Needham and Welsh was their 33.8% (by number) of native *Megalagrion* damselflies in Kokee stream rainbow trout. Phase I of this study found only one *Megalagrion* damselfly out of 485 identifiable prey items. This underscores the importance of obtaining rainbow trout diet data from Kokee Stream, as well as increasing our currently small sample size of 26 stomachs. Additionally, it is well known that rainbow trout undergo seasonal shifts in diet (Filbert and Hawkins 1995, Jenkins et al. 1970, Chaston 1969), and a shift to other prey items such as native damselflies could potentially occur on a seasonal basis.

PRELIMINARY ASSESSMENT OF RAINBOW TROUT CATCH AND RELEASE FISHING WITH NO STOCKING IN KOKEE STATE PARK STREAMS

This study was funded with the primary objective of assessing whether rainbow trout could maintain catch and release populations for recreational fishing in Kokee State

Park streams without annual stocking. Phase I of this study has enabled us to come to preliminary conclusions for the Koaie, Kawaikoi, and Kauaikinana Streams. Some basic needs of a self-sustaining fish population are proper environmental conditions such as water temperature and chemistry, an adequate forage base, and suitable spawning and juvenile rearing sites. Kawaikoi Stream does not appear to meet the conditions for a self-sustaining trout fishery, and would likely need to be stocked at least every two to three years. However, the forage base for rainbow trout in Kawaikoi Stream appears to be more than adequate for a stocked fishery. There is no lack of forage because rainbow trout are mainly drift feeders (Jenkins et al. 1970), and Kawaikoi Stream flows through a near pristine native ‘ohia dominated forest containing high densities of terrestrial insects and millipedes. This would also apply to both Kauaikinana and Koaie Streams. Kawaikoi Stream also had high densities ($8.2 \pm 2.6/ft^2$) of aquatic insect foods such as caddisflies that accounted for 15.7% of rainbow trout diet. Kauaikinana and Koaie Streams thus have a more than adequate forage base for rainbow trout survival.

Portions of Koaie Stream, and Kauaikinana Stream above the Mohihi Ditch currently have the proper conditions allowing for a self-sustaining trout fishery. Natural reproduction was evident in both of these streams, with numerous 2-3 in fish observed in Kauaikinana Stream, and 5-10 in rainbow trout observed and collected in Koaie Stream at Station 6. Assuming that catch and release regulations would be enforced, our preliminary conclusion is that Kauaikinana Stream, and Koaie Stream at Station 6 would be suitable for year-round rainbow trout catch and release fishing without annual stocking.

Due to reasons speculated upon in the RESULTS AND DISCUSSION sections, rainbow trout do not appear to be reproducing in the accessible area of Koaie Stream. Unfortunately, the portion of Koaie Stream that maintains a naturally reproducing trout population may be accessible only to anglers with mountain climbing equipment. Access to this area is dangerous, and it should not be considered accessible to the average angler. Station 6, the spring fed area with natural rainbow trout reproduction, is located downstream of the large waterfalls at the accessible Koaie Camp next to the USGS gaging station.

Koaie Stream still had an excellent trout fishery in 1997 around Koaie Camp, even though this area was last stocked in 1992. However, a complete lack of any small fish either captured or observed indicates that this rainbow trout fishery will not be self-sustaining. Either all the rainbow trout will soon be caught, which is unlikely due to the remoteness of Koaie Stream, or more likely the non-reproducing population will become senescent. Thus, if it is desired to maintain a long-term trout fishery in the accessible areas of Koaie Stream, stocking would be required every 2-3 years at Koaie Camp.

One of the major limitations of this study is that only three streams were assessed during Phase I sampling conducted in August 1997. Further sampling needs to be conducted on other Kokee State Park streams during Phase 2 of this study. Other streams need to be assessed to determine their potential status for year catch and

release rainbow trout fishing without annual stocking. Recreationally important streams such as Waialae, Kokee, and Waiakoali need to be assessed for both trout diet and trout reproduction. Phase II of the study will also allow us to assess current rainbow trout diet in Kokee Stream as compared to that found in 1949 (Needham and Welsh 1953). During the Phase II assessment, repeated sampling will also be conducted to compare seasonal shifts in diet and reproductive success of rainbow trout at Koaie and Kauaikinana Streams.

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Table 1. Distribution of native and introduced aquatic biota captured during aerial net sweeps or general collection in Koaie Stream, Kauai during August 1997 (See Figure 1 for sampling stations).

Taxon	Elevation (ft) 3600-3920 ft	Threatened, Endangered or Candidate Status	Geographic Status
Amphibians			
Wrinkled frog (*Rana rugosa*)	X	None	Introduced
Fish			
Rainbow trout (*Onchorhynchus mykiss*)	X	None	Introduced
Insects			
Damselflies and dragonflies (Odonata)			
Dragonfly (*Anax strenuus*)	X	None	Endemic
Dragonfly (*Nesogonia blackburni*)	X	None	Endemic
Slender Kauai Damselfly (*Megalagrion oresitrophum*)	X	None	Kauai Endemic
Kauai Mountain Damselfly (*Megalagrion heterogamias*)	X	None	Kauai Endemic
Frosty Hawaiian Damselfly (*Megalagrion eudytum*)	X	None	Kauai Endemic
Scarlet Kauai Damselfly (*Megalagrion vagabundum*)	X	None	Kauai Endemic
Fragile Forktail (*Ischnura posita*)	X	None	Introduced
True flies (Diptera)			
Canacidae			
Procanace bifurcata	X	None	Endemic
Procanace nigroviridis	X	None	Endemic
Dolichopodidae			
Genus and species undet.	X	None	?
Campsicnemus nigricollis	X	None	Endemic
Eurynogaster mediocris	X	None	Endemic
E. minor	X	None	Endemic
Paraliancalus metallicus	X	None	Endemic
Sigmatineurum napali	X	None	Endemic
Ephydridae			
Scatella hawaiiensis	X	None	Endemic
S. kauaiensis	X	None	Kauai Endemic
True bugs (Heteroptera)			
Saldula exulans	X	None	Endemic
Aquatic beetles (Coleoptera)			
Rhantus pacificus	X	None	Endemic
Caddisflies (Trichoptera)			
Cheumatopsyche pettiti	X	None	Introduced

Table 2. Distribution of native and introduced aquatic biota captured during aerial net sweeps or general collection in Kawaikoi Stream, Kauai during August 1997 (See Figure 1 for sampling stations).

	Elevation (ft)		
Taxon	**3420-3540 ft**	**Threatened, Endangered or Candidate Status**	**Geographic Status**
Amphibians			
Wrinkled frog (*Rana rugosa*)	X	None	Introduced
Fish			
Dojo loach (*Misgurnus anguillicaudatus*)	X	None	Introduced
Green swordtail (*Xiphophorus helleri*)	below 3420 ft	None	Introduced
Crustaceans			
Crayfish (*Procambarus clarki*)	X	None	Introduced
Insects			
Damselflies and dragonflies (Odonata)			
Dragonfly (*Anax strenuus*)	X	None	Endemic
Slender Kauai Damselfly (*Megalagrion oresitrophum*)	X	None	Kauai Endemic
Kauai Mountain Damselfly (*Megalagrion heterogamias*)	X	None	Kauai Endemic
Scarlet Kauai Damselfly (*Megalagrion vagabundum*)	X	None	Kauai Endemic
True flies (Diptera)			
Dolichopodidae			
Dolichopus exsul	X	None	Introduced
Sigmatineurum napili	X	None	Endemic
Syntormon flexibile	X	None	Introduced
Ephydridae			
Ochthera circularis	X	None	Introduced
Scatella hawaiiensis	X	None	Endemic
S. kauaiensis	X	None	Kauai Endemic
True bugs (Heteroptera)			
Saldula exulans	X	None	Endemic
Caddisflies (Trichoptera)			
Cheumatopsyche pettiti	X	None	Introduced

Table 3. Distribution of native and introduced aquatic biota captured during aerial net sweeps or general collection in Kauaikinana Stream, Kauai during August 1997 (See Figure 1 for sampling stations).

	Elevation (ft)		
Taxon	**3400-3540 ft**	**Threatened, Endangered or Candidate Status**	**Geographic Status**
Amphibians			
Wrinkled frog (*Rana rugosa*)	X	None	Introduced
Fish			
Dojo loach (*Misgurnus anguillicaudatus*)	X	None	Introduced
Rainbow trout (*Onchorhynchus mykiss*)	X	None	Introduced
Crustaceans			
Crayfish (*Procambarus clarki*)	X	None	Introduced
Insects			
Damselflies and dragonflies (Odonata)			
Dragonfly (*Anax strenuus*)	X	None	Endemic
Slender Kauai Damselfly (*Megalagrion oresitrophum*)	X	None	Kauai Endemic
Kauai Mountain Damselfly (*Megalagrion heterogamias*)	X	None	Kauai Endemic
Scarlet Kauai Damselfly (*Megalagrion vagabundum*)	X	None	Kauai Endemic
True flies (Diptera)			
Canacidae: *Procanace* sp. undet.	X	None	Endemic
Dolichopodidae			
Dolichopus exsul	X	None	Introduced
Eurynogaster minor	X	None	Endemic
Ephydridae			
Scatella hawaiiensis	X	None	Endemic
S. kauaiensis	X	None	Kauai Endemic
True bugs (Heteroptera)			
Saldula exulans	X	None	Endemic
S. procellaris	X	None	Endemic
Aquatic moths (Lepidoptera)			
Hyposmocoma sp. undet.	X	None	Endemic
Caddisflies (Trichoptera)	X	None	
Cheumatopsyche pettiti	X	None	Introduced

Table 4. Insect species per aerial-net sweeps of riffles at Koaie, Kawaikoi, and Kauaikinana Streams, Kauai during August 1997.

Stream (n = total sweeps)	Native species / net sweep	Introduced species / net sweep	Total species / net sweep
Koaie (n = 90)	0.17	0	0.17
Kawaikoi (n = 90)	0.08	0.03	0.11
Kauaikinana (n = 110)	0.11	0.02	0.13

Table 5. Mean numbers (± 1 standard error) of aquatic macrofauna (per/ft^2) found in Surber samples collected in Koaie, Kawaikoi, and Kauaikinana Streams in August 1997.

Species	Koaie	Kawaikoi	Kauaikinana
C. pettiti	6.8 ± 1.1	8.2 ± 2.6	12 ± 3.4
Chironomidae	0.8 ± 0.3	1.1 ± 0.6	0.8 ± 0.3
Kauai Mountain Damselfly (*M. heterogamias*)	0.1 ± 0.1	0.2 ± 0.2	0
Oligochaeta	0.4 ± 0.3	0.8 ± 0.4	6.5 ± 1.9
Hirudinea	0.2 ± 0.1	0.2 ± 0.2	0
Tupulidae (*Limonia* sp.)	0.1 ± 0.1	0	0
Rhantus pacificum	0.1 ± 0.1	0	0

Table 6. Observation rate (per hour by D. Preston and R. Englund) of the Kauai Mountain damselfly (*M. heterogamias*), the dominant native damselfly, while walking in Koaie, Kawaikoi, and Kauaikinana Streams in August 1997. All observations conducted in sunny, calm weather, see text for explanation.

Species	Koaie (3820 ft)	Kawaikoi (3500 ft)	Kauaikinana (3450 ft)
Kauai Mountain Damselfly (*M. heterogamias*)	9.5	24	60
Scarlet Kauai Damselfly (*M. vagabundum*)	not counted	6	not counted

Table 7. Mean number (± 1 standard error) of vertebrate and invertebrate species per rainbow trout stomach at Kauaikinana (n = 8) and Koaie (n = 18) Stream, Kauai during August 1997.

Taxon	Terrestrial or Aquatic Species	Mean #/gut (± 1 s. e.)	Total Numbers found in 26 guts	% Total Diet	Geographic Status
Amphibians					
Wrinkled frog (*Rana rugosa*)	Aquatic	0.04 ± 0.04	1	< 1	Introduced
Crustaceans					
'Opae kala'ole (*Atyoida bisulcata*)[1]	Aquatic	0.04 ± 0.04	1	< 1	Endemic
Sow Bugs (Isopoda)					
Porcellio sp.	Terrestrial	0.3 ± 0.1	7	1.5	Introduced
Scuds (Amphipoda)					
Talitroides topitotum	Terrestrial	0.7 ± 0.6	18	3.7	Introduced
Mollusks					
Lymnaeidae sp.	Aquatic	1.0 ± 0.3	25	5.2	Possibly Endemic?[2]
Garlic snail (*Oxychilus alliarius*)	Terrestrial	0.3 ± 0.2	7	1.5	Introduced
Aquatic Worms					
Oligochaeta	Aquatic	0.3 ± 0.2	8	1.7	?
Aquatic Leeches					
Hirudinea	Aquatic	1.1 ± 0.6	29	6.0	?
Millipedes (Diplopoda)					
Cambalidae: *Nannolene* sp.	Terrestrial	0.7± 0.4	17	3.5	Endemic?
Oxidus gracilis	Terrestrial	6.9 ± 2.3	178	36.9	Introduced
Mites (Oribatida)					
Phthiracaridae: Phthiracarus sp.	Terrestrial	0.04 ± 0.04	1	< 1	?
Insects					
Damselflies and dragonflies (Odonata)					
Dragonfly (*Anax strenuus*)	Aquatic	0.9 ± 0.2	24	5.0	Endemic
Kauai Mountain Damselfly (*Megalagrion heterogamias*)	Aquatic	0.04 ± 0.04	1	< 1	Kauai Endemic
True flies (Diptera)					
Chironomidae					
Telmatogeton sp.	Aquatic	0.08 ± 0.08	2	< 1	Endemic
Cricotopus bicinctus	Aquatic	0.2 ± 0.2	6	1.2	Introduced
Dolichopodidae	Aquatic	0.04 ± 0.04	1	< 1	?
Ephydridae					
Scatella kauaiensis	Aquatic	0.04 ± 0.04	1	< 1	Kauai Endemic
Muscidae	Terrestrial	0.08 ± 0.05	2	< 1	?
Tipulidae	Aquatic	0.08 ± 0.05	2	< 1	?
Cockroaches (Blattodea)					
Periplaneta sp.	Terrestrial	0.04 ± 0.04	1	< 1	Introduced

[1]Captured in trout stomach below large falls downstream of USGS gaging station at Station 6.

[2] **See text for explanation of mollusk systematics.**

Table 7 (continued). Mean number (± 1 standard error) of vertebrate and invertebrate species per rainbow trout stomach at Kauaikinana (n = 8) and Koaie (n = 18) Stream, Kauai during August 1997.

Taxon	Terrestrial or Aquatic Species	Mean #/gut (± 1 s. e.)	Total Numbers found in 26 guts	% Total Diet	Geographic Status
Beetles (Coleoptera)					
Coleoptera spp. (unidentified)	Terrestrial	0.08 ± 0.05	2	< 1	?
Alleculidae: *Pseudocistela kauaiensis*	Terrestrial	0.04 ± 0.04	1	< 1	Endemic[3]
Elateridae: *Eopenthes muticus*	Terrestrial	0.04 ± 0.04	1	< 1	Kauai Endemic[3]
Elateridae	Terrestrial	0.08 ± 0.05	2	< 1	Endemic
Hydrophilidae	Aquatic	0.08 ± 0.08	2	< 1	?
Nitidulidae: *Gonioryctus kauaiensis*	Terrestrial	0.04 ± 0.04	1	< 1	Kauai Endemic
Dytiscidae: *Rhantus pacificus*	Aquatic	0.1 ± 0.1	3	< 1	Endemic
Staphylinidae	Terrestrial	0.04 ± 0.04	1	< 1	?
True bugs (Heteroptera)					
Heteroptera unidentified	Terrestrial	0.08 ± 0.08	2	< 1	?
Lygaeidae	Terrestrial	0.04 ± 0.04	1	< 1	Introduced
Cydnidae: *Geotomus pygmaeus*	Terrestrial	0.04 ± 0.04	1	< 1	Introduced
Nabidae: *Nabis sharpianus*	Terrestrial	0.04 ± 0.04	1	< 1	Endemic
Reduviidae: *Haematoloecha rubescens*	Terrestrial	0.04 ± 0.04	1	< 1	Introduced
Veliidae: *Microvelia vagans*	Aquatic	0.08 ± 0.08	2	< 1	Endemic
Pentatomidae: *Oechalia* sp.	Terrestrial	0.04 ± 0.04	1	< 1	Endemic
Saldidae: *Saldula exulans*	Aquatic	0.04 ± 0.04	1	< 1	Endemic
Leafhoppers (Homoptera)					
Homoptera unidentified	Terrestrial	0.04 ± 0.04	1	< 1	?
Cixiidae: *Oliarius* sp.	Terrestrial	0.3 ± 0.1	8	1.7	Endemic
Crickets (Orthoptera)					
Gryllidae	Terrestrial	0.04 ± 0.04	1	< 1	?
Tettigoniidae	Terrestrial	0.04 ± 0.04	1	< 1	Endemic
Bark Lice (Psocoptera)					
Psocidae sp.	Terrestrial	0.04 ± 0.04	1	< 1	Endemic
Caddisflies (Trichoptera)					
Cheumatopsyche pettiti	Aquatic	2.9 ± 1.2	76	15.7	Introduced
Oxyethira maya	Aquatic	0.04 ± 0.04	1	< 1	Introduced
Moths (Lepidoptera)					

Lepidoptera unidentified	Terrestrial	0.5 ± 0.2	12	2.5	?
Crambidae	Terrestrial	0.2 ± 0.2	6	1.2	Endemic
Cosmopterigidae: *Hyposmocoma* sp.	Aquatic	0.04 ± 0.04	1	< 1	Endemic
Geometridae: *Scotorythra* sp.	Terrestrial	0.08 ± 0.05	2	< 1	Endemic
Bees (Apidae)					
European honeybee (*Apis mellifera*)	Terrestrial	0.6 ± 0.3	15	3.1	Introduced
Spiders (Arachnida)					
Tetragnathidae: *Tetragnatha* sp.	Terrestrial	0.2 ± 0.1	5	1.0	Endemic

[3]See text for explanation of these rare beetles.

Table 8. Water quality data for Koaie, Kawaikoi, and Kauaikinana Streams, Kauai during August 1997 (See Figure 1 for sampling stations).

Parameter	Koaie	Kawaikoi	Kauaikinana
Temperature (°C)	21[A]/17.5[B]	22.5	21.7[1]
pH	6.8[A]/7.3[B]	7.4	7.9
Turbidity (NTU)	Not Sampled	0.6	1.4
Conductivity (µs)	Not Sampled	25.8	30.8
Dissolved Oxygen (mg/l)	Not Sampled	7.4	7.4

[A]Measured at USGS gaging station (3800 ft)
[B]Measured below large waterfalls downstream of USGS gaging station (3600 ft)
[1]Measured at large diversion pool and may not reflect true value

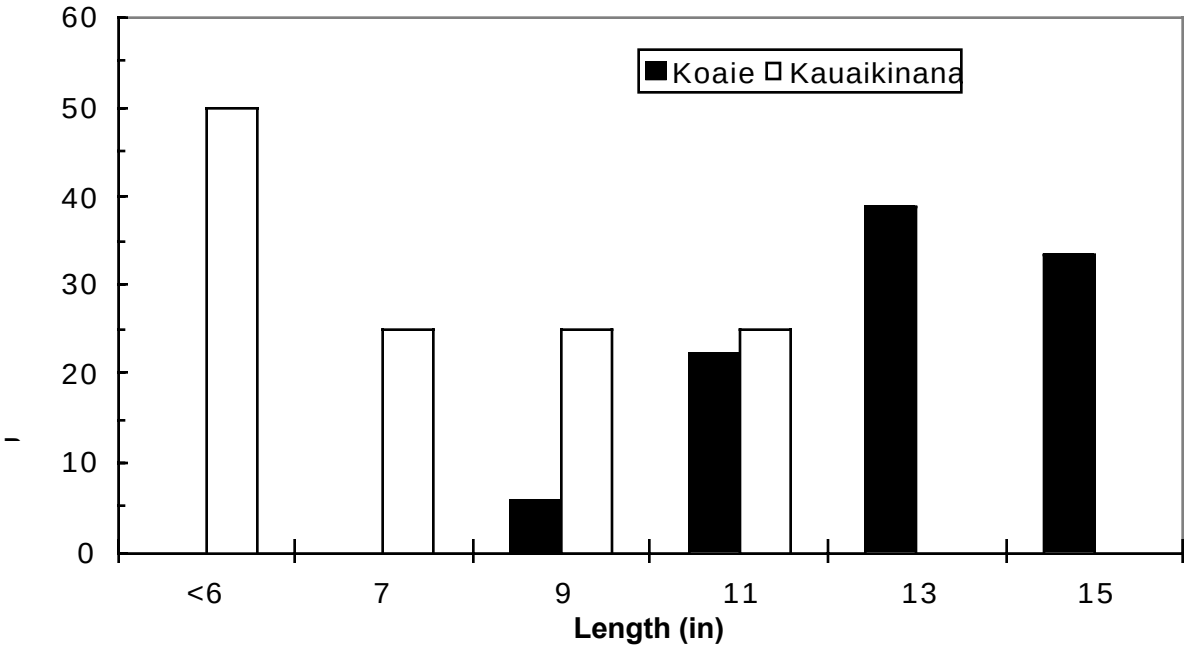

Figure 1. Size distributions of rainbow trout in Koaie and Kauaikinana Streams.

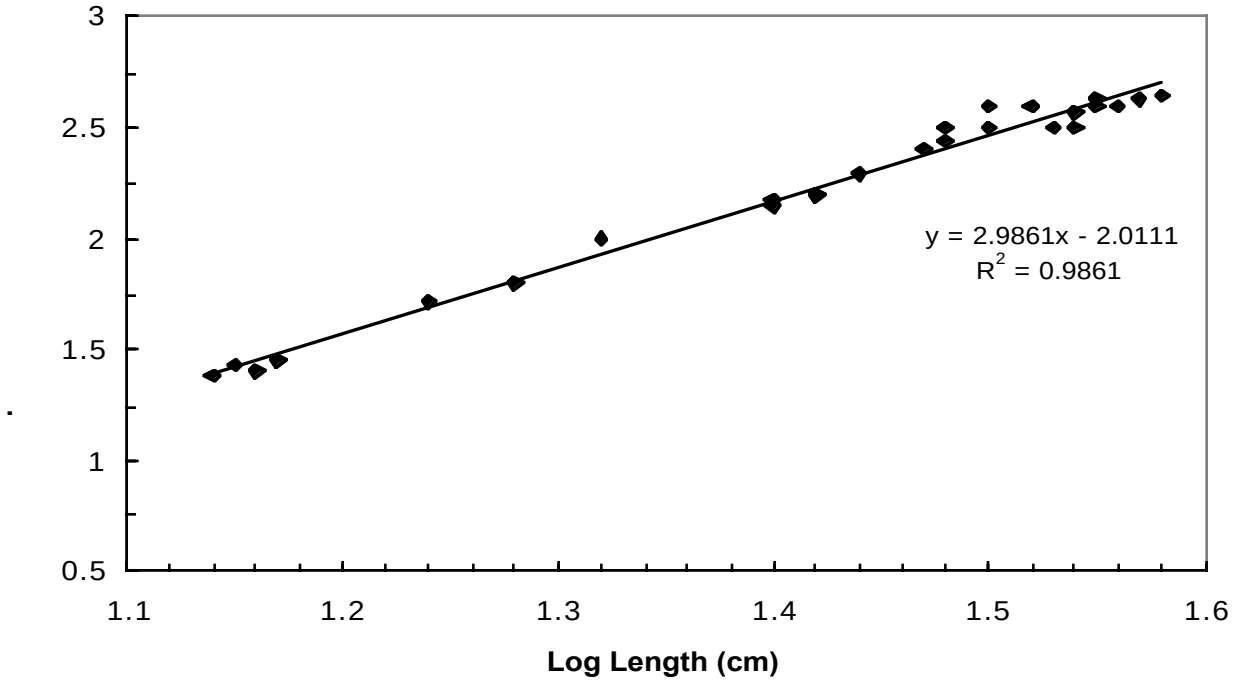

Figure 2. Weight-length regression for rainbow trout collected in Kauaikinana and Koaie Streams for the August, 1997 diet study.

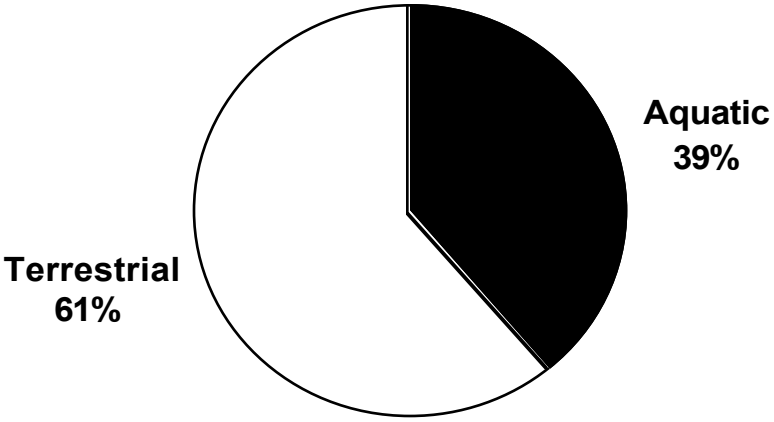

Figure 3. Proportion of terrestrial and aquatic prey items in rainbow trout stomachs in Koaie and Kauaikinana Streams (n = 485 identifiable prey items)

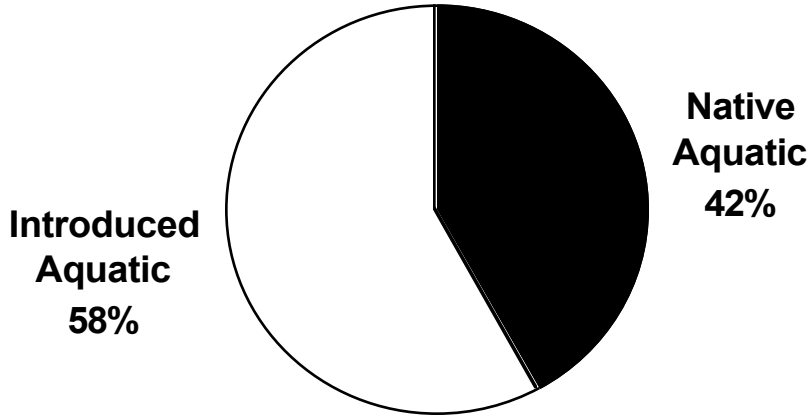

Figure 4. Proportion of introduced and native aquatic prey items in rainbow trout stomachs in Koaie and Kauaikinana Streams (n = 145 identifiable aquatic prey items).

Figure 5. Sampling stations in Kokee State Park streams, August 1997.