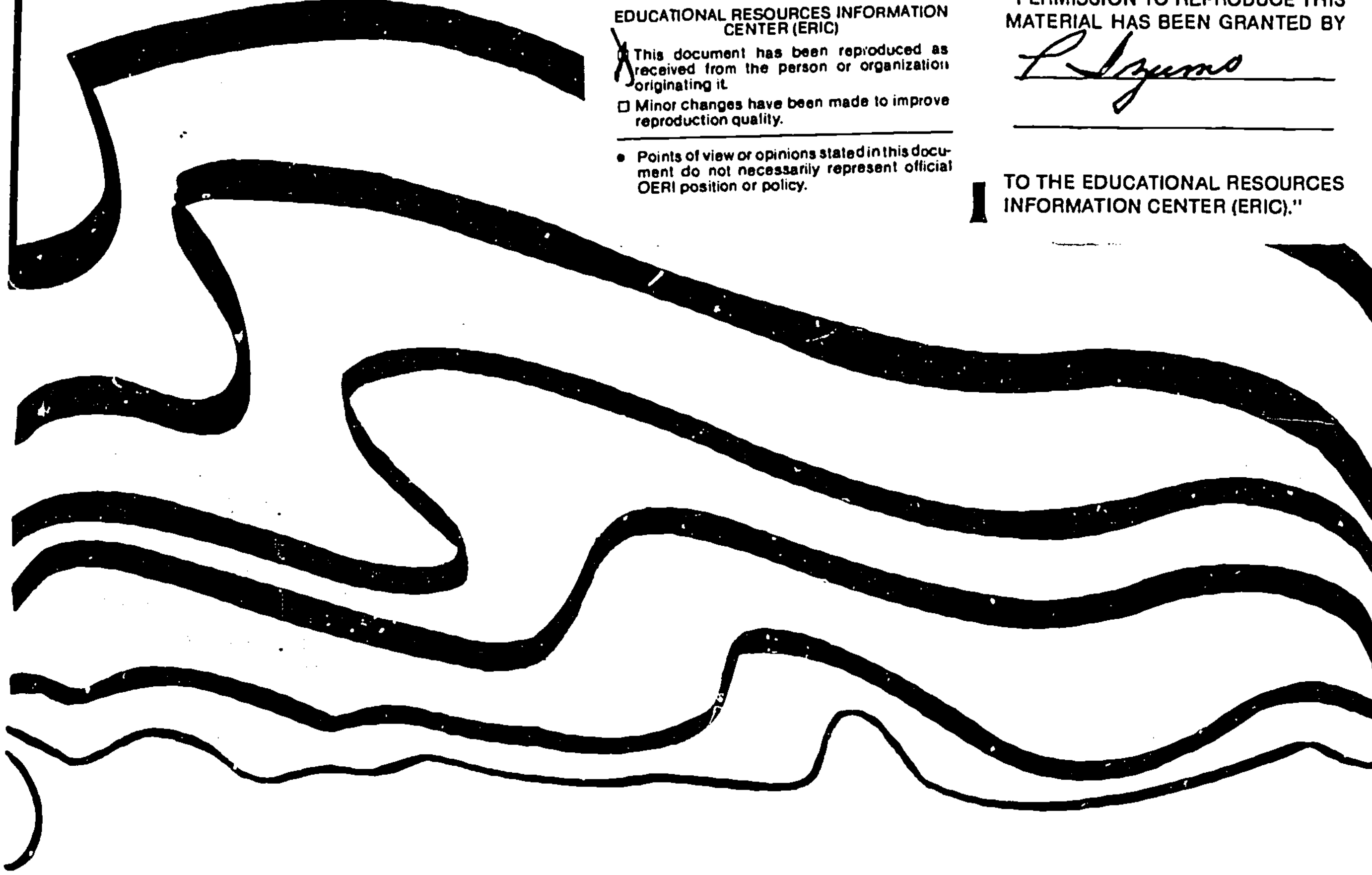
DOCUMENT RESUME

ED 275 550 SE 047 533

AUTHOR	Hawkins, John, Ed.; Murakami, Colleen, Ed.
TITLE	Kaua'i: Streams and Estuaries.
INSTITUTION	Hawaii State Dept. of Education, Honolulu. Office of Instructional Services.
PUB DATE	Jun 86
NOTE	78p.; Drawings may not reproduce well.
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	Ecology; *Elementary School Science; Elementary Secondary Education; Environmental Education; *Estuaries; Experiential Learning; Field Trips; Intermediate Grades; *Marine Biology; Natural Resources; Outdoor Activities; *Science Activities; Science Education; Science Instruction; *Secondary School Science; *Water Resources
IDENTIFIERS	*Hawaii

ABSTRACT

Designed to help teachers develop students' awareness and understanding of some of Hawaii's endangered aquatic resources, this module contains activities and instructional suggestions for use with intermediate as well as high school students. The module is divided into two sections which explore the streams and estuaries of Kauai. Activities in each section contain a learning objective, material list, procedures, and in most cases discussion questions. Many of the activities provide opportunities for students and teachers to interact directly with the environment. Although the module deals with specific sites on Kauai, the information and activities presented are applicable to comparable sites on any of the other islands. Appendices contain several instructional directives among which are: (1) identification guide to exotic stream fuana; (2) identification and biology of native stream animals; (3) plankton net construction; (4) identification guide to life in Hawaiian estuaries; (5) tables for conversion of specific gravity to salinity and (6) suggested additional activities for estuary field trips. (ML)



KAUA'I: STREAMS AND ESTUARIES

Office of Instructional Services/General Education Branch • Department of Education • State of Hawaii • RS 86-9905 (Rev. of RS 84-6211)
June 1986

FOREWORD

Hawai'i has a number of environmental resources that make it attractive to the local population as well as to visitors to the State: a benign climate, magnificent scenery, open spaces, unusual flora and fauna, and miles of beautiful mountains, valleys, and shorelines. These assets, however, are both limited and fragile requiring protection and proper management. Many of Hawai'i's unique environmental resources have already suffered considerable damage from overuse and mismanagement. Imported plants and animals have had considerable adverse effects on native plants and animals causing Hawai'i to have more endangered endemic species than any other area in the world. Soil stability has been affected by the introduction of such non-native animals as deer, goats, sheep, and cattle. The environmental quality of streams, estuaries, and beach and ocean areas has declined greatly in recent years due to encroaching urbanization, increased population pressures, and expanding technology in industry and agriculture. Unless immediate steps are taken to relieve the pressure on environmental resources and repair the existing damage, Hawai'i will no longer retain its beautiful and unique ecosystems.

Kauai: Streams and Estuaries has been designed to help teachers develop students' awareness and understanding of some of Hawai'i's endangered aquatic resources. While not all of Hawai'i's aquatic resources are covered in this module, those that have been chosen represent major environmental concerns of individuals, private environmentally-related groups, and governmental agencies.

Francis M. Hatanaka
Superintendent
Department of Education

HOW TO USE MODULE

The information contained in this module is intended to focus on Hawai'i's endangered aquatic resources, and the impact that humans have had on these fragile resources. Although the materials were primarily designed for intermediate level students, many of the activities have been used successfully with upper elementary and high school students in conjunction with studies on the aquatic environment.

The module is divided into two sections: (1) Kaua'i: Streams and (2) Kaua'i: Estuaries. Each of the two sections contains topics related to some aspect of the aquatic environment. A number of the topics have accompanying activities that provide the opportunity for students and teachers to interact directly with the environment. The approach used in the module reflects the concern with the interrelatedness of humans and their environment, and the approach to give teachers a tool to help their students come to an understanding and appreciation of this interrelatedness.

Although the module deals with specific sites on Kaua'i, the information and activities presented are applicable to comparable sites on any of the other islands.

ACKNOWLEDGMENTS

The materials for the instructional units on Kaua'i's streams and estuaries have been developed by Ann Fielding in conjuction with the staff of the Waikiki Aquarium and the Department of Education. We would especially like to thank the following people for their invaluable help.

Dr. Leighton Taylor, Director
Waikiki Aquarium

Ms. Mary Morioka
Waikiki Aquarium

Ms. Christy Naftel
Waikiki Aquarium

Ms. Barbara Moniz
Waikiki Aquarium

Mr. Les Matsuura
Waikiki Aquarium

Ms. Linda Levins
Waikiki Aquarium

Dr. John Macioleck
U.S. Fish and Wildlife Service

Dr. John Ford
U.S. Fish and Wildlife Service

Dr. Bob Kinzie
University of Hawaii

Dr. Carol Hopper
Waikiki Aquarium

Dr. Dave Seefeldt
Maui Divers

Ms. Sharman Miller
Sea Grant Marine Advisory Program

Dr. Louis Herman
University of Hawaii

Dr. Amadeo Timbol
University of Hawaii

Dr. Ed Shallenberger
U.S. Fish and Wildlife Service

Mr. Paul Bartram
AECOS, Inc.

Mr. Bill Madden
AECOS, Inc.

Mr. Don White
Greenpeace

Mr. Jim Luckey
Lahaina Restoration Foundation

Mr. Paul Wood
Seabury Hall, Maui

Ms. Debbie Hall
Seabury Hall, Maui

Mr. Gordon Nishida
Bishop Museum

Mr. Jim Hudnall
Maui Whale Research Institute

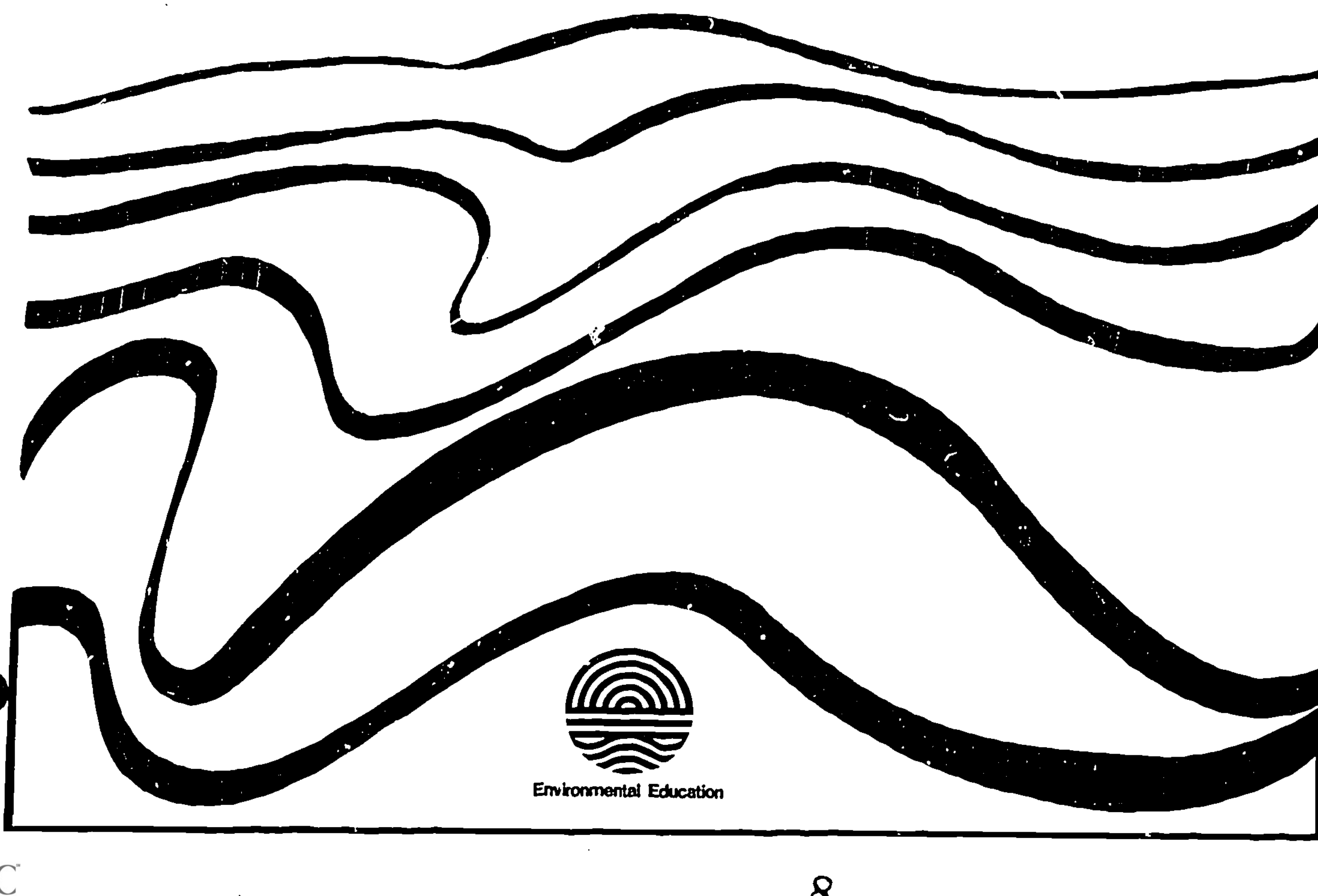
Project Editors:

John Hawkins
State Environmental Education Specialist, Department of Education

Colleen Murakami
Elementary Marine Education Coordinator, Department of Education

TABLE OF CONTENTS

KAUA'I: Streams



Introduction

Hawai'i's streams provide an opportunity to study a fascinating, yet often neglected, environment. Hawai'i has at least 366 perennial streams in the five largest islands. Streams support several species of animals found only in Hawai'i, including shrimp, fish and snails. In the past, these animals provided a valuable food resource.

Other human uses of stream resources include the diversion of water for irrigation and domestic water supply. More recently, streams have been channelized in areas where floods threaten residences or filled in for development.

This section explores the types of streams found in Hawai'i, stream ecology, and human impact on stream environment.

TOPIC I: TYPES OF STREAMS

(Excerpted with permission from "Hawai'i Coastal Zone News," February 1979.)

While island aquatic systems are tiny compared to marine ecosystems, they have more definite boundaries and are more isolated from influx of new organisms. Recovery after a biological catastrophe is more difficult in an insular water body than in the ocean.

Island waters generally may be divided into systems of running waters and systems of standing waters.

Freshwater arrives in Hawai'i as water vapor in the atmosphere, carried largely by tradewinds that travel long distances over the ocean. Hawai'i's prevailing tradewinds come from the northeast, so the windward sides of all islands receive the most rain. Leeward sides are in rain "shadows," so they only receive rainfall when cyclonic storms interrupt the normal weather pattern.

The most conspicuous of these running waters are streams which collect runoff from surrounding higher land, ultimately headed for the sea. Water that travels downward through the soil may reappear on the surface through springs.

These natural channels have been used as conduits to remove wastewater rapidly as irrigation water for agricultural land and as drinking water for the general population.

Three major types of running waters in Hawai'i may be considered coastal ecosystems: 1) perennial streams, 2) intermittent streams, and 3) springs or seeps.

PERENNIAL STREAMS

Perennial streams--well defined channels where freshwater flows year-round--are the most important of the three forms of running waters. They are important for domestic and agricultural water supply, wastewater disposal, commercial fisheries, recreational swimming, recreational and subsistence fishing, scientific research, outdoor education, nature appreciation and photography.

The continuous base or normal flow of these streams is a precious natural resource needed to maintain both the natural function of the stream ecosystem and the native stream species that are traditional food items marketed locally. Perennial streams are the principal habitat of these native stream animals, which are abundant in more isolated streams but scarce or absent from streams where invasions of foreign species, habitat changes or over-fishing have been prevalent.

Such native species include the gobies, o'opu nakea (Awaous stamineus), o'opu 'alamo'o (Lentipes concolor), the freshwater shellfish hihiwai (Neritanina granosa), and the shrimps opae kala'ole (Atya bisulcata) and opae 'oeha'a (Macrobrachium grandimanus).

'O'opu 'alamo'o (lentipes concolor) is listed by the American Fisheries Society and the International Union for the Conservation of Nature as a threatened species.

Perennial streams are the largest and most widely distributed type of freshwater ecosystem in Hawai'i, with more than 360 of them on the five largest islands, mostly on wet windward slopes. Most perennial streams flow continuously from headwaters to the ocean. Some smaller streams, though, are naturally disrupted, and only during wet seasons or after heavy rains do such streams discharge into the ocean. Many naturally continuous streams are artificially interrupted by total diversion of normal flow.

INTERMITTENT STREAMS

Intermittent streams are gulches where freshwater flows seasonally or after heavy rains. Water may reach the sea several times a year, gradually slackening to a few pools of standing water before drying up completely. Intermittent streams are generally found at middle elevations on the dry leeward slopes of all the volcanic islands and on the porous windward slopes of geologically recent lava flows.

Although they lack a year-round fauna, a distinct group of animals appears in intermittent streams where water persists a few weeks (usually as flow diminishes).

The animals most characteristic of intermittent streams are small, bivalved crustaceans called ostracods. Segmented worms (Oligochaetes), freshwater ancylid limpets, water beetles, and backswimmers also inhabit these areas.

Infrequently, the mountain 'opae kala'ole (*Atya bisulcata*) may be found in standing waters of the upper reaches of such intermittent streams as Makaha Stream on O'ahu.

SPRINGS AND SEEPS

Some falling rain goes underground and emerges much later as a spring gushing through cracks in rocks or a seep oozing through the surface. Wherever the composition of the islands' crust is such that the aquafier and its underlying water-bearing layer of impervious rock come to the surface, a spring is produced.

Springs offer cool water, shade, and the shelter of moss-covered banks to many small animals, predominantly insect larvae and endemic snails.

These small ecosystems are numerous and widespread. There are at least hundreds and probably thousands of individual examples of springs and seeps on virtually all banks of deeply cut stream valleys, usually below 1000 meters in elevation.

Activity 1-1

INTRODUCTION TO STREAMS AND SEEPS

Objective: To identify familiar streams and seeps.

Procedure:

1. Prepare a chart listing perennial or intermittent streams or areas where freshwater seeps out of the ground.

2. Describe any vegetation, animals, or insects that may inhabit these areas.

TOPIC II: WATERSHEDS

A watershed is all the area draining into a stream including the area between the two ridges on either side of the stream.

Vegetation in the watershed is very important, as it slows down the flow of water and allows it to sink into the earth. Some of the water, of course, goes into the streams, but much of it sinks into the ground to become part of the underground water supply which is so important to the islands. Besides slowing the flow of water, vegetation also prevents erosion. Plants help collect both water and dirt, and also provide oxygen for the atmosphere. Refer to Figure 1.

Activity 2-1

TOPOGRAPHIC MAPS

Objective: To learn how to use a topographic map.

Background Information: Appendix A is a portion of a topographic map showing the Limahuli Stream area of Kaua'i. Topographic maps can be ordered from the United States Geological Survey Office, Denver, Colorado. Topographic maps are useful because they show the elevation and ground features of an area through the use of contour lines. Each contour line indicates a specific elevation above sea level.

Procedure:

1. Locate Limahuli Stream on the map, and find the road crossing the stream. Determine the elevation of this point.

2. Trace the stream toward the mountain to its origin. Determine the elevation at this point.

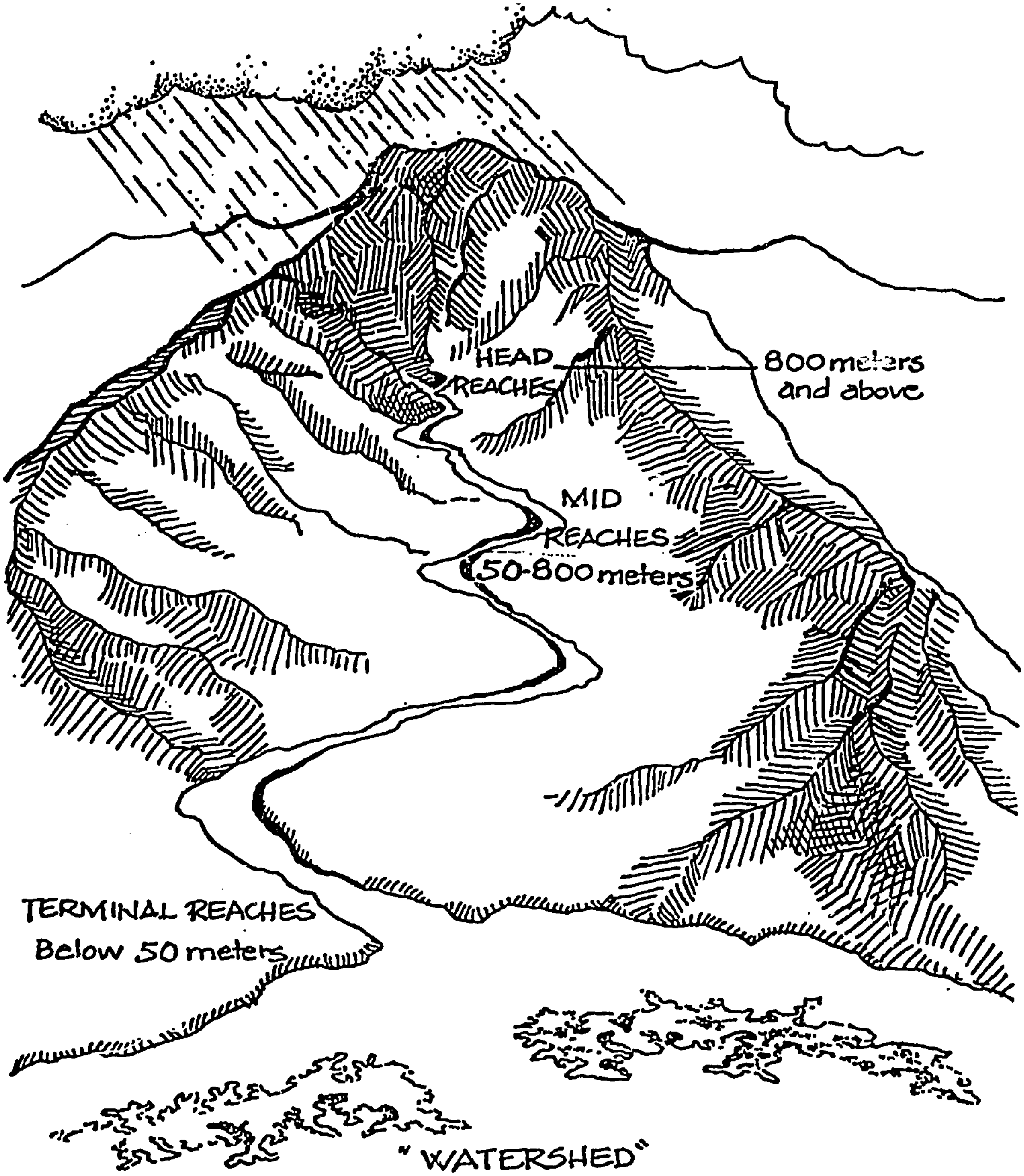
3. Determine the elevations of the ridges on either side of Limahuli Valley.

Discussion Questions:

1. What is the average slope of Limahuli Stream from the falls to where it crosses the road?

2. Based on the map symbols, determine if Limahuli is a perennial or intermittent stream.

3. Based on the map data, what effect does the Stream have on the offshore coral reef?



"WATERSHED"
All the area draining into a stream including the area between the two ridges on either side of the stream.

PROFILE OF A STREAM

HEAD REACHES: 2625 feet (800 meters) and above.

MID REACHES: 164 feet to 2625 feet (50-800 meters).

TERMINAL REACHES: Below 155 feet (50 meters).

Figure 1

Activity 2-2

WATERSHEDS

Objective: To determine the components of a watershed area.

Materials:

Topographic map of Limahuli Stream
Figure 1, Profile of a Stream

Procedure:

1. Use the topographic map and Figure 1 to determine the probable sources of water for the stream.

2. Draw a line on the map encircling the Limahuli watershed area, and label the appropriate sections.

Discussion Questions:

1. What would be the impact of removing trees and shrubs from the watershed area? Why do you think most watershed areas are kapu?

2. Discuss the sources of water used for human consumption and water used for agricultural purposes.

Additional Activity:

View the Science in Hawai'i educational television program, "Hawai'i's Water Resources."

TOPIC III: HAWAI'I'S NATIVE STREAM FAUNA

Hawaiian streams contain only a small number of animal species, yet most of these are endemic, i.e., found only in Hawai'i. Bearing in mind that Hawai'i is thousands of miles from other land masses, how did these animals get here and why aren't they found in other places? (These are good questions for a class discussion.) Many freshwater animals found on high islands of volcanic origin spend part of their life cycle in the ocean. During this time they are often carried to other islands by ocean currents. Having arrived, they can then move up the streams to live. The original ancestors of these stream species were probably near shore or intertidal marine animals that slowly began to colonize estuaries and then streams, taking advantage of an available "niche." Since Hawai'i is so isolated from other island groups, only a few colonizing species arrived to begin new populations. These populations were effectively cut off from the parent population by the wide expanse of ocean. Over time, mutations occurred and the Hawaiian populations evolved into new species unique to Hawai'i.

The fish, shrimp and snails that have colonized island streams have never lost their dependence on the ocean. They have a diadromous life cycle, meaning they make "two runs"; one to and the other from, the sea during their lifetime. The native animals enter the streams from the sea as young of the species, they grow, mature, and reproduce in freshwater. After the eggs hatch in the stream, the small larvae are swept to sea by the stream flow where they spend their young life as marine plankton. At some point in development they reappear at the stream mouth and begin their migration upstream to become the next generation. Refer to Figure 2.

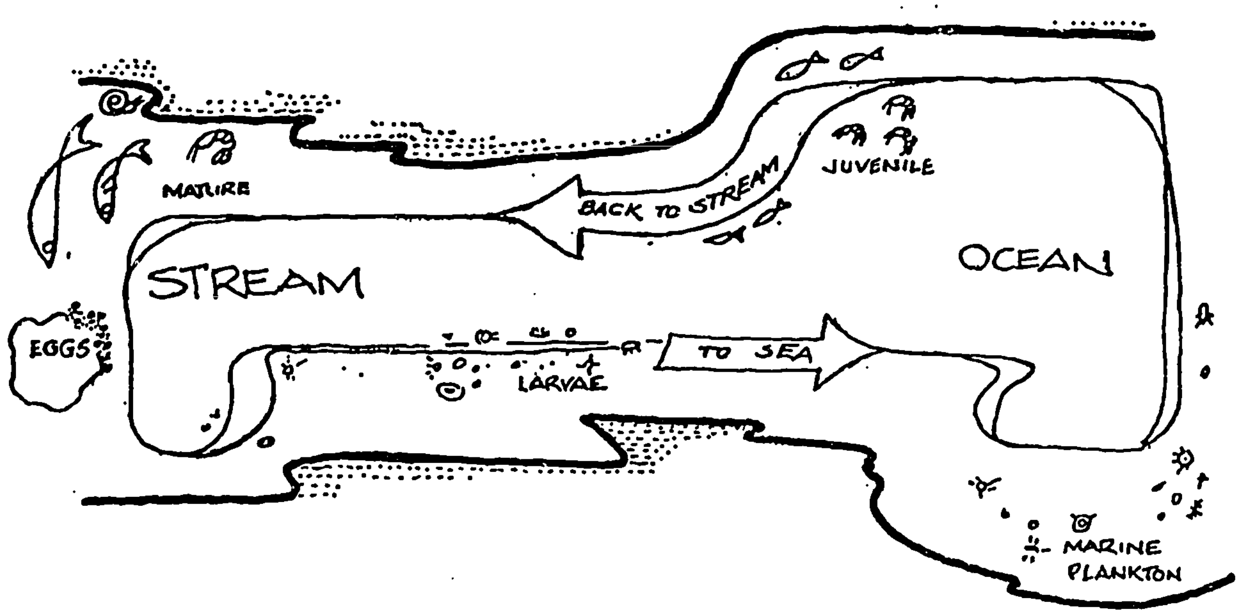


Figure 2

Looking at a plummeting waterfall, it is hard to believe that small animals would be able to migrate up that steep precipice to colonize the upper reaches of the stream, yet they do. The small fishes called o'opu, or gobies, have fused pelvic fins forming a suction disc on the underside of the body. This allows them to cling to wet rocks as they migrate upcurrent. The mollusk, hihiwai, has a strong muscular foot and flattened shell (reminiscent of the opihi, although they are not closely related) for clinging and climbing in strong water currents. Small 'opae, or shrimp, find protection from rushing water by traveling in cracks or among plants. They also have spines on their legs for traction similar to the a'ama crab of rocky shorelines.*

"A definite zonation of fauna exists from one elevation to the next in streams. The cool acidic waters of the 'headwater reach' (800 meters, or 2625 feet, and above) harbor mosses and native aquatic insects - lohelohe or damselfly nymphs, cranefly and midge larvae, and water beetles. This area lacks the conspicuous diadromous species of middle reaches."

NATIVE STREAM FISHES

Hawai'i has five species of freshwater gobies. Four of these are "true gobies," bearing the suction disc (modified pelvic fins) characteristic of the family Gobiidae (Fig. 3a). The fifth, in the family Eleotridae, is very similar, but lacks the suction cup fin (Fig. 3b). Hawaiians called these small stream fishes o'opu wai, or "freshwater o'opu," as opposed to the o'opu kai, the marine gobies. All o'opu spend most of their time sitting on the bottom, rather than swimming. They are normally a brown-mottled color, blending in with the stream bottom.

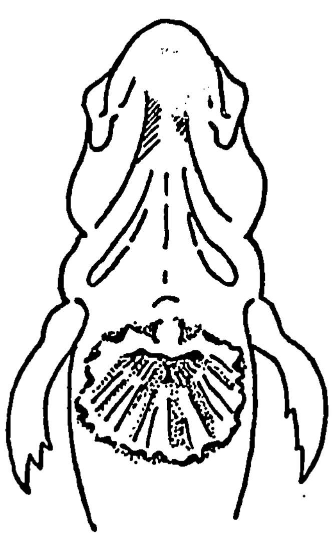


Figure 3a

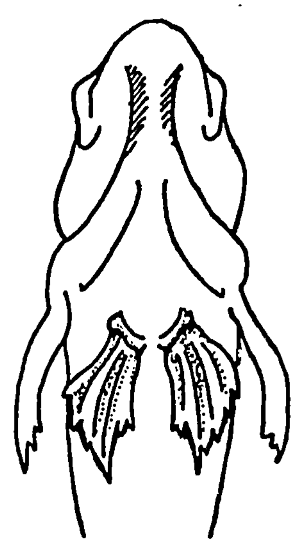


Figure 3b

*See the bibliography for resources on stream animals.

At least some species of o'opu migrate downstream to spawn during the rainy months of fall and winter. Evidence suggests that adults move downstream immediately after a flood. Eggs are laid on rocks by the thousands, then fertilized, with the larvae hatching in 24 hours. It has been suggested that a spawning may be triggered by heavy rainfall. Since the time between egg laying and hatching is so short, the larvae would be washed to sea while the stream was still high from the rain that triggered the spawn. In fact, the unusually short time between egg laying and hatching, combined with spawning being triggered by high water, would be an effective adaptation to ensure that the larvae reach the sea.

The postlarvae, or hinana, return to the streams months later. They are about 2 cm long at this stage. There is no evidence to suggest that they return to the same stream of their birth.

In earlier years, there were more streams of high quality in the Islands, and consequently more o'opu. In those times hinana migrated upstream in huge numbers and were caught for food by the Hawaiians.

Activity 3-1

STREAMS

Objective: To understand Hawaiian streams.

Materials:

Videotape Running Waters to the Sea
Monitor

Procedure:

View the videotape Running Waters to the Sea, and complete the discussion questions.

Discussion Questions:

1. Why did early Hawaiians hold streams in high regard?

2. What part of the fishes' life cycle is spent in the sea?

3. What are the following native stream animals?

   a. 'Opae
   b. Hihi-wai
   c. O'opu

4. What are hinana?

5. What part of the stream does the o'opu okuhe inhabit?

6. How is the o'opu okuhe different from other stream fishes?

7. How big are <u>hinana</u> and what color are they as they begin their upstream migration?

8. What is an estuary?

9. What is a "diadromous" animal? What effect would closing an estuary have on these types of animals?

10. How many streams are found among the five highest islands in Hawai'i?

11. How do artificial channels affect native stream animals?

12. How do introduced animals affect native animals living in streams?

13. How is water quality lowered after the diversion of a stream?

14. List animals that have been introduced to Hawaiian streams.

Activity 3-2

IDENTIFICATION OF STREAM ANIMALS

<u>Objective</u>: To be able to recognize native stream animals.

<u>Materials</u>:

3 x 5 index cards

<u>Procedure</u>:

1. Each team of 3 to 4 students will construct flash cards of native stream animals.

2. On the back of each card, list the Hawaiian name, the part of the stream that the animal was found, and its identifying characteristics.

SKETCH OF ORGANISM
Scientific Name:

Front

TOPIC IV: LIMAHULI STREAM

Limahuli Stream is on the north shore of Kaua'i, almost to the end of the road at Ke'e. It is about ½ mile past Ha'ena Beach Park. Permission to use this site can be obtained from:

William Theobauld, Director
Pacific Tropical Botanical Garden
P.O. Box 340
Lawai, Kaua'i, Hawai'i 96765

The Botanical Garden requests that only one class come at a time, and that students be 6th grade or higher. It is not wise to use this site after heavy rains.

Getting there:

Bridges that pass Hanalei have a load limit of 8 tons, so groups need to be transported in small buses or vans. Parking is available at the Botanical Garden. The nearest restroom facility is at Ha'ena Beach Park.

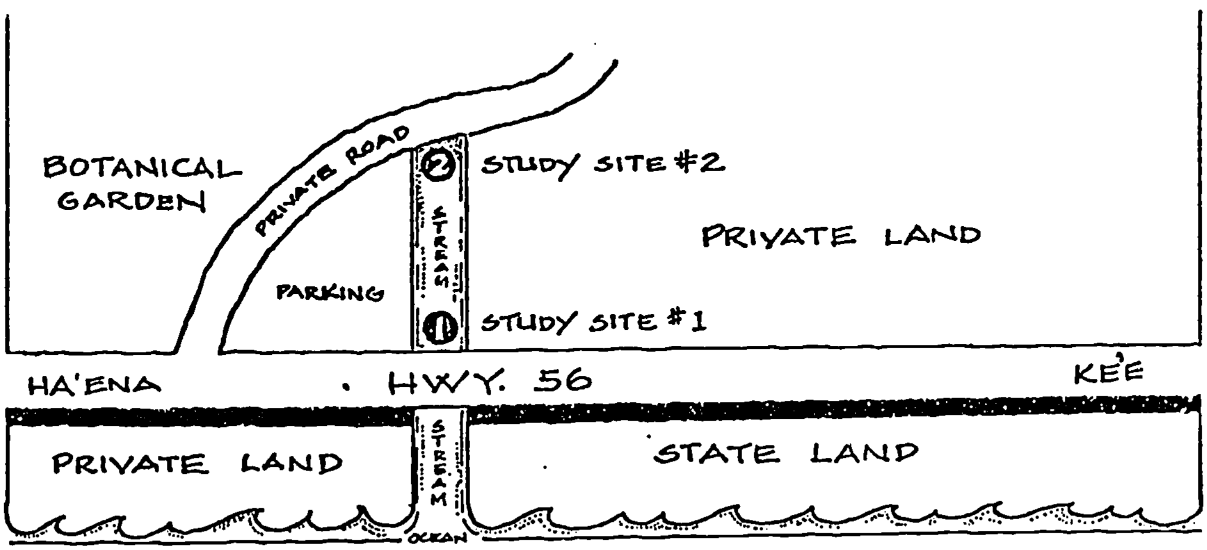


Figure 4

Limahuli Stream is one of the few remaining high quality, non-diverted perennial streams on Kaua'i. It is bordered on one side by the satellite garden site of the Pacific Tropical Botanical Garden, and on the other sides by state and private land. See Figure 4.

It is possible to study both the stream and the estuary here; however, to reach the estuary you will need to go to Ke'e Park and walk back along the beach to avoid crossing private land. For a discussion of this estuary, see the section in this guide on "Estuaries."

ALTERNATE FIELD TRIP SITE

For classes on the Waimea side of Kaua'i, Hanapepe stream and estuary can be used. See Appendix H in the section on "Estuaries" for details.

STUDY SITES ALONG THE STREAM

There are two easily accessible places to study this stream. One is right where the public road crosses the stream, the other is where the Botanical Garden's road crosses the stream.

IMPORTANT NOTE

Because of the possibility of becoming infected with Leptospirosis, no student should go in the stream unless he/she is wearing high top wading boots. Students who have cuts, scratches, or open wounds should not touch the water. There are many activities that can be done here without getting in the water. The activities that do require getting in the water can be done by two students wearing boots and gloves. Contact the State Department of Health for more information on Leptospirosis.

Activity 4-1

STREAM AWARENESS

Objective: To develop an awareness of the stream's ecosystem through the use of the senses.

Materials:

Notebook
Pencil
Paper towel tube painted black on the inside

Procedure:

1. Do not enter the stream. Sit quietly around the stream, then look, listen, feel and smell. React to the water, the stream bank, the wind the stones, the noise, and the silence.

2. Use a tube about 1" diameter and about 6-9" long that has been painted a dull black inside and look at your surroundings through the tube. Compare "feelings" about what is seen.

3. Describe or draw organisms found in the area.

4. Write a poem or haiku about the stream area. Create Cinquain poetry to describe stream colors and the mood they reflect.

5. List words to describe the stream, the stream bank, and behavior of organisms in the area. Categorize these words into feelings, color, and mood.

Discussion Questions:

1. What is the bank of the stream like? Can you see evidence that the water has been higher or overflowed the banks?

2. What are some of the adaptive characteristics that stream animals exhibit in order to protect themselves from predators and stream conditions?

3. Is there much of a vegetation canopy above the stream? What effect might this canopy have on life in the stream?

4. Has the stream been altered in any way by humans?

Activity 4-2

WATER FLOW

Objective: To determine the rate of water flowing past a point and relate this rate to the use of water by humans on a daily basis.

Materials:

50 feet of clothesline rope
Measuring tape 12-25 meters long
Floating object about 6 inches long (to prevent excessive wind influence on floater, use a plastic container half filled with water) - see Figure 5
Stopwatch, or watch with a second hand

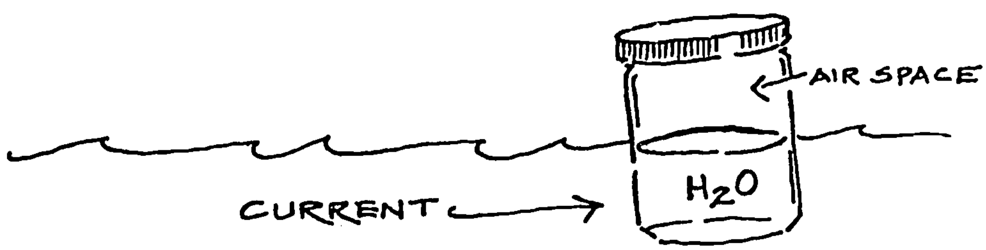


Figure 5

Procedure:

1. Measure and mark a distance along the stream. This distance should be about 10-20 meters. Station a student at the upstream and downstream mark of the measured section. Designate a timer and drop the floating object into the stream above the upstream mark so that the timer can begin the timing process. The timer should be stationed with the upstream person. The downstream individual should call out "mark" as soon as the floater passes the downstream marker. This procedure should be repeated five to six times and the average time in seconds recorded.

2. Calculate the rate of flow. Distance divided by time equals the rate in feet/second or meters/second.

3. Find the average width of the stream by measuring it at 3 places within the upstream and downstream marker. Use the clothesline cord if your measuring tape will not reach. Determine the average stream width.

4. Find the average depth. Measure the depth along the stream in 3 places. Calculate the average depth.

5. Find the cubic feet or meters of water flowing by each second.

Average width	x	average depth	x	rate of flow	=	cubic ft. or cubic m/sec.

6. In order to find out how many people could live from the water in this stream, do the following calculations; (note: a cubic foot of water contains 7.48 gallons; a cubic meter of water contains 1000 liters.) (You may choose to do this as a follow-up activity in the classroom.)

a.	____________ cubic ft/sec cubic m/sec	x	7.48 gal. 1000 liters	=	____________ gal/sec liters/sec
b.	____________ gal/sec l/sec	x	60 sec/min	=	____________ gal/min l/min
c.	____________ gal/min l/min	x	1440 min/day	=	____________ gal/day l/day
d.	____________	÷	200 gal 757 l (Amount of water each person uses daily)	=	____________ Total number of people who could live from this stream

If the water flow were one cubic foot per second, 646,272 gallons of water would flow through the stream each day. If it were one cubic meter per second, 86,400,000 liters would flow through each day.

The total number of people who could live from this stream is also known as the <u>carrying capacity</u> of water resources in this valley.

<u>Discussion Questions:</u>

1. Does 200 gallons a day per person seem like a lot? List some of the ways your family uses water each day. How could you help conserve water? (Contact Board of Water Supply for more information on conservation.)

2. All of this water is running into the ocean. What would happen if we diverted the stream for human uses such as agriculture, housing, resort development, etc.? What would happen to the stream below the point of diversion? What would happen to the plants and animals that live in the stream? What about fish, shrimp, and other animals that must spend their larval stages in the ocean before coming to a stream?

3. Discuss this topic: People do not need the great blue heron, timber wolf, killer whale, Hawaiian goose, or other wildlife. Perhaps the Hawaiian <u>o'opu</u> and <u>'opae</u> should be added to that list, as human needs for water outstrip the resources available.

Activity 4-3

SEDIMENTS

<u>Objective</u>: To measure the amount of sediment in a sample of stream water.

<u>Materials</u>:

Several clear containers (glass or plastic)
Several metric rulers

<u>Procedure</u>:

1. Fill several jars with water samples.

2. Let the containers sit until sediment has settled to the bottom. This could take anywhere from 1 to 24 hours, depending on the type of sediment.

3. Measure the height of the sediment using a metric ruler, then measure the distance from the water line to the bottom of the container. See Figure 6.

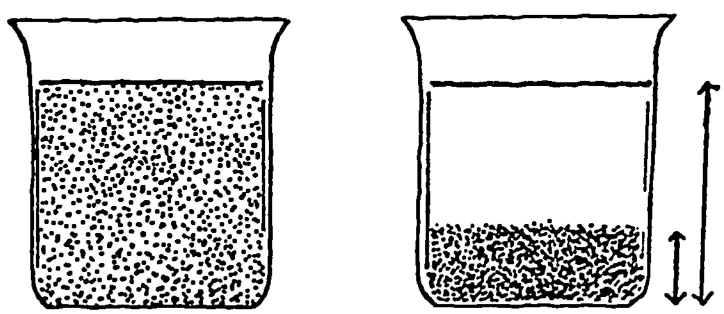


Figure 6

4. Use the following formula to determine the percentage of sediment in the stream water:

$$\frac{\text{Height of sediment}}{\text{Height of sediment and water}} \times 100 = \text{Percent of sediment in water.}$$

Activity 4-4

STREAM TEMPERATURE

Objective: To compare the temperatures at various stream sites.

Materials:

2 jars
2 thermometers
Paper and pencil

Procedure:

1. Put some stream water into the 2 jars.

2. Immediately measure and record the temperature in each.

Activity 4-5

STREAM ANIMALS

Objective: To observe and record the behavior of stream animals.

Materials:

Collecting permit from Department of Land and Natural Resources, Division of Aquatic Resources, State of Hawai'i
Magnifying glasses
A light colored container or bucket to hold animals for observation
Scoop nets
'Opae net - two bamboo poles with net between (See Figure 7)
Plankton net - instructions for making net is given in Appendix E
High top waterproof boots and gloves for students going in the water
Plastic jars
Copies of the Identification Guide (see Appendix B)

Leptospirosis enters the body through body openings, including cuts and scratches. To be safe, do not let any student who has cuts on the hands or feet, go into the water. Check with the State Department of Health for any further recommendations.

Procedure:

How to collect stream animals:

1. Use 'opae nets to collect organisms in the stream beds. Look for a place in the stream that has loose rocks that can be turned over or jiggled. Station student #2 with the 'opae net at a narrow place in the stream, downstream from student #1. The weights on the 'opae net

should touch the stream bed, and the net should touch the rocks on either side. Student #1 can turn over or jiggle rocks, to scare out o'opu or 'opae living there. He/she can also run his/her hands along the submerged portions of stationary rocks to dislodge 'opae and to feel for snails. Watch for broken glass. The dislodged animals will be swept into the 'opae net by the water current.

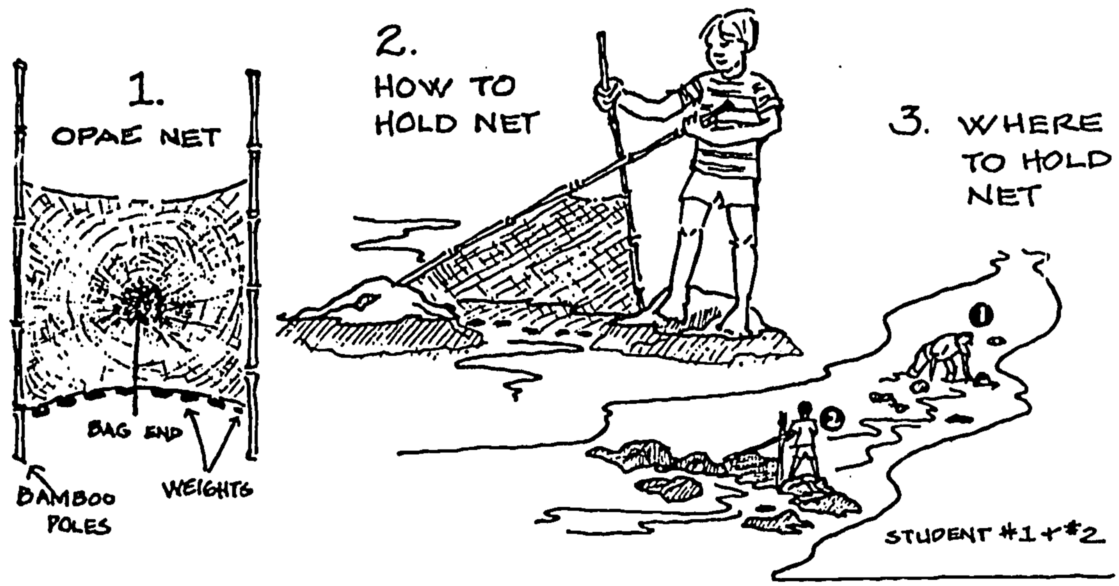


Figure 7

2. Use scoop nets (Figure 8) to collect organisms that may be found in quiet areas along the edges of the stream or run the net along the surface of submerged rocks to catch 'opae.

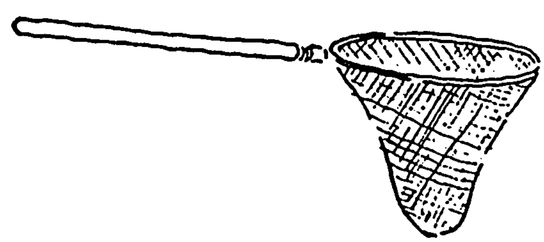


Figure 8

3. Use the plankton net (Figure 9) for collecting some microscopic plants and small microscopic organisms in the stream. Hold the plankton net in one place in the stream where there is a brisk water current. Allow the water to rush through the net for about 10 minutes. Look in the jar at the end of the plankton net for any tiny animals. You may catch the larval forms of o'opu or 'opae on their way to the ocean.

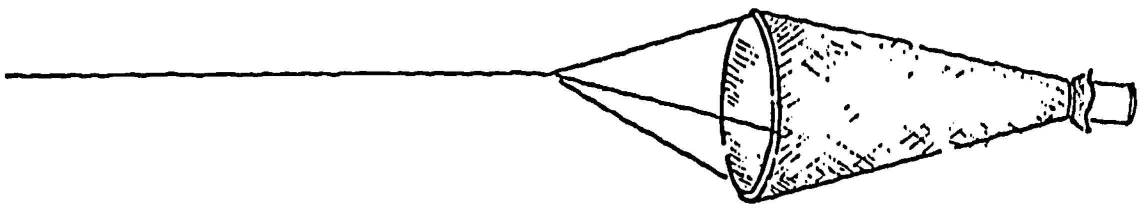


Figure 9

4. Put collected animals in a bucket of water. Be sure they are kept cool and not too crowded.

5. Identify the stream animals using the identification guides found in Appendix B.

6. Return all organisms when observations and measurements have been completed.

Discussion Questions:

O'opu

1. Does the fish have a suction cup disc? (The fish may adhere itself to the side of the jar. Watch how it uses the disc.) How does the disc help it to live in this environment?

2. Are the eyes near the top of the head or more on the sides? How would eye placement help a fish? (Fish living on the bottom usually have eyes near the top of the head so they can see above.)

3. What color is the fish? How does the color help it? (Camouflage coloration.)

4. Can you see the fish breathing through the gills? Time the number of breaths per minute. Put the fish in a sunny place for a short time and time the gill movements after the water has warmed up a little. Try it again in fresh, cold water from the stream with the fish in a shady, cool place. Was there a difference? If so, can you explain why? (Fish may speed up breathing in the warm water in an attempt to lose excess body heat.)

'Opae

1. Which 'opae do you have?

2. If you have the small black 'opae, try to look at the pincers. Describe them.

3. Let the 'opae crawl on your fingers. Do they stick to you? How do you think they do this? How does this help them?

4. Are there any eggs under the abdomen?

TOPIC V: STREAM DIVERSION

Residents of high volcanic islands, such as the Hawaiian Islands, have three major sources of freshwater available to them. These include underground water, surface water, and direct catchment of rainfall.

Islands differ in which type of water resource is most easily accessible. For example, O'ahu and Kaua'i have large supplies of underground water, while Maui does not. Residents on Maui must rely on surface water sources such as streams.

On Kaua'i, while underground water is tapped for residential use, sugar plantations often use surface water for irrigation. Streams are diverted from their natural courses by ditches, and water is stored in reservoirs. While this type of stream diversion aids humans, it can be detrimental to native stream animals through habitat degradation. All Hawaiian native stream animals find food and refuge around rocks and crevices and under sand and gravel. An irrigation diversion ditch supplies a reduced amount of this type of habitat. Also, as mentioned in the section on "Hawaiian Streams," young stages of the life cycle of native species must be spent in the ocean. By passing through ditches that offer less protection for them, into reservoirs containing predaceous species of introduced animals (see Topic VI), and finally into other ditches filled with silt from sugar cane fields, chances of survival of both the adults and returning young are probably lessened.

However, "Comparison of altered and unaltered streams (on Kaua'i) showed little difference in species richness or abundance of macrofauna. This may be due to the relatively innocuous channel modifications in Kaua'i streams, cleared and/or realigned channels (51%) being closest to unaltered conditions compared to other types of modification." (Timbol and Maciolek, 1978.)

The "other types of modifications" referred to include concrete-lined channels for flood control and wooden flumes to carry irrigation water.

Another positive aspect of stream diversion on Kaua'i is that the connection between the freshwater and the ocean is usually maintained. Irrigation water is often allowed to flow into the sea. The most devastating type of stream diversion is found on the other islands, such as Maui, where whole streams are diverted for human use allowing no water to return to the sea.

KEALIA STREAM AND KANEI RESERVOIR, KAUA'I

The field trip to Kealia Stream focuses on the ecological effects of stream diversion (Topic V) and the introduction of exotic stream animals (Topic VI).

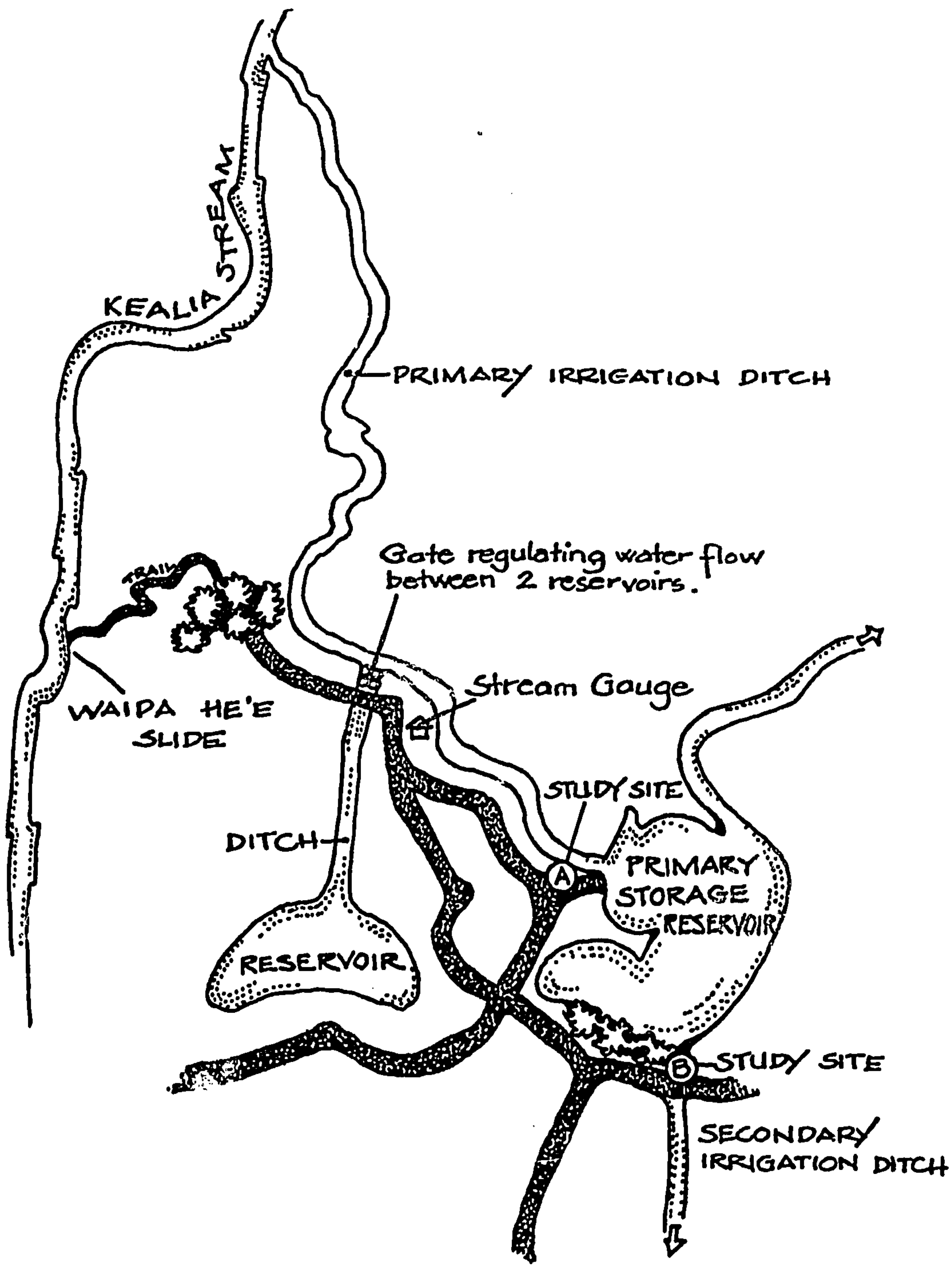


Figure 10

Permission:

For permission to use this site, call Lihue Plantation Company, 245-3871 and speak to Mr. Hubbard, Employee Relations Director. All persons entering the property will be required to sign a liability waiver. Teachers should make arrangements 2-3 weeks prior to the field trip.

How to get there:

To reach the reservoirs and irrigation ditch formed from Kealia Stream, take Kealia Road (about 2 miles north of Kapaa town on the east side of Kaua'i). Turn off the main highway by the small rodeo grounds. Kealia Road passes through sugar cane fields and parallels the secondary irrigation ditch. This is the same road that goes to the Waipahe'e slippery slide. Travel up this road approximately 6-7 miles until you come to a large reservoir fronted by Hau trees. Park here.

Using the map provided (Figure 10), find Study Site A. This is the point at which the primary ditch enters the reservoir. A "primary ditch" carries water from a stream to a "primary storage reservoir", so-called because it is the first reservoir formed from the stream water. Study Site B is the point at which a "secondary ditch" carries water from the primary reservoir to either a secondary reservoir or to the fields.

Activity 5-1

WATER TEMPERATURE

Objective: To compare the water temperature in the primary and secondary ditches, and in the reservoir.

Materials:

Thermometers
Jars or beakers

Procedure:

1. Use jars or beakers to take water samples for temperature readings from Study Sites A and B, and from the secondary ditch 1-2 miles down the road.

2. Record the temperature of the water in each area. Are there any appreciable differences in temperature? How might a rise in temperature affect stream animals?

Activity 5-2

WATER-BORNE SEDIMENTS

Objective: To measure the sediment load of the water in the reservoir and ditches.

Materials:

6 straight-sided jars with screw-top lids, approximately 20-30 oz. capacity.

Procedure:

1. Fill the jars to ½" from the top with water samples from Study Sites A and B and from the secondary ditch 1-2 miles down the road. Fill 2 jars at each site.

2. Take these samples back to the classroom.

3. Let the samples sit overnight, allowing the sediment to settle to the bottom.

4. Use a metric ruler to measure (a) the height of the sediment and (b) the distance from the water line to the bottom of the jar. Record these values.

5. Use the following formula to determine the percentage of sediment in the stream water:

$$\frac{\text{Height of sediment}}{\text{Height of sediment and water}} \times 100 = \text{\% of sediment in water}$$

Discussion Questions:

1. Are there any appreciable differences in the amount of sediment in the different areas?

2. How might the sediment load (%) affect the aquatic ecosystems?

Activity 5-3

WATER QUALITY

Objective: To compare the water quality of Limahuli Stream with the diverted portions of Kealia Stream.

Materials:

Thermometer
6 small jars

Procedure:

1. Review the procedure for determining the sediments found in a water sample in activity 5-2.

2. Take three water samples from both the Kealia and Limahuli Stream sites.

3. Measure the temperature of the water at each of the sites, collect water samples, and determine the sediment load (%) for each of the sites.

Sample Location	Temperature	% Sediment
<u>Limahuli</u>		
Site A		
Site B		
Site C		
<u>Kealia</u>		
Site A		
Site B		
Secondary Ditch		

Discussion Questions:

1. Are the temperatures or sediment loads of Limahuli Stream and the diverted Kealia Stream appreciably different? What factors would account for differences found?

2. What conclusions could one draw about the ecological effects of this type of stream diversion?

TOPIC VI: INTRODUCTION TO EXOTIC STREAM FAUNA

Hawai'i's native stream fauna developed from ancestral forms which arrived by ocean currents. Few species were able to survive the long ocean journey to Hawai'i and successfully establish breeding populations.

Since the arrival of humans in the islands, many species of freshwater animals have been introduced to Hawaiian streams. In many instances, these exotic forms (not found naturally) prey upon the native ones, or out-compete them for necessary resources such as living space and food.

At this time, exotic species outnumber the native ones.

> "Within a group of nearly 50 foreign non-marine animals (decapod crustaceans, mollusks, amphibians and mostly fishes) known to have been released in Hawai'i, 36 species have become established. Among the 36 established exotics, 27 species are found in streams." (Kanayama, 1968 in Timbol and Maciolek, 1978)

The Hawaiian native stream fauna numbers 11 species, which include 6 fish, 2 shrimp, 2 mollusks and one polychaete annelid worm. Almost every Hawaiian stream now contains at least some exotic fauna. Several species can be seen in Kaneha reservoir.

Activity 6-1

OBSERVATION OF EXOTIC FAUNA

Objective: To observe exotic aquatic animal species that have become established in a Hawaiian freshwater habitat.

Materials:

Containers to hold organisms for observation
Hand nets
(Optional - fishing poles)
Collecting permit from State Division of Fish and Game
Identification Guide to Exotic Stream Fauna (See Appendix C.)

Procedure:

1. Attempt to capture fish and tadpoles along the edges of the reservoir.
2. Place animals in containers, partially filled with water, for observation and identification.
3. Use the "Identification Guide to Exotic Stream Fauna" to identify the animals caught.

KAUA'I: Estuaries

Environmental Education

Introduction

Estuaries are semi-enclosed coastal basins where sea water is measurably diluted by fresh water. On the continents, estuaries support important fisheries, provide hydro-electric power, form protected harbors, and provide recreational areas for boaters and fishers. They also serve as nursery grounds for many species of economically important fishes and shellfishes. In the continental United States, for example, the salmon, trout, and shrimp fisheries depend on the estuarine environment.

In Hawai'i, estuaries are much smaller than their continental counterparts; however, they are critical to the life cycle of many species of aquatic organisms.

This section on estuaries will explore formation of estuaries, their importance as ecosystems, and the types found in Hawai'i.

TOPIC I: FORMATION OF ESTUARIES

During the last ice age, approximately 18,000 years ago, the sea level was lower than it is today. Much of the ocean was frozen in the polar ice caps; on the land, rivers and glaciers were cutting valleys. When the ice caps melted, the ocean water rose, flooding the mouths of these valleys. These semi-enclosed areas became estuaries. The formation of an estuary as it might have occurred in Hawai'i is shown in Figure 11.

Lower sea level; river cuts valley.

Rising sea level; valley flooded by seawater.

Partial filling of estuary by sediments, plants, human activities and rising sea levels.

Figure 11
(Coastal Zone News: March 1979)

Compared to many geological features on the earth, estuaries are relatively temporary. Sediments deposited from streams, encroachment by plants, changes in sea level, and human activities all interact to alter estuaries. As rain and wind erode away the land, the sediments are washed to sea by rivers and streams. Agricultural activities, such as deforestation and crop cultivation can increase the rate of erosion as soil once held by plants is washed away. These sediments are deposited in the estuary, filling it in.

Plants, such as mangroves and grasses, begin to grow in the sediment-rich areas at the edges of the estuary. Once established, their roots trap more sediments and the filling-in process is hastened. Changes in the earth's crust, either by uplifting or subsidence processes, can also affect where estuaries occur.

Finally, the impact of human actions through agriculture, dam and harbor construction, dredging, land reclamation for building, industrial and agricultural pollution, and the impact of natural forces act concomitantly to alter estuaries.

TOPIC II: TYPES OF HAWAIIAN ESTUARIES
(Excerpted with permission from "Estuaries Create Environmental Crossroads," Hawai'i Coastal Zone News, March, 1979.)

Stream mouth estuaries occur in submerged stream valleys where a rise in the sea level has flooded a stream valley and sediments have not yet filled-in the basin.

The greatest number of stream mouth estuaries are found on the island of Kaua'i. But even the largest of those in Hawai'i are small compared to their mainland counterparts.

Most Hawaiian estuaries are vertically stratified and are characterized by a swiftly running stream flowing into a deep and narrow coastal basin. This fresh water flows into the sea over a distinct "wedge" of ocean water. Lumaha'i Stream estuary on Kaua'i is a good example.

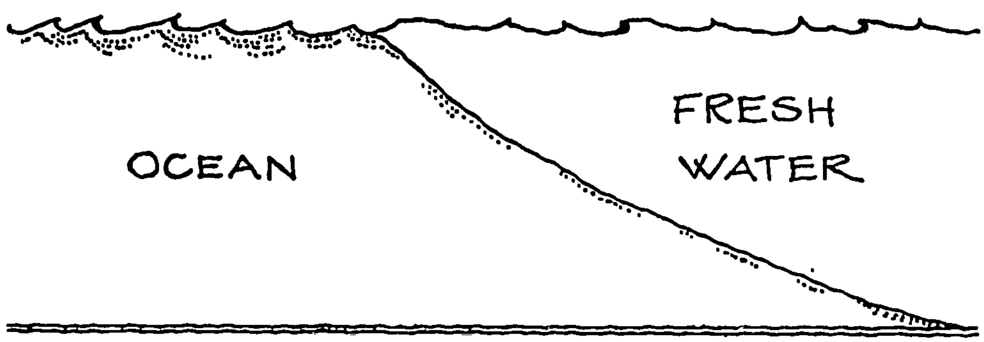


Figure 12
(Coastal Zone News: March 1979)

In horizontally stratified estuaries (more typical in the mainland's larger rivers and streams), incoming seawater pushes in over fresh water. Displaced by the lighter freshwater flowing in the center, the saltwater moves to the sides of the estuary. Estuaries of this type, such as in Pearl Harbor, are characterized by broad, shallow basins and small stream flow volume.

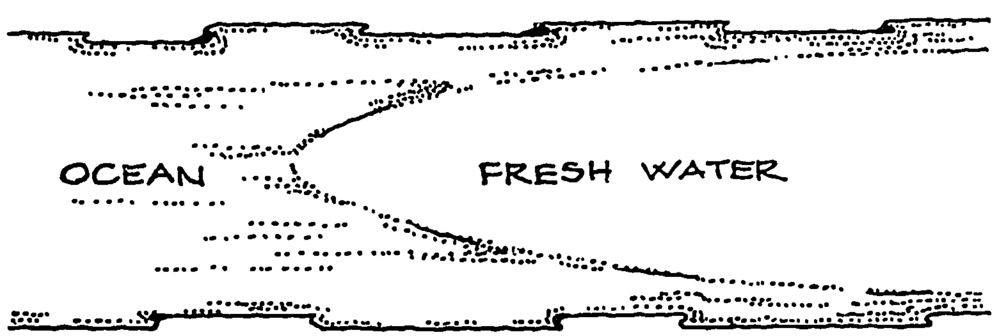


Figure 13
(Coastal Zone News: March 1979)

When stream flow is not sufficient to maintain a channel at all times, an estuary may be cut off from the sea, either seasonally or semi-permanently, by drifting sand that forms a bar blocking the mouth.

Spring-fed estuaries lack a surface source of freshwater, like a stream. These estuaries receive their freshwater through seepage of coastal springs, and the waters contained within these estuaries are often brackish. Waiakea and Ninole Ponds on the Big Island are the best examples of this type of estuary.

TOPIC III: ESTUARIES AS ECOSYSTEMS

Biologically, estuaries are secondary ecosystems between the ocean and inland waters characterized by a mixture of fresh and salt water. Plants and animals that can live here are known as euryhaline species (eury = broad, haline = salt). This term refers to their ability to tolerate wide fluctuations in the salinity of the surrounding water. Organisms living here must be able to cope with this constant salinity change. If an aquatic organism's body fluid is a different salinity than that of the surrounding water, it may lose or gain water and salts depending on the concentration gradient. Estuarine animals have various ways of coping with this problem. Some crustaceans (crabs and shrimp) have highly impermeable body coverings. Some fish living in estuaries are able to regulate the amount of salt in their bodies through their gills by using a process called "active transport." In this case the unwanted molecule is actively removed from the body's cells against the concentration gradient. Other animals can tolerate wide changes in the salt content of the blood. Most animals living in estuaries are marine-derived and have adapted to living in water of a lower salt content.

Some major groups of marine animals have never adapted to conditions of lower salinity and are never found in estuaries. Generally, these include the corals and echinoderms (starfish, sea urchins). Corals, in fact, are so sensitive to freshwater that coral reefs will not grow across an area of lowered salinity, a situation which occurs at the mouths of large streams. These natural breaks in a reef allow for channels that serve as passages for boats, and the bays and estuaries so affected provide good harbors. (See Figure 14.)

Figure 14

As previously mentioned, Hawaiian estuaries are much smaller than those on the continents and geologically much younger. For these, and other reasons, species diversity in Hawaiian estuaries is much lower than that in the larger continental systems. An important effect of the small size is that environmental conditions vary more (e.g. salinity) than in a larger estuary. Because of the recent formation of Hawaiian estuaries, few species have adapted to this environment.

Estuaries in Hawai'i are important biologically because (1) they serve as a nursery ground for several species of economically important fish; (2) they serve as a habitat for water birds; and (3) they provide a connection between streams and the sea for diadromous stream animals which must spend their larval stages in the ocean, then migrate upstream as juveniles. Many of these stream animals are found only in Hawai'i, and as stream and estuarine environments are degraded through human activities, their populations are declining. In addition, introduction of exotic stream animals further threatens these populations, as other species out-compete the native ones for food and space.

TOPIC IV: LIMAHULI ESTUARY

Kaua'i has, by Hawaiian standards, many good estuaries. These include Lumaha'i, Anahola, Wailua, Hanalei, Kalihiwai, Nawiliwili, and many more. (See Figure 15.)

While it is helpful for students to see these larger estuaries, it is easier to have a field trip to the smaller ones such as Kealia, Limahuli, Kilauea, Hanapepe, and Hanama'ulu.

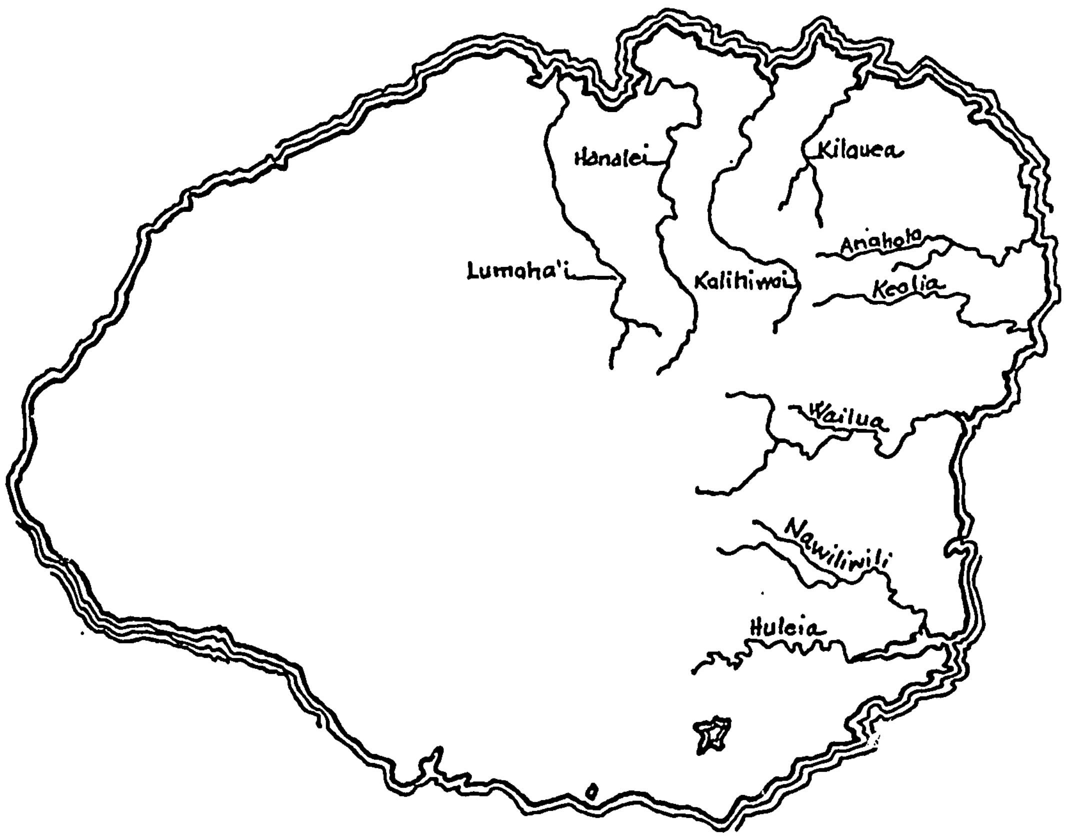


Figure 15

The specific field trip site to be investigated will be Limahuli, as it is hoped that classes will observe both the stream and the estuary on a single field trip day. While Limahuli qualifies as an estuary because of the freshwater and seawater mix, it is not a "typical" estuary, because there is no bay or inlet at the mouth of the stream.

How to Get There:

Drive to the end of the road on the north shore of Kaua'i, and park at Ke'e Beach. Walk back along the beach toward the stream to avoid crossing private land. (Refer to the Limahuli Stream Field Trip in the "Streams" section.)

Activity 4-1

GEOLOGY

Objective: To observe the geological features of the shoreline between Ke'e Beach and Limahuli Stream.

Materials:

One quadrat per team or group

Procedure:

1. Walk from Ke'e Beach to Limahuli Stream and observe the types of rocks along the shoreline. Are these rocks basaltic (black - formed during volcanic eruptions) or limestone (white - made by coral and coralline algae)? Randomly place quadrats along the walk and approximate the percent of basalt and limestone rock contained within the quadrat. Numerically label your quadrats as you move from Ke'e Beach to Limahuli Stream.

2. Conduct a transect perpendicular to the shore to determine the distribution of basaltic rock from the shoreline to ten meters on the beach. Place a quadrat every two meters along this transect and determine the size of approximately ten basaltic rocks. Record the average size for that quadrat.

3. Look out to sea. Visually determine where the waves are breaking on a shallow reef. Construct a diagram to record your data.

Sample Data Sheet

	Quadrats			
	Ke'e Beach			Limahuli Stream
Beach Rock (%)	1	2	3	4
Basaltic				
Limestone				

	Transect Line Quadrats				
	2	4	6	8	10
Average size of Basaltic Rock					

Discussion Questions:

1. Was there a change in the percentage of basaltic and limestone rock as you moved closer to Limahuli Stream? If so, how might you account for this change?

2. With respect to the distribution of basaltic rock as you moved away from the shoreline to the back of the beach, did there appear to be any sorting according to size? If so, how might you account for the sorting action?

3. Do the waves break across the whole bay in front of the stream? Are there areas where no waves are breaking? Explain your observations.

Activity 4-2

THE ZONE OF MIXING

Objective: To determine the zone where fresh and saltwater mixing occurs.

Materials:

Hydrometers
Thermometers
100 ml graduated cylinders
Clipboards
12 or 25 ft. measuring tapes
Wide mouth jars with screw top lids
Data sheets
Teams of not more than four students

Procedure:

1. Each team will select a recorder for the group. The recorder will sketch the lower part of the stream and shoreline near the stream mouth. The location of each team's assigned sites will be recorded on the sketch.

2. Assign each site on the sketch a station number (see Figure 16). Use this same number to refer to the water sample when recording the information on the data sheet.

3. Determine the salinity of the selected sites, using the procedure in Appendix I, suggested activity five. Record the information on your data sheet.

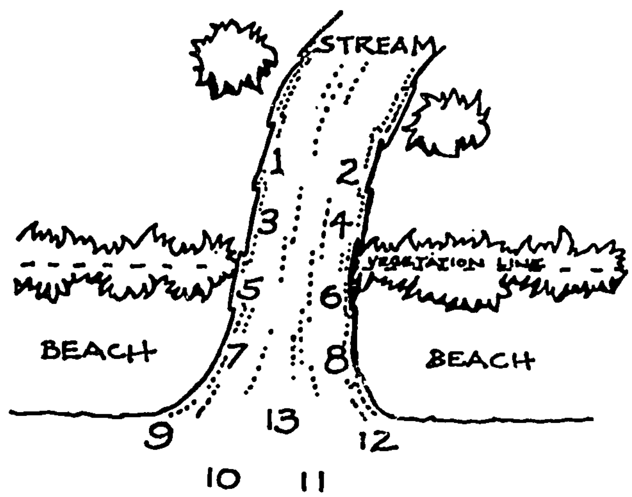


Figure 16

4. Draw approximate boundaries of the zone of mixing on the sketch. The zone of mixing of the estuary can be determined by looking for areas of salinity that fall between totally fresh and totally saltwater values.

Sample Data Sheet

Station Number	Temperature (Degrees C)	Specific Gravity	Salinity
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Discussion Questions:

1. How large is the area where fresh and saltwater mix?
2. How might the size of the area be affected by changes in tide or stream flow?
3. Was there any evidence of freshwater flow into the ocean? If so, what was the pattern of flow?
4. Was there any indication of layering of fresh and saltwater? If so, what was the pattern, and how deep was the top layer?
5. Based on the patterns of water flow and layering, what implications might there be for the distribution of organisms in an estuary?

Additional Activity:

From the team data, construct a map of the area using isohaline lines. An isohaline line connects areas of equal salinity.

ANIMAL LIFE

Objective: To compare animal life found in fresh and brackish waters.

Materials:

Scoop nets
Opae nets
Plankton nets
Light-colored dish pans
Plastic petri dishes
Hand lens
Field keys

Procedure:

1. Sit quietly by the edge of the estuary and look for movement of fish and shrimp. Disturb the environment as little as possible while attempting to catch estuarine organisms. Organisms that are caught should be handled as considerately as possible.

2. Use the scoop net to look for animals that are normally found in the quiet areas of an estuary. Generally, two scoop nets are used together. Put the nets around a rock, then gently lift the rock. Animals under the rock will swim out and into the nets.

3. Hold the opae net with the lead weights on the bottom of the stream, downstream from other students. Upstream students should turn over rocks. Animals flushed out should be caught in the downstream net. Return any overturned rock to its original position.

4. Collect planktonic organisms in the estuary by holding a plankton net in the stream water flow for ten minutes. Any organism caught will be found in the glass jar or appropriate container at the end of the net.

5. Place any animal caught in containers for closer observations. Very small animals can go in petri dishes or plastic cups, and the larger ones can go in the plastic dish pans. All organisms should be returned to as close to the original areas as they were found when observations are completed.

6. Compare and investigate, using the tools indicated above, organisms from three major areas of the estuary: (a) freshwater; (b) brackish water; and (c) the estuary banks. Many animals can be easily collected in the vegetation along the banks of estuaries. The young of these animals move upstream by clinging to the undersides of rocks.

Sample Data Sheet

Estuary Location

Type of Organism	Freshwater	Brackish Water	Estuary Banks

Activity 4-4

SEDIMENTS

Objective: To measure the amount of sediment in the water.

Materials:

Several clear containers (glass or plastic)
Several metric rulers

Procedure:

1. Fill several jars with water samples.

2. Let the containers sit until sediment has settled to the bottom. This could take anywhere from 1 to 24 hours, depending on the type of sediment.

3. Using a metric ruler, measure the height of the sediment, then measure the distance from the water line to the bottom of the container. See Figure 17.

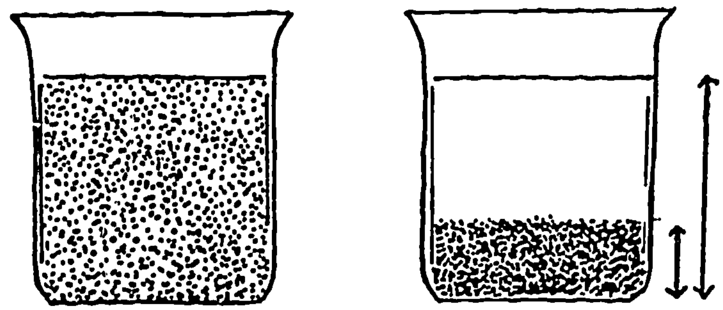


Figure 17

4. Use the following formula to determine the percentage of sediment in the stream water:

$$\frac{\text{Height of sediment}}{\text{Height of sediment and water}} \times 100 = \text{Percent of sediment in water}$$

Discussion Questions and Additional Problems:

1. Discuss how the following might affect animal life in an estuary:

   Stream diversion
   Pesticides
   Dredging
   Erosion due to clearing of the surrounding land
   Channelization of the stream for flood control

2. Discuss how a change or the manipulation of one environmental element in an estuary might affect all of the other environmental factors. If an estuary can be described as an ecosystem, what does the term ecosystem imply about environmental relationships?

3. Suggest ways to guard against detrimental environmental manipulation of ecosystems.

4. Determine what human activities take place upstream of the estuary or estuaries you have visited.

5. Why are estuaries important?

BIBLIOGRAPHY

Brock, V.E., 1960. The Introduction of Aquatic Animals into Hawaiian Waters. Int. Revue ges. Hydrobiol, 45 (4): 463-480. (Copy available in the library of the Waikiki Aquarium.)

Couret, C.L., 1976. The Biology and Taxonomy of a Freshwater Shrimp, Atya bisculata Randall, Endemic to the Hawaiian Islands. M.S. Thesis in Zoology, University of Hawai'i.

Crowles, L., 1977. Status of Damselflies (Odonata: Zygoptera) in Hawai'i in 1977, with Special Reference to the Endemic Genus Melagrion. Senior Honors Thesis, Biology Dept., University of Hawai'i.

Ego, K., 1956. Life History of Freshwater Gobies. Freshwater Game Fish Management Research. Proj. No. F-4-R. Honolulu.

Ford, J.A., 1979. Biology of Neritina granosa, a Diadromous, Endemic Gastropod. M.S. Thesis in Zoology, University of Hawai'i; 94 pp.

Harwood, P.D., 1976. Dragonflies (Odonata) Observed in Hawai'i in 1973 and 1974. Proc. Hawai'i. Entomol. Soc. 22 (2): 251-254.

Kay, A., 1979. Hawaiian Marine Shells. Bernice P. Bishop Museum Special Publication 64 (4). Bishop Museum Press, Honolulu; 653 pp.

Lau, E.Y.K., 1973. Dimorphism and Speciation in the Hawaiian Freshwater Goby Genus Lentipes. Senior Honors Thesis, Biology Dept., University of Hawai'i; 82 pp.

Maciolek, J.A., 1977. Taxonomic Status, Biology and Distribution of Hawaiian Lentipes, a Diadromous Goby. Pac. Sci 31 (4): 355-362.

Maciolek, J.A., and F. Howarth, 1979. Megalagrion paludicola, a New Species of Damselfly (Odonata: Zygoptera: Coenagrionidae) from Kaua'i. Pac. Insect. Vol. 21:2-3, 165, 171.

Morita, C.M., 1981. Freshwater Fishing in Hawai'i. Division of Aquatic Resources, Department of Land and Natural Resources, Honolulu, Hawai'i; 20 pp.

Timbol, A.S., and J.A. Maciolek, 1978. Stream Channel Modification in Hawai'i. Part A: Statewide Inventory of Streams, Habitat Factors and Associated Biota. Fish and Wildlife Service, U.S. Department of the Interior; 158 pp.

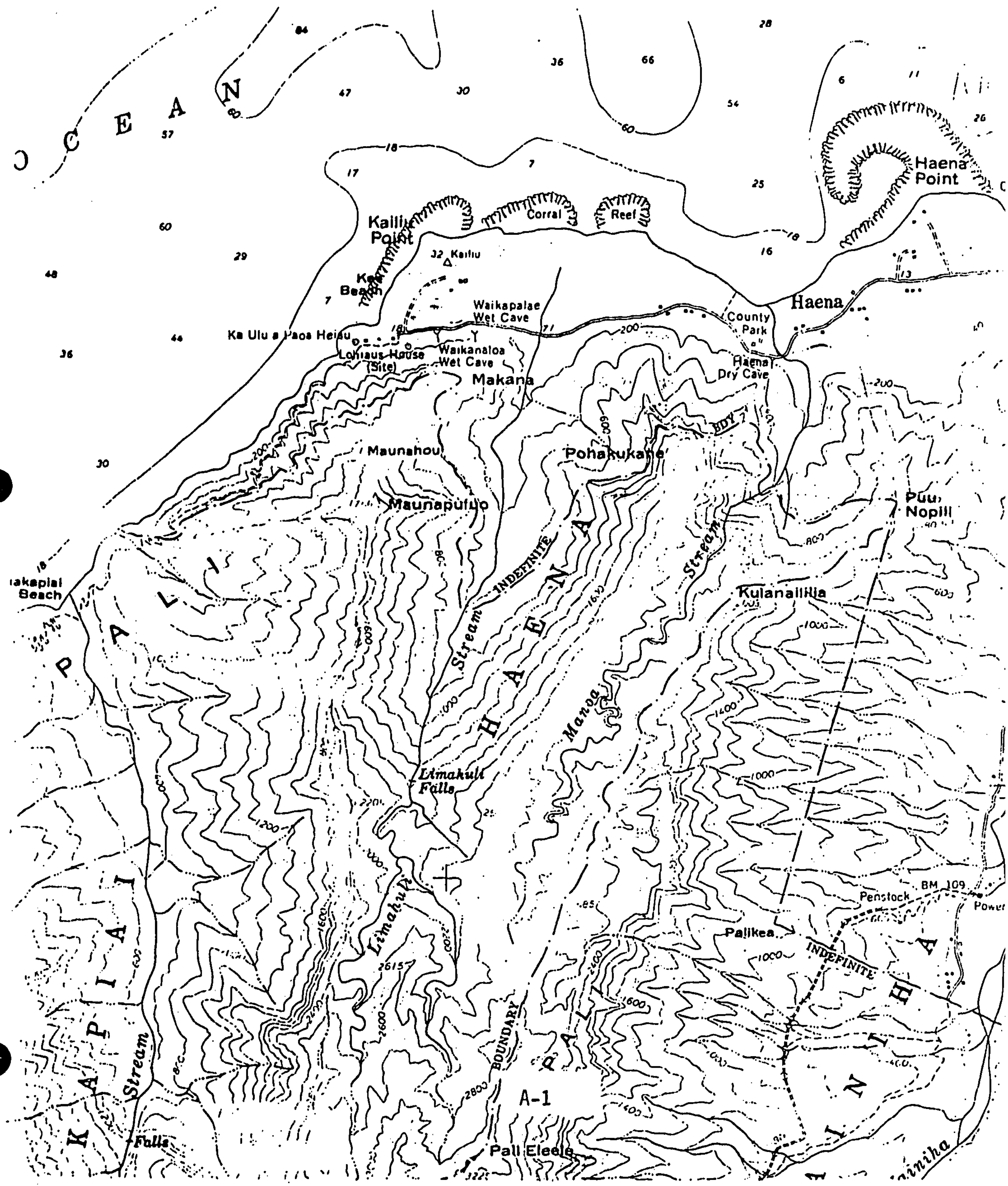
Titcomb, M., 1979. Native Use of Marine Invertebrates in Old Hawai'i. University Press of Hawai'i; 61 pp.

Tomihama, M.T., 1972. The Biology of Sicydium Stimpsoni, Fresh Water Goby Endemic to Hawai'i. Senior Honors Thesis, Biology Dept., University of Hawai'i; 123 pp.

Zimmerman, E.C., 1948. Insects of Hawai'i, Volume 2. Apterygota to Thysanoptera, Inclusive. University Press of Hawaii, Honolulu.

APPENDICES

LIMAHULI VALLEY



IDENTIFICATION AND BIOLOGY OF NATIVE STREAM ANIMALS

Fishes

O'opu nakea (Awaous stamineus)

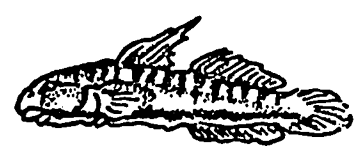
This is the largest of the stream gobies, reaching 14 inches (35 cm) in length. It is endemic to Hawai'i, omnivorous in its eating habits, and found in middle to lower reaches. The color pattern is distinctive. The dorsal fins are yellowish with black bars and the base of the tail is dark in color. This species occurs on all the larger Hawaiian islands. Probably because of its large size and abundance, o'opu nakea was a popular food fish among the Hawaiians. It is still caught and sold at market on Kaua'i during the late summer spawning migrations.

O'opu naniha (Awaous genivittatus)

This species is indigenous but not endemic, which means that it is found naturally in Hawai'i, but is also found in other islands in the Pacific Basin. It is omnivorous and found only in lower reaches of the stream and in estuaries. The head is marked by a dark band that extends under the eye and on to the cheek, and the body may be marked with 12 dark vertical bands. Large specimens reach 6 inches (15 cm) in length.

O'opu nopili (Sicydium stimpsoni)

Titcomb (1972) reports: "It can climb a vertical stone jar or wall by moving slightly its suction disc, first on one side then on the other... The nopili was greatly relished as food, and also a favorite food with the priests. As the nopili clings, so will luck." It often has a distinct black line running from the mouth to the tail. The very high first dorsal fin is the best positive identifying character. This is a small (up to 7 inches; 18 cm), endemic herbivorous fish, found in all areas of the stream, but more abundant in the middle and higher reaches.



O'opu alamo'o (Lentipes concolor)

This is a rare goby, found only in the middle and upper reaches of pristine streams. The Hawaiian name, o'opu alamo'o, refers to the belief that they represented two species. The female is olive to brownish all over, while the males are brownish on the head and pale yellow to bright red on the tail.

"Lentipes is diadromous as are most other prominent native Hawaiian stream animals. Only postlarvae and small juveniles appear to actively migrate upstream. These migrants demonstrate superb climbing ability and are known to surmount single waterfalls 100 meters high, as well as a series of six falls surpassing 300 meters in combined drop. Mature Lentipes characteristically reside in middle to upper stream reaches at elevations from about 50 to more than 500 meters" (Maciolek, 1977). These gobies may reach 6 inches (15 cm) in length.

O'opu okuhe or akupa (Eleotris sandwicensis)

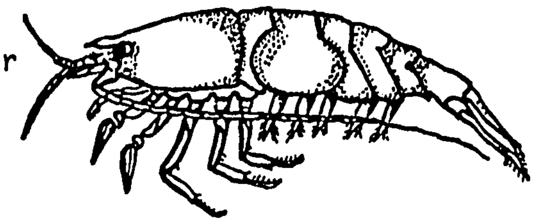
This species is not a true goby, and lacks the fused pelvic fins characteristic of that group. It is endemic and found on all islands. Length may reach 10 inches (25 cm). Coloration may be brownish above and lighter below with the second dorsal fin narrowly edged with white, black and white, or mottled brown. This species is carnivorous. Titcomb (1972) quoting another source, says:

"'Its normal motion is characterized by a slow, easy movement along the bottom, poking its head under rocks and bits of vegetation and debris. Occasionally it moves with a fast, jerky burst of speed...' It is eaten like other o'opu. This, with nakea and nopili, are the three favorite o'opu."

Crustaceans

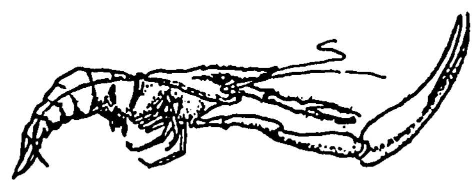
There are two endemic shrimp ('opae) found in Hawaiian streams. Both apparently have marine larval stages.

'Opae kala'ole (Atya bisulcata)



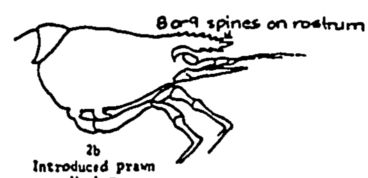
Common names are "black 'opae" and mountain 'opae." These small (up to 3 inches; 8 cm), dark shrimp are found in the middle and upper reaches of the stream. They can be found on the sides of rocks where the water flow is the fastest (the "riffle" zone). Feeding is accomplished in an unusual manner: bristle-tipped pincers are held out into the water flow to trap organic particles for food. This species can be recognized by the blunt appear- of the head and the small, bristled pincers. Kala'ole are found on all islands and are netted for use as food and fish bait. This is the most common native stream animal other than insects.

'Opae 'oeha'a (Macrobrachium grandimanus)



This brown native prawn is recognized by the long rostrum (swordlike structure between the eyes) with 12 or more spines on the upper border. In large males the pincers are longitudinally striped and unequal in size; in fact, the species name, grandimanus, means "large hand." This species prefers downstream areas and estuaries. It is omnivorous and reaches 5 inches (13 cm) in length. Do not confuse it with the introduced Tahitian prawn, Macrobrachium lar, which reaches a much larger size, has long, thin blue pincer legs, and less spines on the rostrum (8 or 9). Figs. 2a and 2b show the difference in the rostrums.

2a
Native prawn
M. grandimanus



2b
Introduced prawn
M. lar

Mollusk

Two mollusks common in streams are the hihi-wai and the hapa-wai. Both have a limpet-like shell and a strong muscular foot which aid in clinging to rocks in swift currents. Both are in the family Neritidae, which includes the black pipipi (Nerita picea) common along Hawai'i's rocky shorelines. The hihi-wai and hapa-wai are endemic to Hawaiian streams.

Hihi-wai (Neritina granosa)

This species live attached to stones in streams and under waterfalls. The low, rounded tubercles of the black shell are distinctive of animals living near the sea. (Hihi-wai shells found above waterfalls or on vertical cliffs may have fairly smooth shells which are oval in shape.)

(Discuss with the class what might lead to the clear difference in shell shape within the same species.) This species is not abundant on O'ahu and Kaua'i due to over-fishing and habitat degradation. It is herbivorous and grows to 2" (5 cm). Its eggs are deposited on submerged rocks and on the shells of other hihi-wai in tough white capsules about 2 mm in length. Each capsule may contain as many as 450 developing hihi-wai. When the capsules break open, the surviving larvae are swept out to sea where they also undergo early development as marine plankton. Spawning takes place in late spring and summer, and postlarvae (spat) return to streams from June through September.

Hapa-wai (Theodoxus vespertinus)

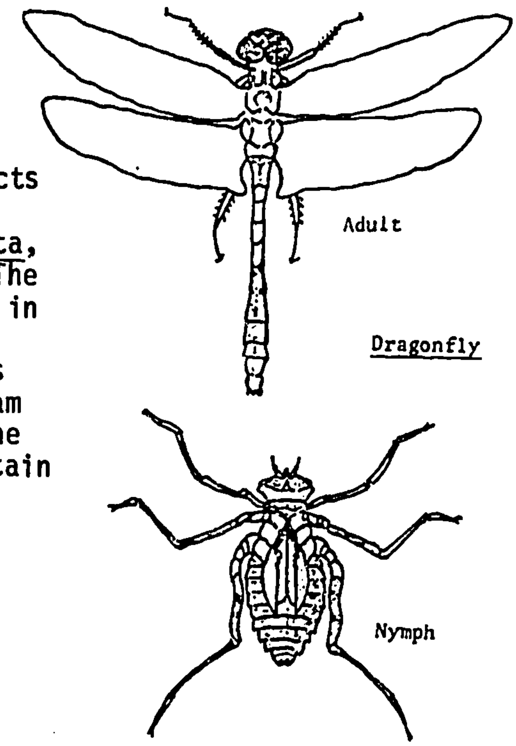
The Hawaiian name "hapa-wai" means "half water" and refers to the brackish water habitat of this species. It resembles the hihi-wai, but lacks the low, rounded tubercles and is brown in color. It is found attached to rocks in stream areas where the freshwater meets the saltwater. It grows to 1 inch (2.5 cm) and is herbivorous. It reproduces in the same fashion as the hihi-wai.

(ventral view)

Insects

Dragonflies and Damselflies

The most conspicuous of the freshwater insects are the dragonflies and damselflies. Both belong to the order of insects called Odonata, and both have members endemic to Hawai'i. The larval forms are called nymphs. These live in freshwater and are part of that ecosystem. Some nymphs occur in running streams, others are found in damp vegetation along the stream bank, and one occurs in water captured in the leaves of the 'ie'ie plant, high up on mountain sides. Nymphs are predaceous on other small animals.

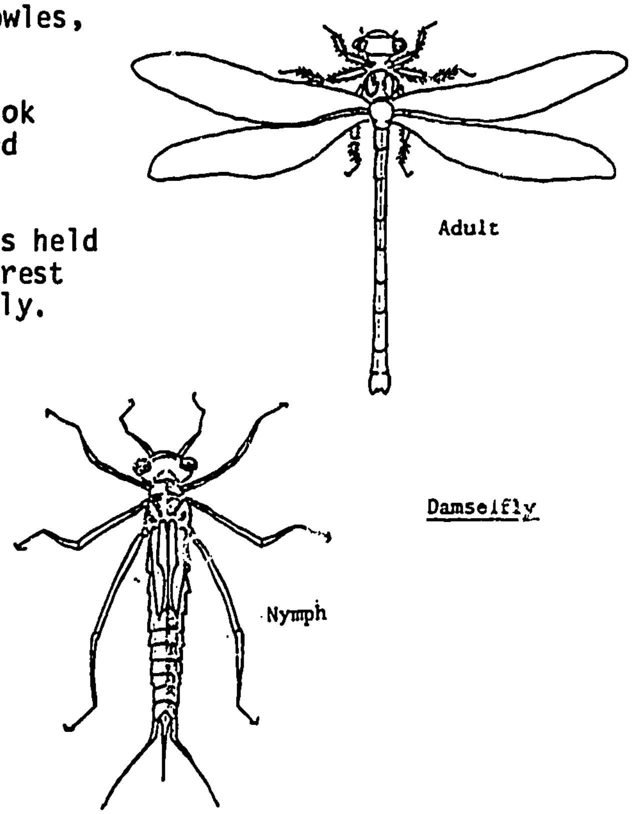


Hawai'i's endemic dragonfly, the "green darner" or pinao (*Anax strenuus*) is the largest of Hawaiian insects, with a body length of 11 cm and a wingspan of 14 cm.

The damselflies have evolved into at least 23 different endemic species belonging to the family *Megalagrion*. (For more information on Hawaiian insects, see Zimmerman, 1948, Maciolek & Howard, 1979 and Cowles, 1977.)

While dragonflies and damselflies look superficially similar, it is not hard to tell them apart:

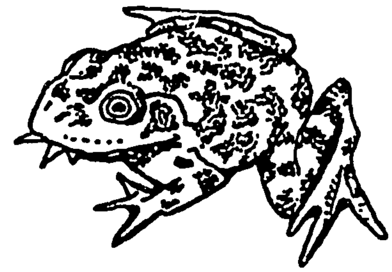
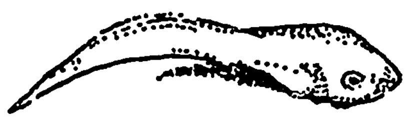
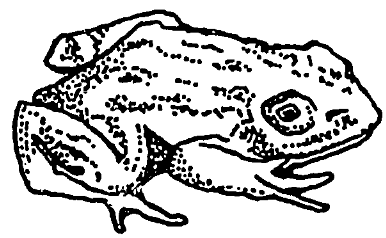
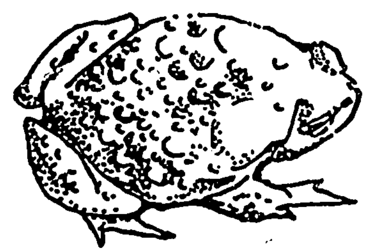
1. Dragonflies rest with their wings held horizontally, while damselflies rest with their wings folded vertically.
2. Dragonfly eyes are joined, while damselfly eyes are separate.



IDENTIFICATION GUIDE TO EXOTIC STREAM FAUNA

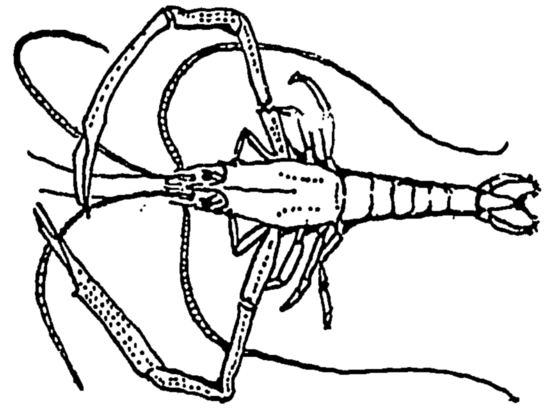
A. Amphibians

There are 3 species of frogs and toad in Hawaiian streams. The adults and tadpoles can be identified by using the following chart:

Species	Tadpole	Adult
Bullfrog Rana catesbeiana	 Length to 4 inches Light in color	 Length 4-7 inches Smooth skin Mottled brown with green snout
Wrinkled frog Rana rugosa	 Length to 1½ inches Light in color Dotted outline on head	 Length 1 1/4 to 1 3/4 inches Wrinkled skin Brown
Neotropical toad Bufo marinas	 Top view - actual size	 Length to 7 inches Warty skin Brownish

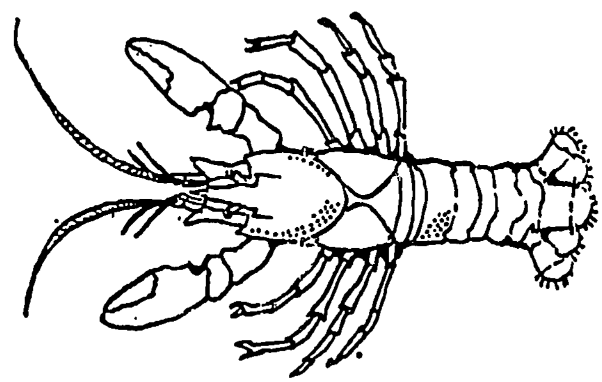
Reference: McKeown, S., Hawaiian Reptiles and Amphibians, Oriental Publishing Company.

B. Crustaceans



Tahitian prawn (Macrobrachium lar)

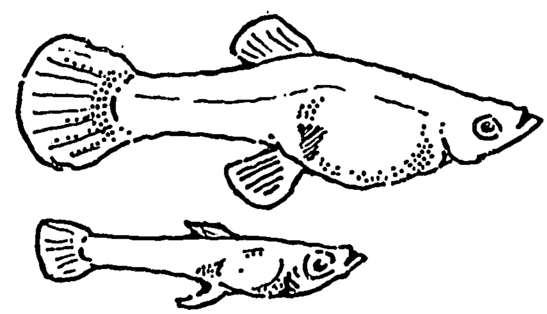
Introduced in 1956 into Pelekunu Stream on the northern coast of Moloka'i and subsequently on O'ahu in 1957 and 1961. Now found on all major islands. May grow up to 6 inches (14 cm) in length. Brownish with long, thin dark pincer legs. Rostrum with 8-9 spines on dorsal surface.



Crayfish (Procambarus clarkii)

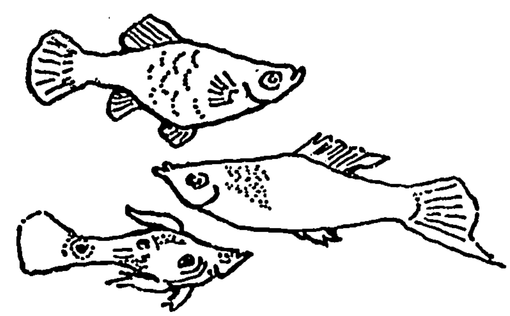
There is no record of this species being introduced to Hawai'i, but there are records of introductions of two other species. Perhaps this one was mistakenly identified as one of the others. Abundant on all major islands. Considered a pest in taro patches where it burrows through dikes. Can reach a length of 4 inches (10 cm). Reddish to brown in color.

C. Fish



Mosquito fish (Gambusia affinis) (Family Poeciliidae)

Brought from Texas in 1905 for mosquito control. Abundant in lower reaches of streams. Found on all the islands. Can reach a length of 1 inch (2.5 cm).

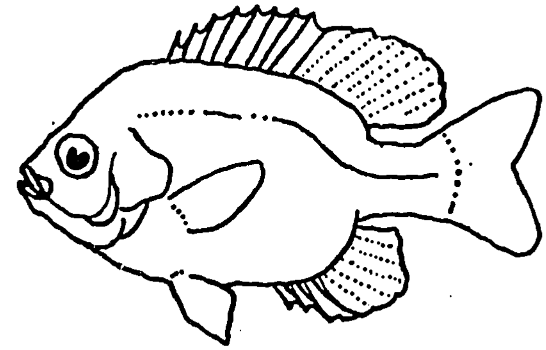


Mollies, guppies, top minnows, swordtails (Family Poeciliidae)

Common in streams, ponds, reservoirs. A large family of small, live-bearing fish. Used as aquarium fish and as bait fish. Suitable for classroom aquariums. Mosquito fish is also a member of this family.

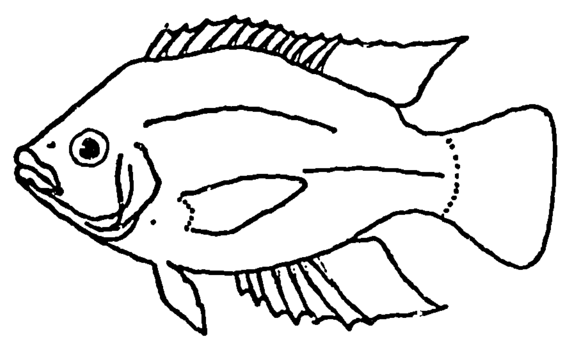
Bluegill (Lepomis macrochirus)

Introduced in 1946. Usually 4 to 6 inches (10-14 cm) in length. Greenish in color with a dark blue or black opercular flap (gill cover). Eats insects, crustaceans, small fishes.



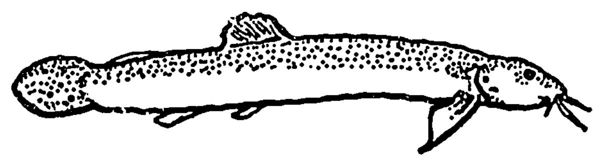
Tilapia (four introduced species)

Introduced in the 1950's. Cultured for food in Africa and Asia. Characterized by the long dorsal fin. Differentiated from the bluegill by having no blue or black opercular flap. Useful to control aquatic plants in irrigation systems and as a food fish. Adult size 4 to 6 inches (10-14 cm) in length. Young have, dorsally, horizontal black bars.



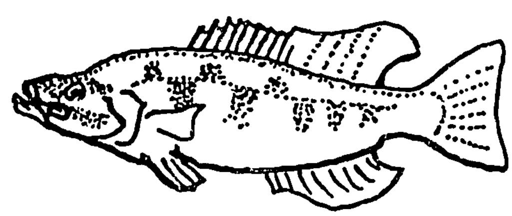
Dojo (Misgurnus anguillicaudatus)

Introduced prior to 1900 on Kaua'i, O'ahu, and Mau'i. Used as bait. Adult size 4 inches (10 cm) in length.

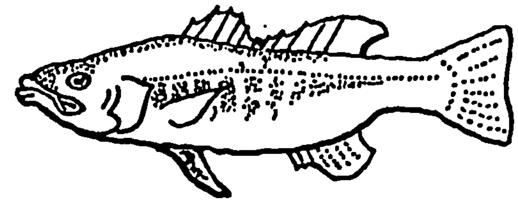


Smallmouth Bass (Micropterus dolomieu)

Introduced in 1953. Ranges from one-half to three pounds. Distinguished from the Largemouth Bass by a less deeply-notched dorsal fin. Carnivorous. Mouth ends in front of eye.

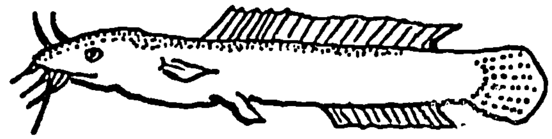


Largemouth Bass (Micropterus salmoides)



Introduced in 1908. Ranges from one to seven pounds. Has a more deeply-notched dorsal fin than the Smallmouth Bass. Mouth extends beyond the eye.

Chinese Catfish (Clarius fuscus)



Introduced around 1900. Inhabits muddy bottoms of taro patches, streams and ditches. Color ranges from black to flesh-colored.

Reference: Morita, Clyde M., Freshwater Fishing in Hawaii, Department of Planning & Economic Development, State of Hawaii, 1981.

DOI: EMI SHOULD BE DENIED PERMIT

Recommends Hanawi Stream be left alone
Brian Thornton, Staff Writer

East Maui Irrigation (EMI) Co. should be denied a county permit to take 10 million gallons of water per day from the Hanawi Stream near Nahiku, according to a recommendation to the Maui Planning Commission prepared by Honolulu attorney Masato Doi.

The commission does not have to follow Doi's recommendation.

Doi, a retired circuit judge, acted recently as a county-hired hearings officer (or judge) in a contested case in which the Legal Aid Society of Hawaii and numerous East Maui residents protested EMI's plans to take water from Hanawi Stream.

EMI said the water was needed to expand sugar production. The Planning Commission was asked to approve a Special Management Area (SMA) permit for EMI to siphon off the water.

Doi, in a "final findings of fact and conclusions of law" report to the commission released Wednesday, said "the evidence indicates a great risk that (EMI's) project will have a substantial adverse environmental and ecological effect" on Hanawi Stream.

He continued: "There has also been no showing that any compelling public interest (in having the SMA permit for EMI granted) would be served that would clearly outweight the adverse effects of the project at this time."

Doi went on to say "Hanawi is one of the few remaining essentially pristine, perennial streams in the state ... It has a large minimum flow on a continuous basis with waters of a cool temperature ... making it a unique valuable habitat for abundant stream fauna.

"Hanawi ranks as one of the highest in the state in environmental and ecological quality. It has the highest abundance ratio of native to introduced plant and fish species among all the streams in the state. [illegible] constitutes a major habitat for various freshwater fauna, including various species of o'opu (goby), hihiwai (freshwater mollusk) and 'opae (shrimp). It is also a prime habitat of a species of o'opu alamao'o that is possibly threatened or endangered, Doi said.

In summary, Doi said Hanawi Stream "is a significant educational and research resource and a valuable coastal ecosystem because of its abundant fauna."

Doi wrote that after reviewing arguments on both sides in the case he has decided that EMI's water drainage plans would cause "a significant and substantial adverse decrease in stream habitat."

His opinion would appear to be a major victory for the Hana Community Association and Keanae-Waiuanui Co-op, citizens activist groups that strongly oppose EMI's plans for Hanawi Stream.

All of the parties involved in the EMI/Hanawi Stream issue now have 10 days to respond to Doi's report and make any possible appeals of it known.

The county planning commission now has 45 days from the time it received Doi's report to make its final decision on whether to grant EMI's permit request.

If the commission takes no action at all after 45 days, the permit automatically will be approved under county rules.

In the majority of contested cases like this one, the commission usually goes along with the recommendation of its hearings officer. But it is not clear in this case whether that will happen, since several county agencies have come out in favor of EMI's plans, including the water department.

EMI also has repeatedly emphasized to the planning commission that water from Hanawi Stream would be pumped into the Wailoa ditch, which supplies Hawaiian Commercial & Sugar Co. mi[illegible]nd upcountry sugarcane fields as well as the county water department.

Brian Thornton, Staff Writer. Maui News, September 6, 1980.

PLANKTON NET CONSTRUCTION

PLANKTON

In the study of ocean life, it is with the plankton that all things begin. The word plankton means "drifter" or wanderer. Hence all plankton are those creatures that must drift at the mercy of the currents because they are either too weak or too small to swim against those forces. These organisms are the foundation of the aquatic food chain.

The kinds of things included in the plankton are such things as larval fish, baby crabs, tiny shrimp, bug-like creatures called copepods, one-celled plants called phytoplankton, and many other tiny creatures of the sea.

The plankton live in the surface waters of the ocean, and serve as the ultimate food source for many of the sea's larger creatures.

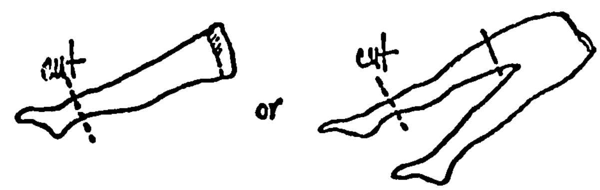
A HOMEMADE PLANKTON NET

Scientists have special nets with which to capture plankton. The net is towed through the water behind a ship for 5 to 10 minutes, then is brought aboard for examination. This is how you can make a net using simple materials you find around the house.

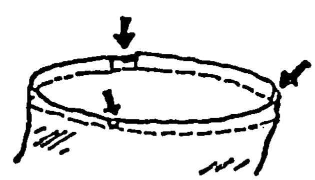
MATERIALS NEEDED: nylon stocking or pantyhose, scissors, needle and thread, wire clothes hanger, pliers, about 15 feet of line, and a baby food jar.

STEP 1: Form a ring from the wire hanger, twisting the ends to form a smooth joint.

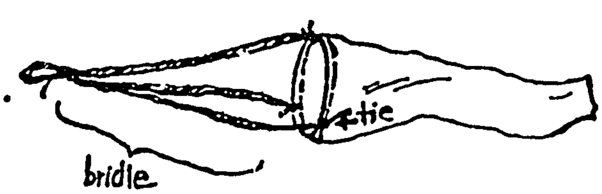
STEP 2: Cut the stocking as in the diagram.



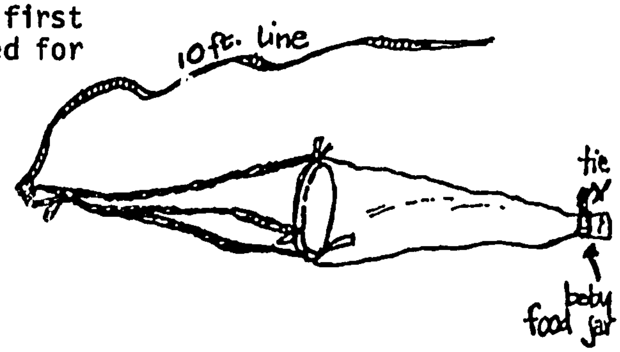
STEP 3: Sew the stocking onto the ring, leaving 3 evenly spaced ¼" gaps where the bridle will be tied.



STEP 4: Fashion a bridle, knotting three 2' lengths of line together on one end. Tie the other ends to the hoop at the gaps.



STEP 5: Sew a hem on the other end of the stocking net so that it does not ravel. Then tie the jar on to the end of the completed net. Add a line about 10' in length to the bridle. Now you are ready for your first stream tow. (A longer line is needed for an ocean plankton tow from a boat.)

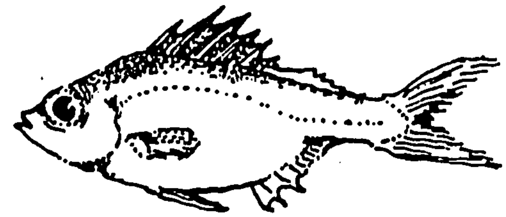


Rose Pfund, Editor. "Teacher's Guide," Makahiki Kai, 1977.

IDENTIFICATION GUIDE TO LIFE IN HAWAIIAN ESTUARIES

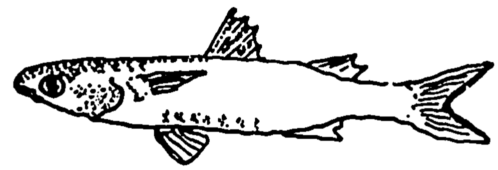
Juvenile Aholehole (Kuhlia sandwicensis)

Similar in appearance to mullet, but deeper-bodied; also the tail is more forked, with a black trailing edge. Solitary or schooling. Feed on plankton.



Juvenile Mullet (Mugil cephalus)

Gray to silvery, swim in schools, feed on algae, 2 to 3 inches in length.



'O'opu naniha (Awaous genivittatus))

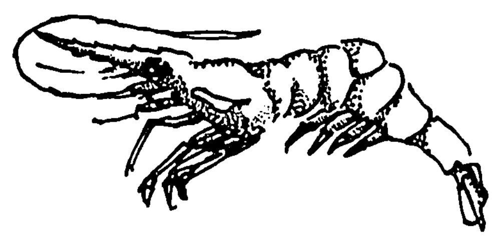
A small native goby; grows up to 6 inches in length. Recognized by 12 dark vertical bars on the body. Herbivorous.

'O'opu okuhe or akupa (Eleotris sandwicensis)

Similar to a goby, but lacks the fused pelvic fins. Grows up to 10 inches in length. Carnivorous. Endemic. Dark above, light underneath.

'Opae-huna (Palaemon debilis)

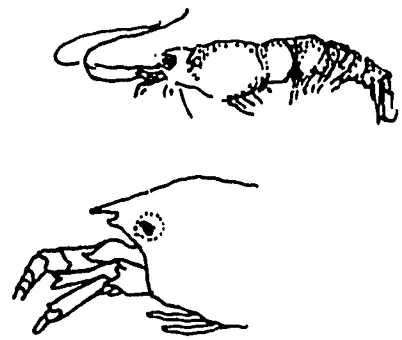
A transparent shrimp with small patches of black and white over the body. Probably feeds on detritus. To 1 inch in length.



'Opae-ula (Halocaridina rubra)

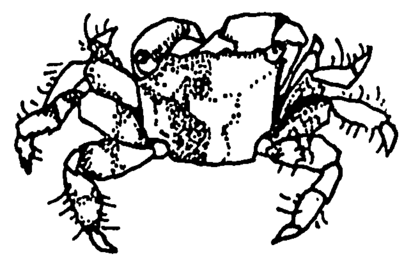
A small red shrimp endemic to Hawai'i and found only in this habitat. Feeds on benthic algae, detritus and phytoplankton. Has brush-like pincers. About ¼ inch in length.

Red Shrimp (Metabetaeus lohena)



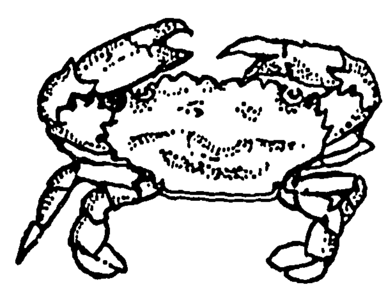
Like the previously mentioned 'Opae-ula, this shrimp is also red, endemic and found only in this habitat. However, this species is twice as large (½ inch), and is carnivorous, preying upon the 'Opae-ula. Other differences that help to identify this shrimp are the abdomen is red and pink striped, their eyes are covered by a clear portion of the carapace and, they have pincers. They are often seen chasing the smaller red shrimp.

Black crab (Metopograpsus thunkuhar)



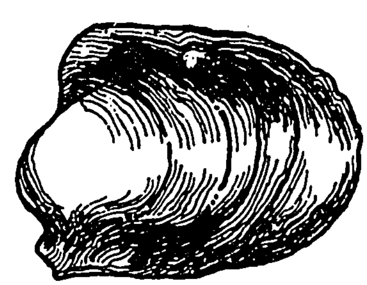
This small crab is about 3/4 inch across the body. Usually dark, may be speckled. Found along the shores of the ponds or in holes in the mud. Semi-terrestrial (able to live out of water part of the time). Herbivorous.

Swimming crab (Thalamita crenata)



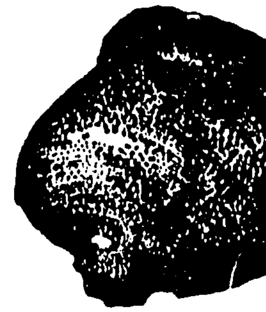
Small crabs easily recognized by the paddle-shaped last pair of legs that are used to scull through the water. About 1 inch across the back. Color is mottled brown with blue pincers. Feeds on plants and detritus.

Hapa-wai (Theodoxus vespertinus)



A limpet-like snail about ½ inch in length. Olive to brown in color. These herbivores graze algae off rocks. Endemic to Hawai'i.

Pipi-wai (Theodoxus caricsus)



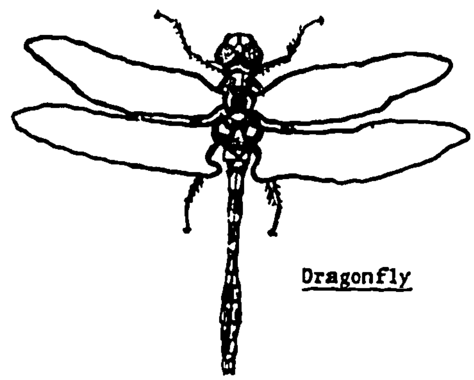
Similar to T. vespertinus, but often wider than long. Black in color. About ½ inch long. Endemic. Herbivorous.

'Okohekohe, barnacles (Chthamalus intertextus)

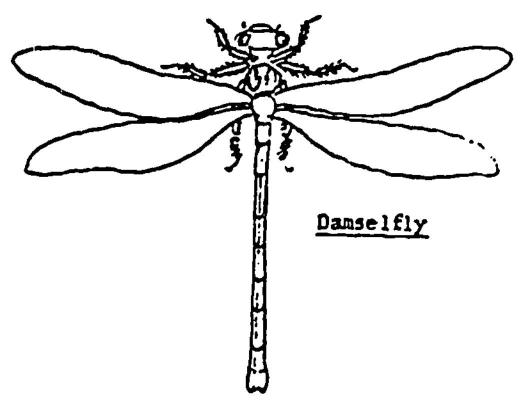
These barnacles incrust rocks and concrete piers between the tide marks. Color is light purple. Base of the shell is ribbed and wrinkled. About 1/4 inch across the base. Jointed fanlike appendages filter phytoplankton from the water.

Dragonflies and damselflies (Odonata)

Common in areas of freshwater. These insects are predators, feeding on smaller flying insects.



Dragonfly



Damselfly

TABLES FOR CONVERSION OF SPECIFIC GRAVITY TO SALINITY

TABLE I: Specific Gravity/Temperature Corrections

Observed Reading	Temperature of Water in Graduated Cylinder (°C)									
	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	18.5	19.0
0.9960										
0.9970										
0.9980							3	4	5	6
0.9990	-4	-3	-2	-1	0	1	3	4	5	6
1.0000	-4	-3	-2	-1	0	1	3	4	5	6
1.0010	-4	-3	-2	-1	0	1	3	4	5	6
1.0020	-4	-3	-2	-1	0	1	3	4	5	6
1.0030	-4	-3	-2	-1	0	1	3	4	5	6
1.0040	-5	-4	-3	-1	0	2	3	5	6	6
1.0050	-5	-4	-3	-1	0	2	3	5	6	7
1.0060	-5	-4	-3	-1	0	2	3	5	6	7
1.0070	-5	-4	-3	-2	0	2	3	5	6	7
1.0080	-5	-4	-3	-2	0	2	3	5	6	7
1.0090	-5	-4	-3	-2	0	2	3	5	6	7
1.0100	-5	-4	-3	-2	0	2	3	5	6	7
1.0110	-5	-4	-3	-2	0	2	3	5	6	7
1.0120	-6	-4	-3	-2	0	2	3	5	6	7
1.0130	-6	-4	-3	-2	0	2	4	5	6	7
1.0140	-6	-4	-3	-2	0	2	4	5	6	8
1.0150	-6	-4	-3	-2	0	2	4	5	6	8
1.0160	-6	-5	-3	-2	0	2	4	6	7	8
1.0170	-6	-5	-3	-2	0	2	4	6	7	8
1.0180	-6	-5	-3	-2	0	2	4	6	7	8
1.0190	-6	-5	-3	-2	0	2	4	6	7	8
1.0200	-6	-5	-3	-2	0	2	4	6	7	8
1.0210	-6	-5	-3	-2	0	2	4	6	7	8
1.0220	-7	-5	-3	-2	0	2	4	6	7	8
1.0230	-7	-5	-4	-2	0	2	4	6	7	8
1.0240	-7	-5	-4	-2	0	2	4	6	7	8
1.0250	-7	-5	-4	-2	0	2	4	6	7	8
1.0260	-7	-5	-4	-2	0	2	4	6	7	9
1.0270	-7	-5	-4	-2	0	2	4	6	7	9
1.0280	-7	-6	-4	-2	0	2	4	6	8	9
1.0290	-7	-6	-4	-2	0	2	4	6	8	9
1.0300	-7	-6	-4	-2	0	2	4	6	8	9
1.0310	-8	-6	-4	-2	0	2	4			

TABLE I (Continued)

Observed Reading	Temperature of Water in Graduated Cylinder (°C) 19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0
0.9960										
0.9970					10	11	12	14	15	16
0.9980	7	8	9	10	11	12	13	14	15	16
0.9990	7	8	9	10	11	12	13	14	15	16
1.0000	7	8	9	10	11	12	13	14	15	16
1.0010	7	8	9	10	11	12	13	14	15	17
1.0020	7	8	9	10	11	12	13	14	16	17
1.0030	7	8	9	10	11	12	13	15	16	17
1.0040	7	8	9	10	11	12	14	15	16	17
1.0050	8	9	10	11	12	13	14	15	16	17
1.0060	8	9	10	11	12	13	14	15	16	18
1.0070	8	9	10	11	12	13	14	15	17	18
1.0080	8	9	10	11	12	13	14	16	17	18
1.0090	8	9	10	11	12	13	15	16	17	18
1.0100	8	9	10	11	12	14	15	16	17	18
1.0110	8	9	10	12	13	14	15	16	17	19
1.0120	8	9	10	12	13	14	15	16	18	19
1.0130	8	10	11	12	13	14	15	16	18	19
1.0140	9	10	11	12	13	14	15	17	18	19
1.0150	9	10	11	12	13	14	16	17	18	20
1.0160	9	10	11	12	13	14	16	17	18	20
1.0170	9	10	11	12	13	15	16	17	18	20
1.0180	9	10	11	12	14	15	16	17	19	20
1.0190	9	10	11	12	14	15	16	18	19	20
1.0200	9	10	11	13	14	15	16	18	19	20
1.0210	9	10	12	13	14	15	17	18	19	21
1.0220	9	11	12	13	14	15	17	18	19	21
1.0230	9	11	12	13	14	16	17	18	20	21
1.0240	10	11	12	13	14	16	17	18	20	21
1.0250	10	11	12	13	15	16	17	18	20	21
1.0260	10	11	12	13	15	16	17	19	20	22
1.0270	10	11	12	14	15	16	17	19	20	22
1.0280	10	11	12	14	15	16	18	19	20	22
1.0290	10	11	13	14	15	16	18	19	21	22
1.0300	10	11	13	14	15	16	18			
1.0310										

TABLE I (Continued)

Observed Reading	Temperature of Water in Graduated Cylinder (°C) 24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0	28.5	29.0
0.9960			19	20	21	23	24	25	27	28
0.9970	17	18	19	20	22	23	24	26	27	28
0.9980	17	18	19	21	22	23	25	26	27	29
0.9990	17	18	20	21	22	24	25	26	28	29
1.0000	17	19	20	21	22	24	25	26	28	29
1.0010	18	19	20	21	23	24	25	27	28	30
1.0020	18	19	20	22	23	24	26	27	28	30
1.0030	18	19	21	22	23	25	26	27	29	30
1.0040	18	20	21	22	23	25	26	28	29	30
1.0050	19	20	21	22	24	25	26	28	29	31
1.0060	19	20	21	23	24	25	27	28	30	31
1.0070	19	20	21	23	24	26	27	28	30	31
1.0080	19	20	22	23	24	26	27	29	30	32
1.0090	19	21	22	23	25	26	28	29	30	32
1.0100	20	21	22	24	25	26	28	29	31	32
1.0110	20	21	22	24	25	27	28	30	31	32
1.0120	20	21	23	24	25	27	28	30	31	33
1.0130	20	22	23	24	26	27	29	30	32	33
1.0140	20	22	23	24	26	27	29	30	32	33
1.0150	21	22	23	25	26	28	29	31	32	34
1.0160	21	22	24	25	26	28	29	31	32	34
1.0170	21	22	24	25	27	28	30	31	33	34
1.0180	21	23	24	25	27	28	30	31	33	34
1.0190	21	23	24	26	27	29	30	32	33	35
1.0200	22	23	24	26	27	29	30	32	33	35
1.0210	22	23	25	26	27	29	31	32	34	35
1.0220	22	23	25	26	28	29	31	32	34	36
1.0230	22	24	25	26	28	30	31	33	34	36
1.0240	22	24	25	27	28	30	31	33	34	36
1.0250	23	24	25	27	28	30	31	33	35	36
1.0260	23	24	26	27	29	30	32	33	35	37
1.0270	23	24	26	27	29	30	32	34	35	37
1.0280	23	25	26	28	29	31	32			
1.0290	23									
1.0300										
1.0310										

TABLE I (Continued)

Observed Reading	Temperature of Water in Graduated Cylinder (°C)							
	29.5	30.0	30.5	31.0	31.5	32.0	32.5	33.0
0.9960	29	31	32	34	35	37	38	40
0.9970	30	31	33	34	36	37	39	40
0.9980	30	31	33	34	36	38	39	41
0.9990	30	32	33	35	36	38	39	41
1.0000	31	32	34	35	37	38	40	41
1.0010	31	32	34	35	37	39	40	42
1.0020	31	33	34	36	37	39	41	42
1.0030	32	33	35	36	38	39	41	42
1.0040	32	33	35	36	38	40	41	43
1.0050	32	34	35	37	38	40	42	43
1.0060	32	34	36	37	39	40	42	44
1.0070	33	34	36	38	39	41	42	44
1.0080	33	35	36	38	39	41	43	[illegible]
1.0090	33	35	36	38	40	41	43	[illegible]
1.0100	34	35	37	38	40	42	43	45
1.0110	34	36	37	39	40	42	44	45
1.0120	34	36	37	39	41	42	44	46
1.0130	35	36	38	39	41	43	44	46
1.0140	35	36	38	40	41	43	45	46
1.0150	35	37	38	40	42	43	45	47
1.0160	35	37	39	40	42	44	45	47
1.0170	36	37	39	40	42	44	46	47
1.0180	36	38	39	41	42	44	46	48
1.0190	36	38	39	41	43	44	46	48
1.0200	37	38	40	41	43	45	47	48
1.0210	37	38	40	42	43	45	47	49
1.0220	37	39	40	42	44	45	47	49
[illegible]	37	39	41	42	44	46	47	49
[illegible]	37	39	41	42	44	46	48	49
1.0250	38	39	41	43	44	46	48	50
1.0260	38	40	41	43	45	46	48	50
1.0270	38	40						
1.0280								
1.0290								
1.0300								
1.0310								

TABLE II: Corresponding Densities and Salinities

Density	Salinity	Density	Salinity	Density	Salinity
0.9991	0.0	1.0026	4.5	1.0061	9.0
0.9992	0.0	1.0027	4.6	1.0062	9.2
0.9993	0.2	1.0028	4.7	1.0063	9.3
0.9994	0.3	1.0029	4.8	1.0064	9.4
0.9995	0.4	1.0030	5.0	1.0065	9.6
0.9996	0.6	1.0031	5.1	1.0066	9.7
0.9997	0.7	1.0032	5.2	1.0067	9.8
0.9998	0.8	1.0033	5.4	1.0068	9.9
0.9999	0.9	1.0034	5.5	1.0069	10.1
1.0000	1.1	1.0035	5.6	1.0070	10.2
1.0001	1.2	1.0036	5.8	1.0071	10.3
1.0002	1.3	1.0037	5.9	1.0072	10.5
1.0003	1.5	1.0038	6.0	1.0073	10.6
1.0004	1.6	1.0039	6.2	1.0074	10.7
1.0005	1.7	1.0040	6.3	1.0075	10.8
1.0006	1.9	1.0041	6.4	1.0076	11.0
1.0007	2.0	1.0042	6.6	1.0077	11.1
1.0008	2.1	1.0043	6.7	1.0078	11.2
1.0009	2.2	1.0044	6.8	1.0079	11.4
1.0010	2.4	1.0045	6.9	1.0080	11.5
1.0011	2.5	1.0046	7.1	1.0081	11.6
1.0012	2.6	1.0047	7.2	1.0082	11.8
1.0013	2.8	1.0048	7.3	1.0083	11.9
1.0014	2.9	1.0049	7.5	1.0084	12.0
1.0015	3.0	1.0050	7.6	1.0085	12.2
1.0016	3.2	1.0051	7.7	1.0086	12.3
1.0017	3.3	1.0052	7.9	1.0087	12.4
1.0018	3.4	1.0053	8.0	1.0088	12.6
1.0019	3.5	1.0054	8.1	1.0089	12.7
1.0020	3.7	1.0055	8.2	1.0090	12.8
1.0021	3.8	1.0056	8.4	1.0091	12.9
1.0022	3.9	1.0057	8.5	1.0092	13.1
1.0023	4.1	1.0058	8.6	1.0093	13.2
1.0024	4.2	1.0059	8.8	1.0094	13.3
1.0025	4.3	1.0060	8.9	1.0095	13.5

TABLE II: Corresponding Densities and Salinities (Continued)

Density	Salinity	Density	Salinity	Density	Salinity
1.0096	13.6	1.0131	18.2	1.0166	22.7
1.0097	13.7	1.0132	18.3	1.0167	22.9
1.0098	13.9	1.0133	18.4	1.0168	23.0
1.0099	14.0	1.0134	18.6	1.0169	23.1
1.0100	14.1	1.0135	18.7	1.0170	23.3
1.0101	14.2	1.0136	18.8	1.0171	23.4
1.0102	14.4	1.0137	19.0	1.0172	23.5
1.0103	14.5	1.0138	19.1	1.0173	23.7
1.0104	14.6	1.0139	19.2	1.0174	23.8
1.0105	14.8	1.0140	19.3	1.0175	23.9
1.0106	14.9	1.0141	19.5	1.0176	24.1
1.0107	15.0	1.0142	19.6	1.0177	24.2
1.0108	15.2	1.0143	19.7	1.0178	24.3
1.0109	15.3	1.0144	19.9	1.0179	24.4
1.0110	15.4	1.0145	20.0	1.0180	24.6
1.0111	15.6	1.0146	20.1	1.0181	24.7
1.0112	15.7	1.0147	20.3	1.0182	24.8
1.0113	15.8	1.0148	20.4	1.0183	25.0
1.0114	16.0	1.0149	20.5	1.0184	25.1
1.0115	16.1	1.0150	20.6	1.0185	25.2
1.0116	16.2	1.0151	20.8	1.0186	25.4
1.0117	16.3	1.0152	20.9	1.0187	25.5
1.0118	16.5	1.0153	21.0	1.0188	25.6
1.0119	16.6	1.0154	21.2	1.0189	25.8
1.0120	16.7	1.0155	21.3	1.0190	25.9
1.0121	16.9	1.0156	21.4	1.0191	26.0
1.0122	17.0	1.0157	21.6	1.0192	26.1
1.0123	17.1	1.0158	21.7	1.0193	26.3
1.0124	17.3	1.0159	21.8	1.0194	26.4
1.0125	17.4	1.0160	22.0	1.0195	26.5
1.0126	17.5	1.0161	22.1	1.0196	26.7
1.0127	17.7	1.0162	22.2	1.0197	26.8
1.0128	17.8	1.0163	22.4	1.0198	26.9
1.0129	17.9	1.0164	22.5	1.0199	27.1
1.0130	18.0	1.0165	22.6	1.0200	27.2

TABLE II: Corresponding Densities and Salinities (Continued)

Density	Salinity	Density	Salinity	Density	Salinity
1.0201	27.3	1.0241	32.5	1.0281	37.3
1.0202	27.5	1.0242	32.7	1.0282	37.9
1.0203	27.6	1.0243	32.8	1.0283	38.0
1.0204	27.7	1.0244	32.9	1.0284	38.1
1.0205	27.8	1.0245	33.1	1.0285	38.2
1.0206	28.0	1.0246	33.2	1.0286	38.4
1.0207	28.1	1.0247	33.3	1.0287	38.5
1.0208	28.2	1.0248	33.5	1.0288	38.6
1.0209	28.4	1.0249	33.6	1.0289	38.8
1.0210	28.5	1.0250	33.7	1.0290	38.9
1.0211	28.6	1.0251	33.8	1.0291	39.0
1.0212	28.8	1.0252	34.0	1.0292	39.2
1.0213	28.9	1.0253	34.1	1.0293	39.3
1.0214	29.0	1.0254	34.2	1.0294	39.4
1.0215	29.1	1.0255	34.4	1.0295	39.6
1.0216	29.3	1.0256	34.5	1.0296	39.7
1.0217	29.4	1.0257	34.6	1.0297	39.8
1.0218	29.5	1.0258	34.8	1.0298	39.9
1.0219	29.7	1.0259	34.9	1.0299	40.1
1.0220	29.8	1.0260	35.0	1.0300	40.2
1.0221	29.9	1.0261	35.1	1.0301	40.3
1.0222	30.1	1.0262	35.3	1.0302	40.4
1.0223	30.2	1.0263	35.4	1.0303	40.6
1.0224	30.3	1.0264	35.5	1.0304	40.7
1.0225	30.4	1.0265	35.7	1.0305	40.8
1.0226	30.6	1.0266	35.8	1.0306	41.0
1.0227	30.7	1.0267	35.9	1.0307	41.1
1.0228	30.8	1.0268	36.0	1.0308	41.2
1.0229	31.0	1.0269	36.2	1.0309	41.4
1.0230	31.1	1.0270	36.3	1.0310	41.5
1.0231	31.2	1.0271	36.4	1.0311	41.6
1.0232	31.4	1.0272	36.6	1.0312	41.6
1.0233	31.5	1.0273	36.7	1.0313	41.9
1.0234	31.6	1.0274	36.8	1.0314	42.0
1.0235	31.8	1.0275	37.0	1.0315	42.1
1.0236	31.9	1.0276	37.1	1.0316	42.3
1.0237	32.0	1.0277	37.2	1.0317	42.4
1.0238	32.1	1.0278	37.3	1.0318	42.5
1.0239	32.3	1.0279	37.5	1.0319	42.7
1.0240	32.4	1.0280	37.6	1.0320	42.8

ALTERNATE ESTUARY FIELD TRIPS

I. Hanapepe Estuary

How to Get There:

From Highway 50, turn makai on Puolo Road, drive to Hanapepe Park. On the banks of the Hanapepe Estuary, walk down short dirt road to the estuary.

Restroom Facilities:

Restrooms, tables, a pavilion, and shade trees are located at the site.

On-site Activities:

Measure temperature and salinity in the ocean and along the river. Conduct a sand analysis study. This area has a high olivine content. Look for ghost crabs ('ohiki), juvenile fishes, o'opu, and identify coastal plants. Discuss the use of the shoreline here, and discuss why estuaries are important.

II. Kealia Estuary

How to Get There:

Kealia estuary is 1.8 miles north of Kapa'a. Park by the ironwoods next to the coastline.

Restroom Facilities:

Restroom facilities are available at Kapa'a Company Beach Park or Kapa'a High School with permission from the principal.

On-site Activities:

Measure temperature and salinity in the ocean and along the stream. Identify coastal plants. Monitor the presence of the sandbar at the mouth of the estuary over the year. How does its presence or absence affect the salinity of the water in the estuary? Look for birds, especially migratory species in the fall. In the estuary look for o'opu, aholehole, mullet, native prawns, and snails. Take a bag to pick up litter.

III. Hanama'ulu Estuary:

How to Get There:

This site is near the airport. Take Highway 56 and turn makai on Hanama'ula Street, then right on Hehi Street. You'll come to Hanama'ula Company Beach Park. Drive through the park to where the stream reaches the ocean.

Restroom Facilities:

Restroom facilities are available at the site.

On-site Activities:

Measure temperature and salinity, measure stream flow, look for stream animals.

SUGGESTED ADDITIONAL ACTIVITIES FOR ESTUARY FIELD TRIPS

Suggested Activities:

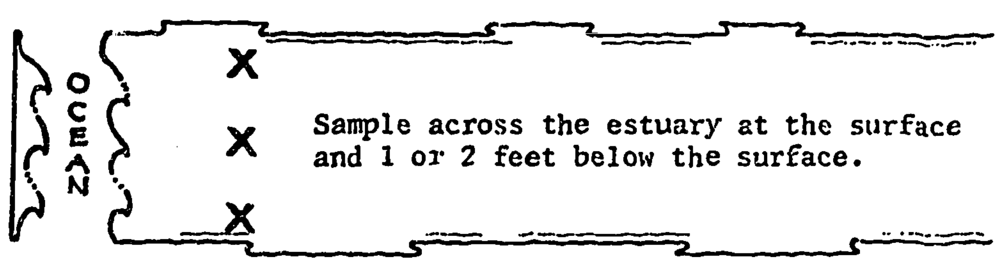
1. Have students do library research on characteristics of an estuary. Have them compare the sizes of continental estuaries with those found in Hawai'i.

2. Have students construct several models (papier mache, clay, etc.), illustrating the formation of an estuary. The students may begin by showing a newly formed land mass following it through wind. water and glacial erosion during an ice age, and ending with an ero i valley filled in by the melting of the polar ice caps.

3. As you drive out to the estuary you are going to study, you will probably pass several other estuaries along the way. Check a map and take a moment to stop at some of these. Have the class decide whether these are stream mouth or developed estuaries.

4. While stopped at an estuary, determine if the estuary is vertically or horizontally stratified. Students can take samples on the edge of the estuary, and in the center if the estuary is shallow. Use a plastic container with cover to collect the water samples. For collecting of water samples below the surface, submerge the empty container; then remove the cap to fill. Have students determine the salinity of the water samples collected. If the estuary is vertically stratified, you will find freshwater on the surface and saltwater beneath. If it is horizontally stratified saltwater will be found on the edges with freshwater in the center of the estuary.

Stream - Top View



5. Provide opportunity for students to become familiar with a technique for measuring salinity:

<u>Materials</u>:

100 ml graduated cylinder
Specific gravity hydrometer (must be shorter than the graduated cylinder)
Celsius (centigrade) thermometer
Three stock solutions: Tap water, sea water, and a 50-50 mixture of salt and freshwater
Tables I and II in Appendix G

<u>Procedure</u>:

1. Fill a 100 ml graduated cylinder about 2/3 full with seawater.

2. Gently lower the hydrometer into the water and give the stem a <u>gentle</u> downward tap. Be sure the hydrometer is clean and the surface of the water is free of floating material.

3. Set the cylinder on a level, solid surface and allow the float to reach an equilibrium position. The best way to read the scale on the hydrometer stem is to start with your eyes slightly below the plane of the water surface and slowly raise your eyes until the surface appears as a straight line.

4. Take the reading from the place where the line of the water surface crosses the scale. The reading you take from the scale will be the specific gravity of the water. Estimate this reading to the fourth decimal place (e.g. if you have a reading of 1.022, make that 1.0220). Take the temperature reading simultaneously.

5. Refer to Table I in Appendix G. Find your specific gravity on the left hand side of the page. Find your temperature at the top of the page (there are four pages of temperatures). Read across the page until you find a number where the values for temperature and specific gravity intersect. For example, if your specific gravity is 1.0220, and your temperature is 20°C, these two value intersect at 11. This value is the correction factor for the effect of temperature on salinity, and is added to the specific gravity of the water sample (e.g. 1.0220 + .0011 = 1.0231).

6. From Table II in Appendix G, read the value for salinity. In this case (1.0231) the salinity is 31.2 grams of salt per 1000 grams of water. This value is referred to in parts per thousand, so you would say that this sample had a salinity of 31.2 parts per thousand, and you would write it as 31.2 o/oo. Normal salinity in saltwater around Hawai'i is 33-35 o/oo.

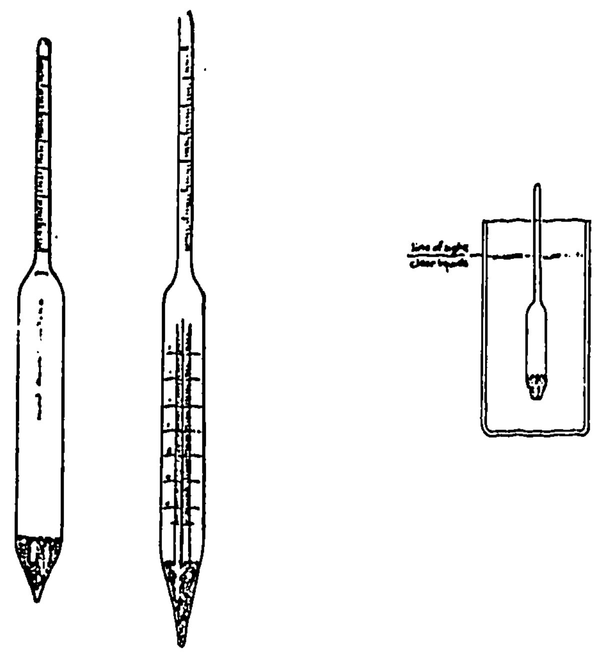


Figure 9

7. Repeat steps 1-6 for the remaining two samples.

Sample Data Sheet

Water Sample	Temperature	Specific Gravity	Salinity
1			
2			
3			

8. Compare your results with other teams in the class.

END

U.S. DEPT. OF EDUCATION

OFFICE OF EDUCATIONAL RESEARCH AND IMPROVEMENT (OERI)

ERIC®

DATE FILMED

MAR. 20, 1987