Klemm

Aquatic project WILD

Hawai'i Supplement

Aquatic Education Activity Guide

Writers
Hannah Bernard
David Hanaike
Randy Harr
Pete Hendricks
Randy Honebrink
Wade Ishikawa
Charlotte Izutsu
Karen Kimura
Marilyn Kubota
Grace Kwon
Charlotte Okada
Annette Tagawa
Brooks Tamaye
Kati Zimmerman

Editor
Randy Honebrink

Project Advisors
Carol Hopper
Colleen Murakami
Stephen Marble

Produced by the Education Program, Hawaii Division of Aquatic Resources

Funded in part by the Federal Aid in Sport Fish Restoration Program, U.S. Fish and Wildlife Service

Original illustrations by Sharon Oetting. Other illustrations as noted. *Project WILD* illustrations used with permission.
Photo page 89 by Scott Epperson, courtesy U.S. Coast Guard, 14th District. Photo page 73 courtesy Aquaculture Development Program.

Appendices 1, 2, 3, 5 from DOE's *Limu: Learning About Hawaii's Edible Seaweeds*
Appendices 6, 7, 8 from DOE's *Kaua'i: Streams and Estuaries*
Appendix 9 from DOE's *Coral: A Hawaiian Resource*

CONTENTS

USING THIS SUPPLEMENT *iv*

SECTION ONE
AWARENESS AND APPRECIATION

How Wet Is Our Planet 2
Water Plant Art 4
Are You Me? 6
Designing a Habitat 18

SECTION TWO
DIVERSITY OF VALUES

Water Canaries 22
Leapin' Limu Luau (Kelp Help) 28

SECTION THREE
ECOLOGICAL PRINCIPLES

The Edge Effect (The Edge of Home) 32
Blue Ribbon Niche 38
Wild Wanderings (Hooks and Ladders) 40
Fashion a Fish 46

SECTION FOUR
MANAGEMENT AND CONSERVATION

Migration Miracle (Migration Headache) 50
Aquatic Roots 56
Net Gain, Net Effect 60
Where Have All the Reef Fish Gone? 64
(Where Have All the Salmon Gone?)

SECTION FIVE
CULTURE AND WILDLIFE

Water We Eating? 70

SECTION SIX
TRENDS, ISSUES AND CONSEQUENCES

To Dam or Not to Dam 74
Facts and Falsehoods 80
Deadly Waters 84

SECTION SEVEN
RESPONSIBLE HUMAN ACTIONS

Waikahe (Dragonfly Pond) 90
Turtle Hurdles 96
Plastic Jellyfish 98
Watershed 100
Something's Fishy Here 106

APPENDICES

1 Limu Background Information 113
2 Limu Descriptive Information 118
3 Field Sites Suitable for Limu Study 123
4 Limu Pressing Handout 126
5 Limu Recipes 127
6 Identification of Native Stream Animals 128
7 Identification of Exotic Stream Animals 133
8 Identification of Estuarine Animals 137
9 Guide to Marine Invertebrates 140
10 Examples of Exotic Plants and Animals 147
11 Making an Egg-carton Turtle Puppet 150
12 Dangerous Marine Organisms 151
13 Fish Identification 154

USING THIS SUPPLEMENT

Both the original *Project WILD* and the subsequent *Project WILD Aquatic* were designed to provide teachers with activities that may be used to augment their existing curricula. These activities provide opportunities for variation to regular classroom activities in a number of subject areas and for different grade levels.

This Supplement was produced in order to make certain *Project WILD Aquatic* activities more relevant to the local environment, and more useful to Hawai'i's teachers. The degree to which existing activities were modified varies from minimal changes to complete revisions.

Changes to activities are fairly self-explanatory. If reference is made at the beginning of the activity to a *Project WILD Aquatic* activity, you should first become familiar with the original, then refer to the Supplement for recommended changes. Those sections within the activity which have no changes are indicated. In most cases, changes to sections involve adding, replacing or deleting background information or steps to the procedure. Unless noted, no change has been made to "Evaluation" sections.

If no reference is made to *Project WILD Aquatic* at the beginning of an activity, the activity can be used as is without reference to the original. However, you may still wish to refer to the box containing subject, skills, conceptual framework, etc. found in the original activity. The page number for the original activity is then located at the end of the Supplement activity.

References to page numbers in the original activity correspond to 1992 and later versions of *Project WILD Aquatic.* Recommended grade levels are noted at the end of Supplement activities; please note that in some cases these differ slightly from the original.

A few activities in the Supplement have a section titled "Correlations", which directs teachers to other existing local materials dealing with similar subject matter.

A number of original *Project WILD Aquatic* activities can be used without modification, and no reference is made to them in this Supplement.

The Division of Aquatic Resources appreciates your interest in this Supplement. Hopefully, you will find it a very worthwhile addition to your classroom materials. We would be grateful for any comments or suggestions on how to make the Supplement more useful.

Aquatic project WILD

Hawai'i Supplement

Aquatic Education Activity Guide

Project WILD is an interdisciplinary, supplementary environmental and conservation education program for educators of kindergarten through high school age young people.

HOW WET IS OUR PLANET?

Ref: *Project WILD Aquatic* Page 8

No change to:
OBJECTIVES
METHOD
MATERIALS
PROCEDURE

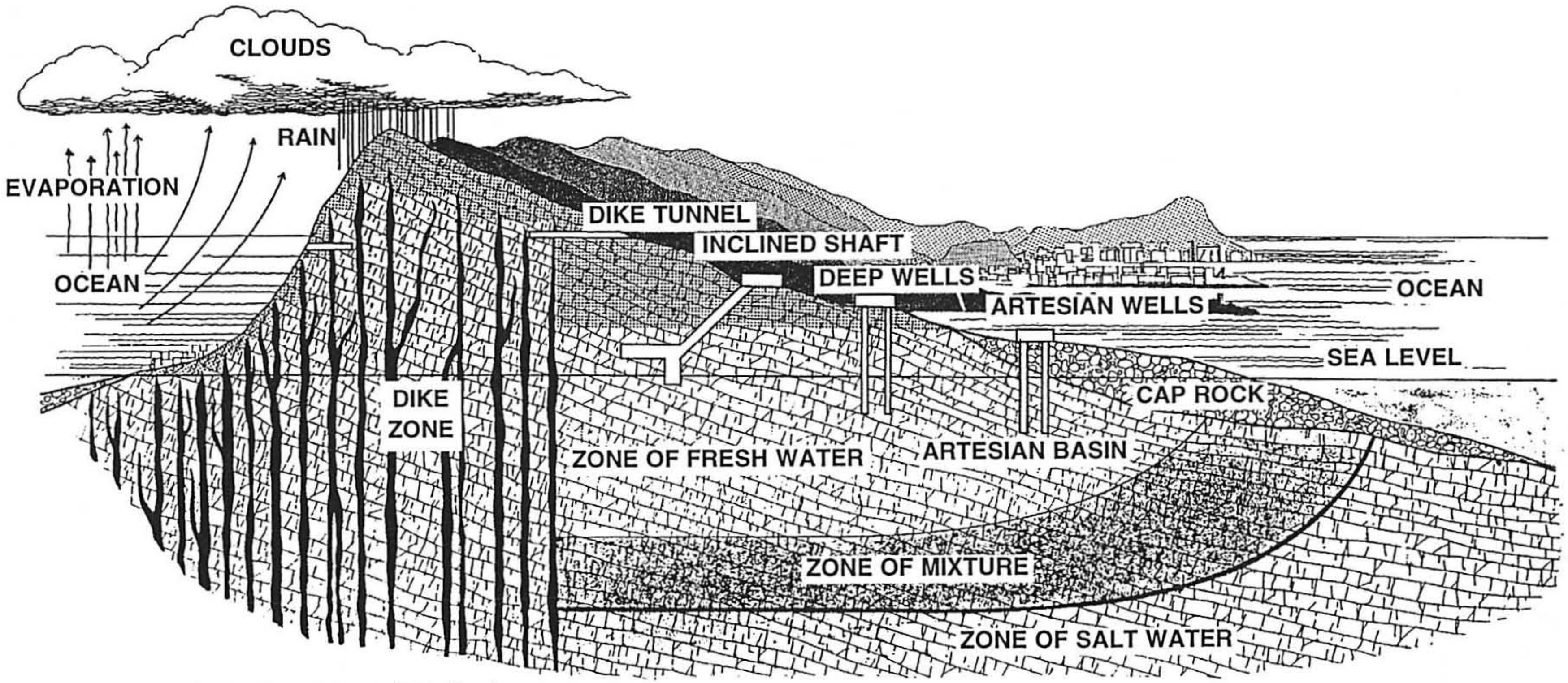
BACKGROUND
The following additional information may be interesting.
About one meter of water evaporates each year from the surface of the oceans. Roughly 91% of that returns to the ocean as rain, and the rest falls on land. Of the water which returns to the land, about 20% is temporarily stored as groundwater, and about 60% evaporates from freewater surfaces and from plants.

EXTENSIONS
Add:
5. Investigate the water cycle in the Hawaiian islands (see illustration on following page). Contact your local water supply department or board and report on sources of water for residential and agricultural uses. What makes your island's water supply unique compared with other islands?
6. Visit a pumping station or tunnel. Contact your county water supply agency for information on tours.

CORRELATIONS
A number of educational materials are available from the Honolulu Board of Water Supply, including activities books, comic books, board games, posters and brochures. Contact the Community Relations Section at 527-6120.

Age: Grades 6-12

OAHU'S WATER SOURCES



Courtesy Honolulu Board of Water Supply

WATER PLANT ART

Ref: *Project WILD Aquatic* Page 12

No change to:
OBJECTIVE
METHOD

BACKGROUND
Add:
Additional background information on Hawaiian limu (seaweeds), habitat and distribution can be found in Appendix 1.

Impress on students the importance of not removing the holdfast when limu is picked. A good comparison is mowing the lawn—if the roots are left alone, the lawn keeps growing back.

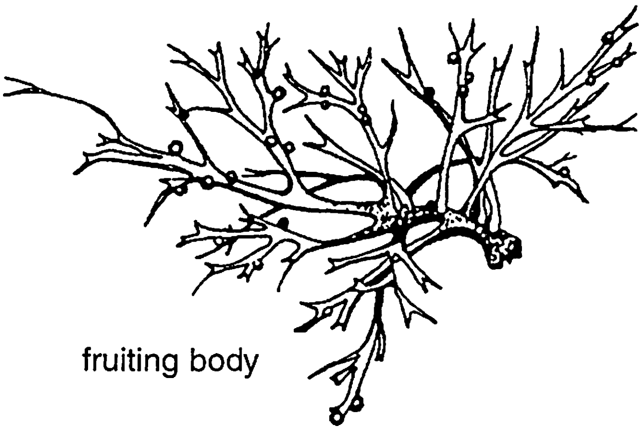
MATERIALS
Diagrams and descriptive information on a number of Hawaiian limu is given in Appendix 2. Additional sources are listed in "References". Coastal field sites suitable for limu collecting are listed in Appendix 3.

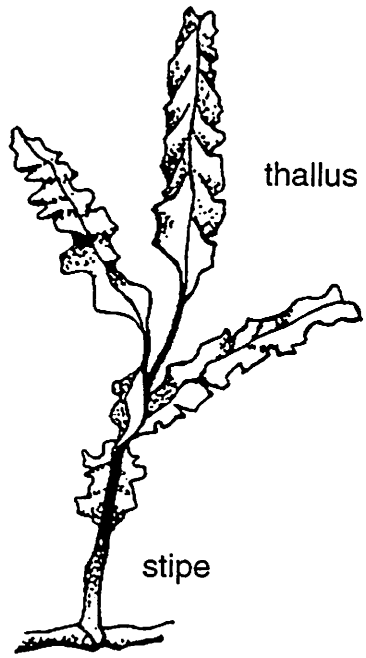
PROCEDURE
No change to steps 1 through 4.
Replace steps 5 through 12 with the slightly modified procedure given in Appendix 4. This page can be reproduced and distributed to students.

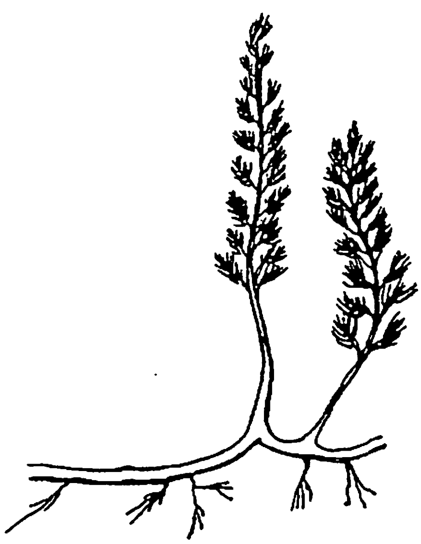
EXTENSIONS
Add:
6. Create models or stamps of limu and use them to discuss parts and uses.
a) Make a "fossil" of limu in clay. Place a piece of modeling clay in a jar cover or similar object (the size depends on the size of the piece of limu). Make an impression of the limu by firmly pressing it into the clay. Remove the limu and coat the impression with a thin layer of cooking oil. Pour in plaster of Paris or Fixal (Fixal is a bathroom tile plaster that is harder and dries faster than plaster of Paris; it is available at hardware stores). Remove the cast.
b) Pour rubber cement into the clay mold and see if a stamp can be made from it. Mount the stamp on a kamaboko board. It can be used to make stationary, wrapping paper, etc.
7. Graph by color the variety of limu found at a site or that the teacher has collected. Check with an identification key.
8. Collect several dried limu specimens from the shoreline. Have students predict which species each might be, then place it in a glass of saltwater. Use identification key to see if prediction was correct.
9. Have students assist in an "Eat Your Homework" session, in which limu is prepared and eaten. Several recipes are given in Appendix 5.

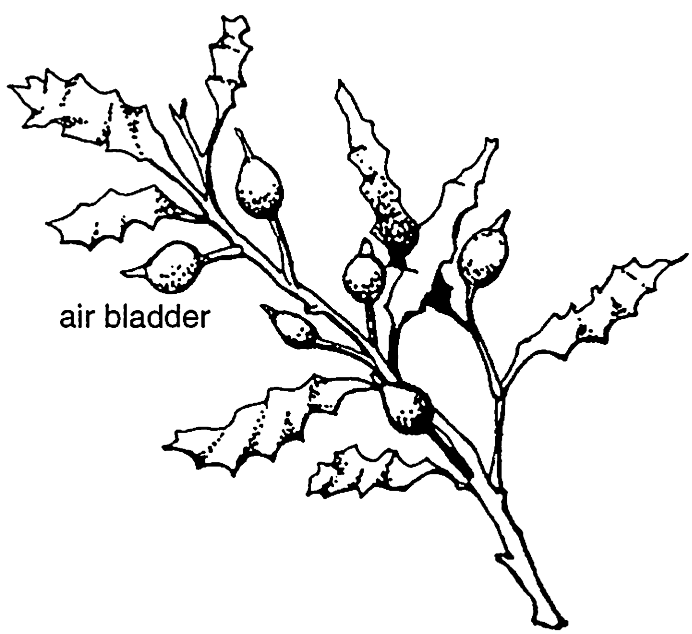
CORRELATIONS
DOE's *Limu: Learning About Hawaii's Edible Seaweeds* contains additional information and activities related to this topic.

Age: Grades K-5


fruiting body


thallus
stipe


holdfast


air bladder

ARE YOU ME?

Ref: *Project WILD Aquatic* Page 14

No change to:
OBJECTIVE
METHOD
MATERIALS

BACKGROUND
Add:
The following additional general information may be useful with regard to life histories of the animals pictured.

Phylum **Cnidaria:** Examples include corals and sea anemones, jellyfish, Portuguese man-o-war, hydras. Mostly marine animals; may be free swimming (*medusa* form) or attached (*polyp* form). Sac like body, one body opening surrounded by tentacles armed with stinging cells. Reproduce asexually (by budding) and sexually. Fertilization leads to free-swimming ciliated *planula* larvae, which may attach to the substrate. Planulae *metamorphose* into the polyp or medusa form.

Phylum **Mollusca:** Examples include snails and slugs, clams, octopuses and squid. Marine, freshwater, and land representatives. All have a tissue fold (mantle) covering the body. Most have a shell, secreted by the mantle, and a muscular foot. Eggs may be deposited on a surface or released into the water. Eggs of most develop through a veliger larval stage, then metamorphose into the juvenile form. Development of cephalopods (octopus, squid, etc.) is *direct*—no larval stage, hatchlings resemble the adult form.

Phylum **Arthropoda:** Examples include insects (e.g. butterflies, dragonflies, mosquitoes), crustaceans (e.g. lobsters, crabs), and arachnids (spiders, etc.). Most diverse animal phylum on earth. All have a segmented body, exoskeleton and jointed appendages. Depending on the class, development may be *indirect*, involving a larval stage and metamorphosis through a series of molts, or direct, in which hatchlings resemble the adult form.

Phylum **Echinodermata:** Examples include seastars, brittlestars, sea urchins, sea cucumbers. Entirely marine; almost all bottom dwellers. Body wall contains internal skeleton of plates and may include surface spines. Unique water vascular system, which includes tube feet, aids in movement, feeding, gas exchange and sensory reception. Larvae swim and feed by means of one or more ciliated bands that wind over the body. Larval stages undergo complex metamorphosis into the juvenile form.

Phylum **Chordata:** Examples include fishes (skates, sharks, eels, etc.), amphibians (frogs, etc.), reptiles (turtles, snakes, etc.), birds and mammals. Skate embryos develop within a protective capsule, while most sharks brood their offspring internally; development is direct. Eggs of many bony fishes hatch into free larvae which spend time as part of plankton, then metamorphose into juvenile form. Amphibian eggs must be laid in water; most develop into aquatic larvae that later metamorphose into terrestrial juveniles. Eggs of reptiles and birds are enclosed within a shell that provides protection and prevents dessication, but permits gas exchange; development of young is direct. Young of nearly all mammals develop internally, nourished by a placenta; development is also direct.

PROCEDURE
Follow the procedure as written but substitute the following pages for the animal cards. Be sure to trim off the animals' names when making the cards.

EXTENSIONS
Add:
5. Make a habitat—a diorama, large class mural or individual murals. Have students draw, mold

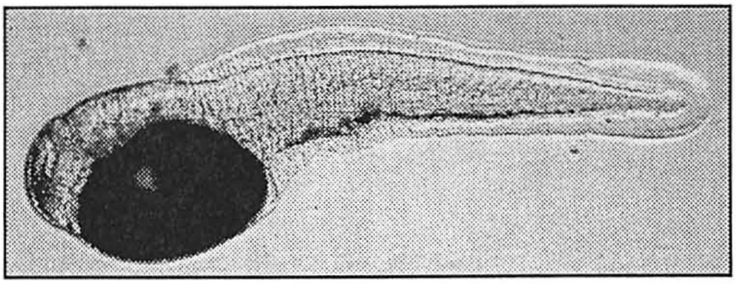
out of clay, or use these cards to place the adult and juvenile animals within the habitat to demonstrate life cycles and/or habitats.

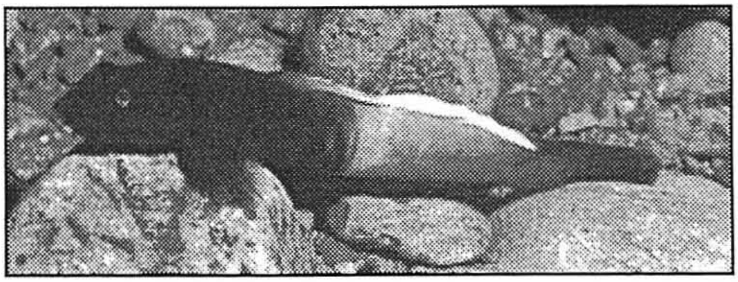
6. Make a mobile with adult and juvenile joined together with the same color yarn. The mobile could be of a particular habitat (stream, ocean, tidepool, etc.).

7. Group the adults by characteristics (legs vs. no legs, fins vs. no fins, etc.). Group juveniles by the same characteristics. Now see if the adults and juveniles match be the characteristic selected. This will emphasize how some animals change as they develop.

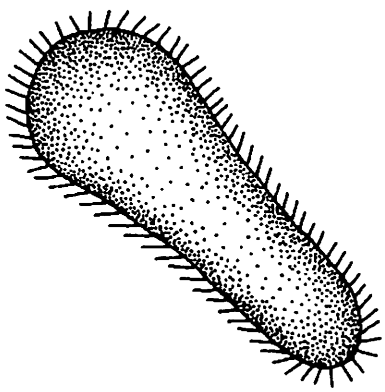
8. Use similarities in appearance at larval stage to show relationships between animals in the same phylum. Without referring to classification terms like phylum, class, etc., point out that some animals are more closely "related" than others. Refer to the background information above.

Age: Grades K-2

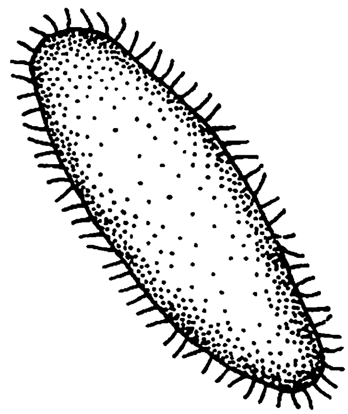


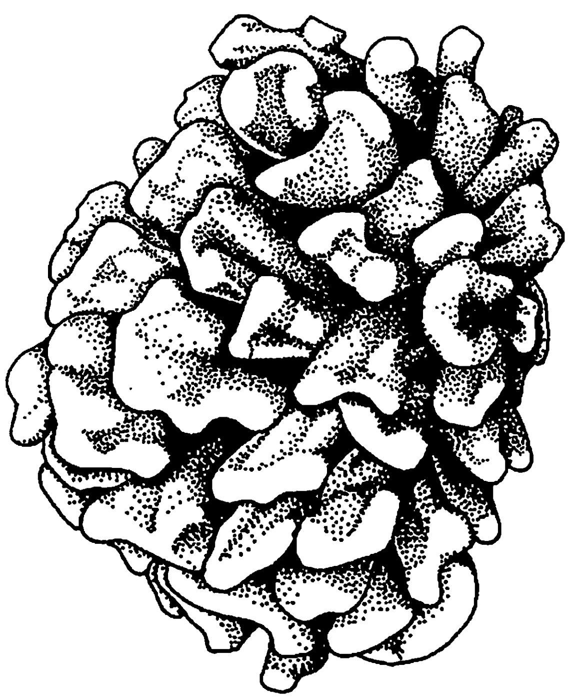


Coral Larva

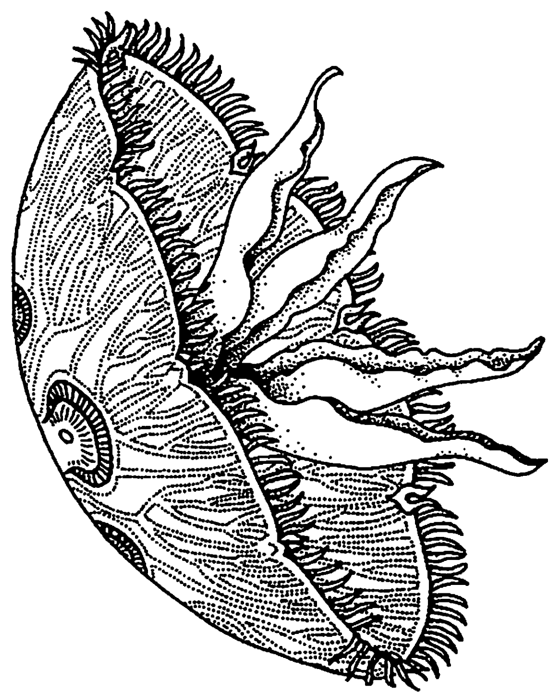


Jellyfish Larva



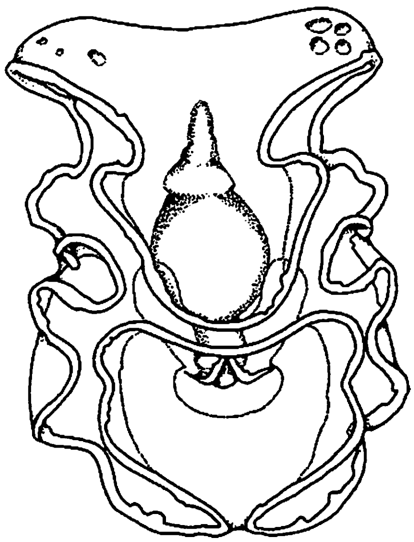


Coral

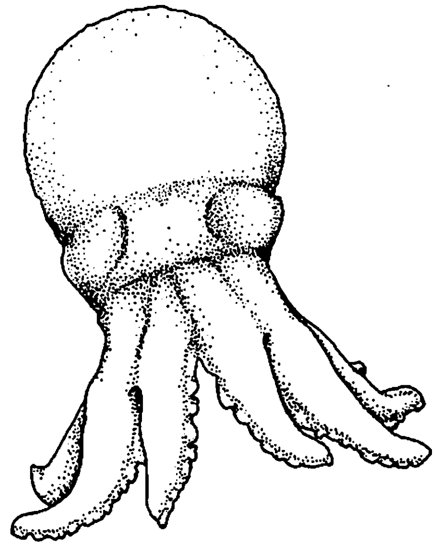


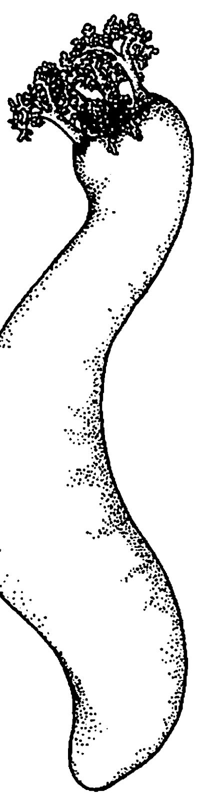
Jellyfish

Sea Cucumber Larva

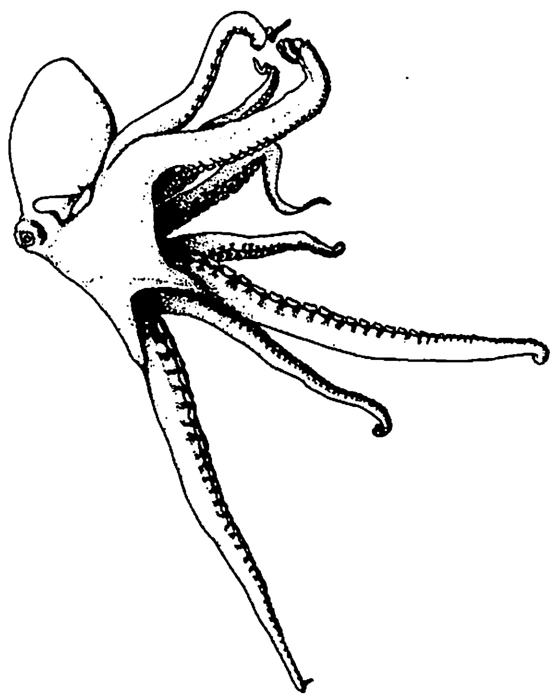


Young Octopus



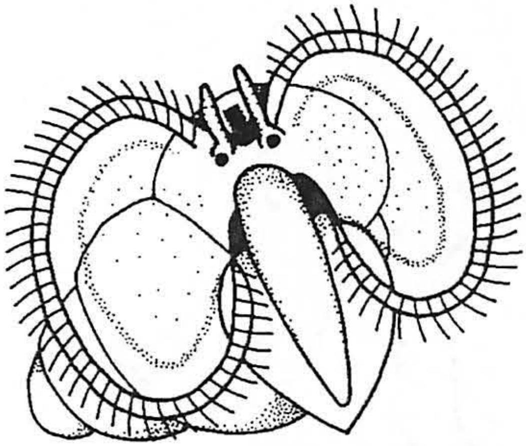


Sea Cucumber

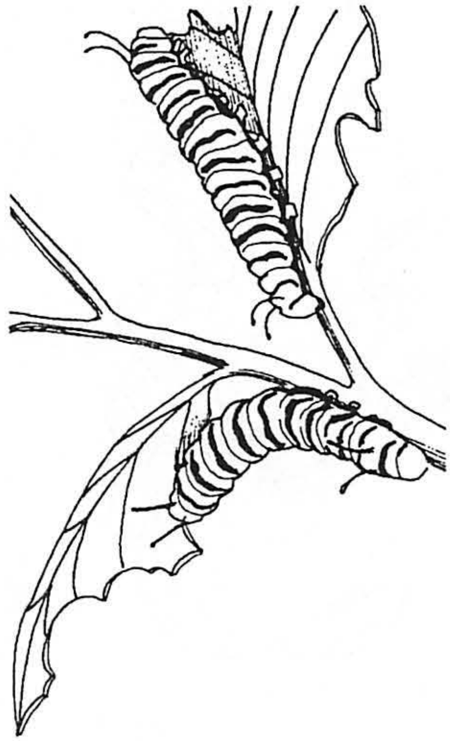


Octopus

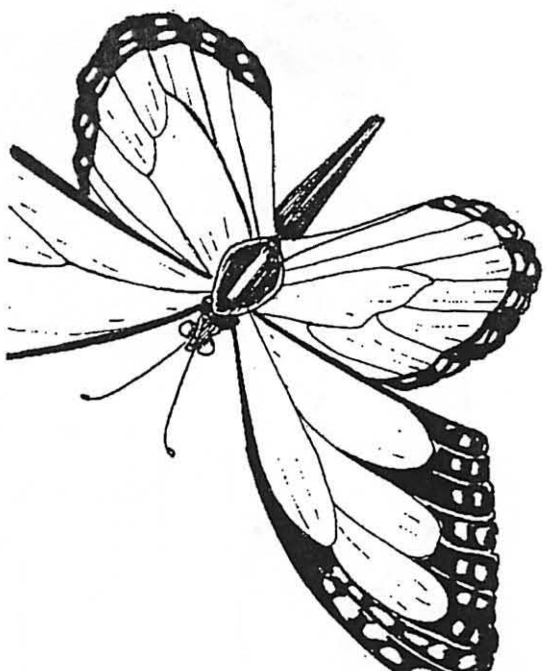
Cone Snail Larva



Butterfly Larvae

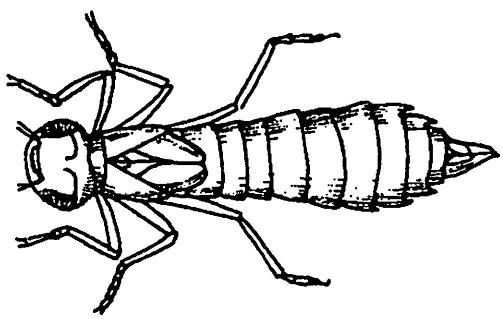


Cone Snail

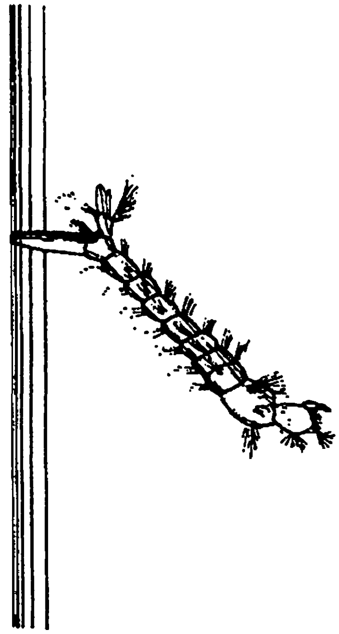


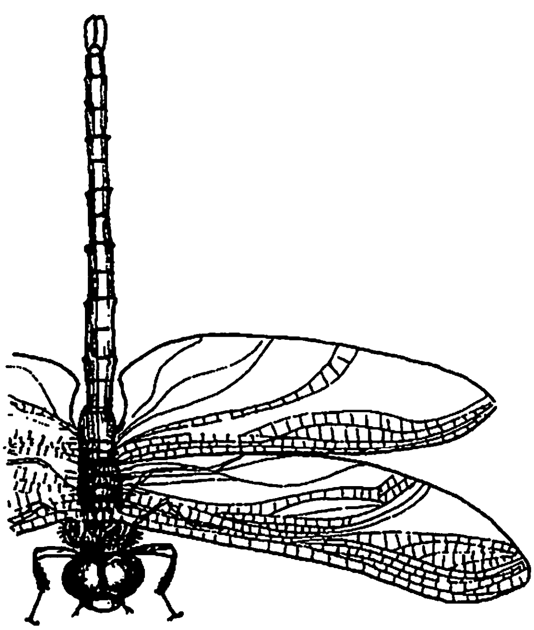
Butterfly

Dragonfly Nymph

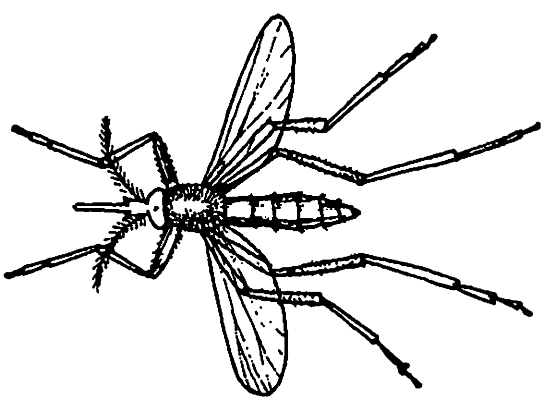


Mosquito Larva



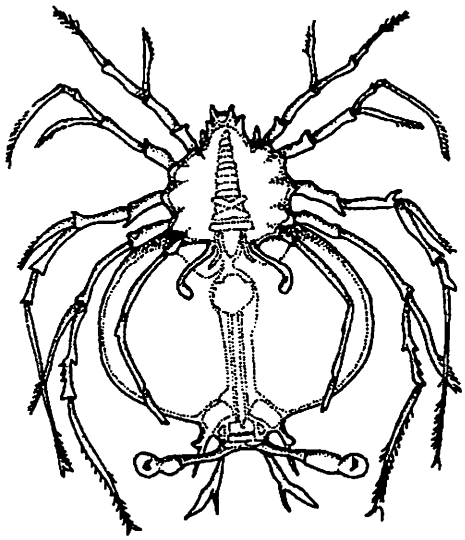


Dragonfly

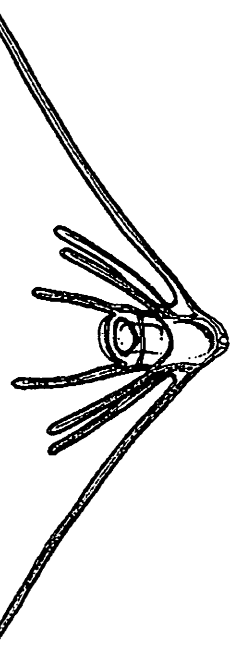


Mosquito

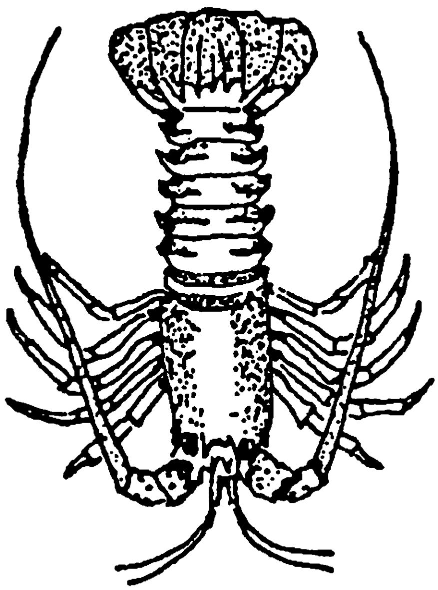
Spiny Lobster Larva



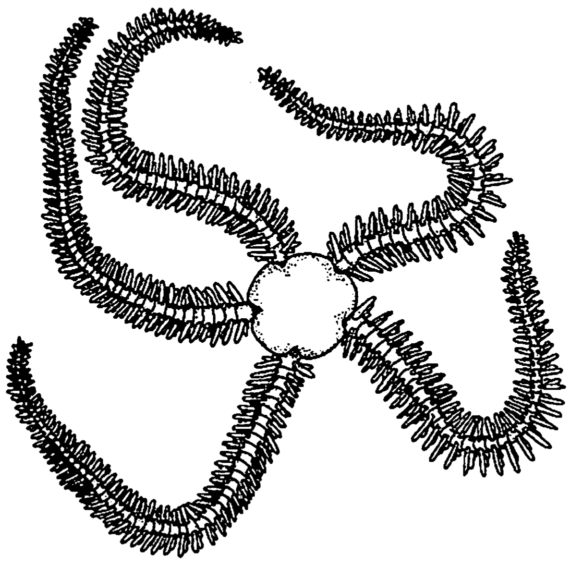
Brittlestar Larva



12

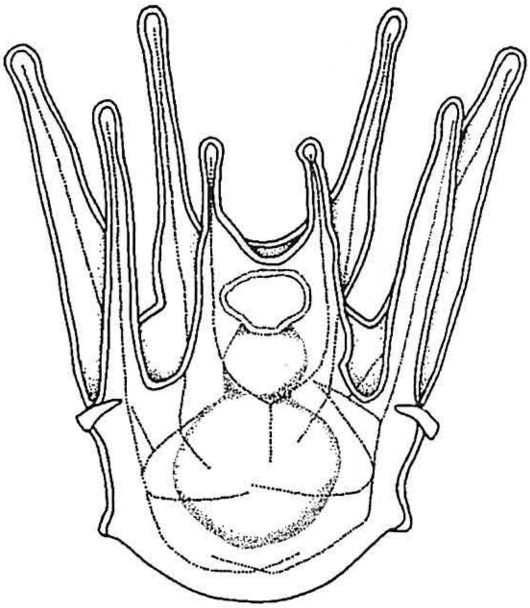


Spiny Lobster

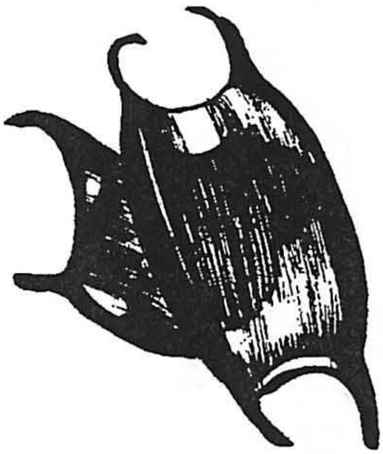


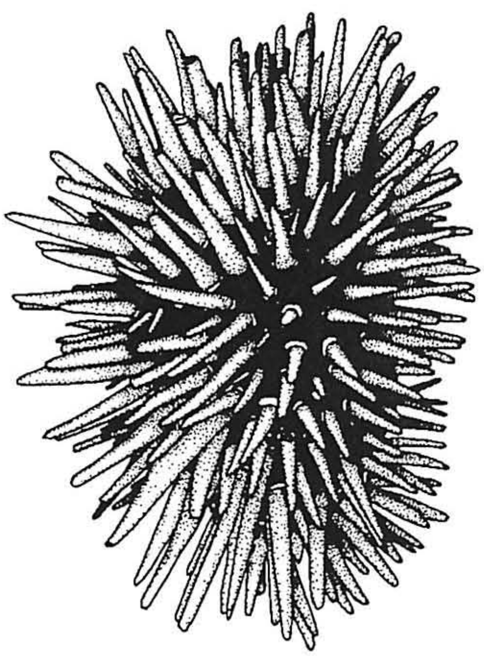
Brittlestar

Sea Urchin Larva

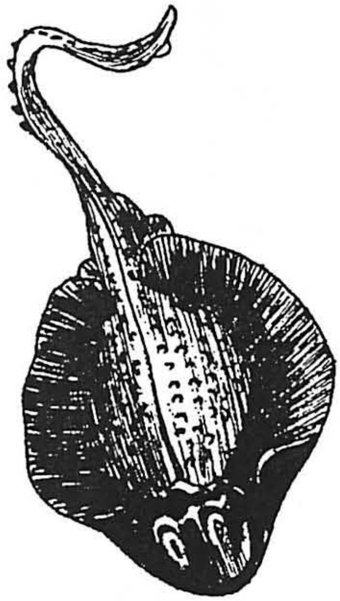


Skate Egg Cases



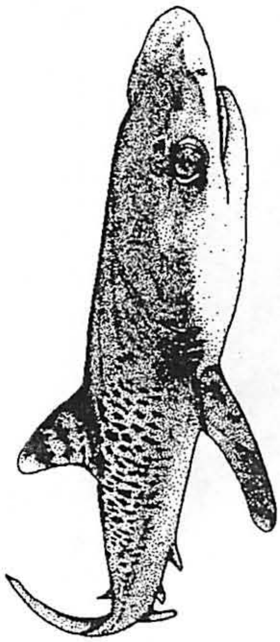


Sea Urchin

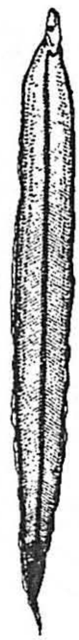


Skate

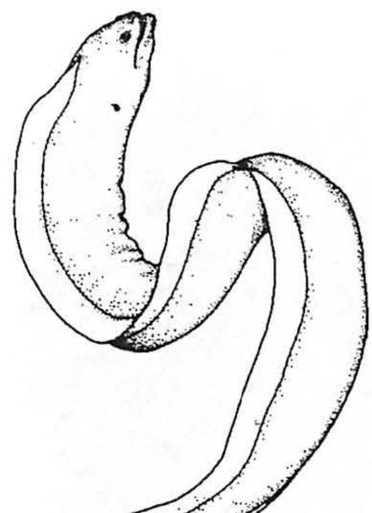
Young Tiger Shark



Eel Larva

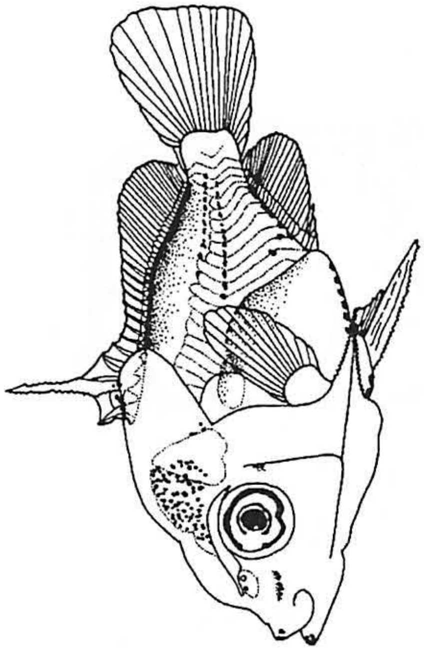


Tiger Shark

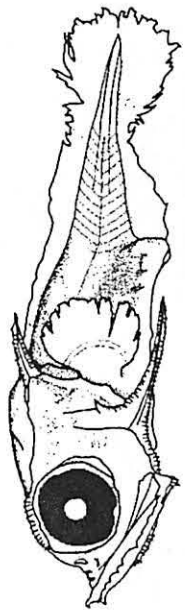


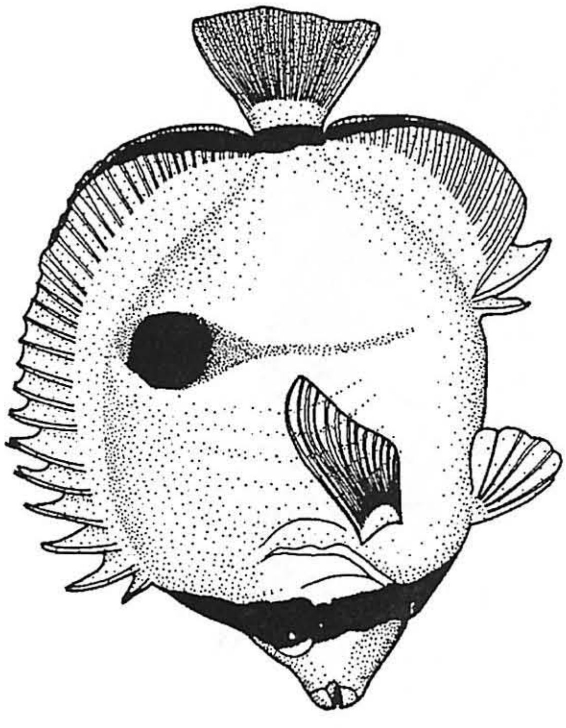
Eel

Butterflyfish Larva

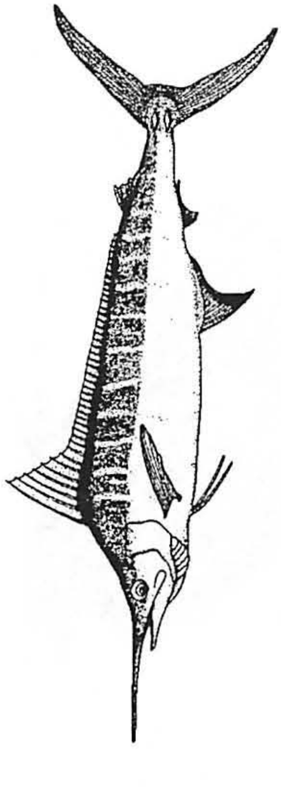


Billfish Larva



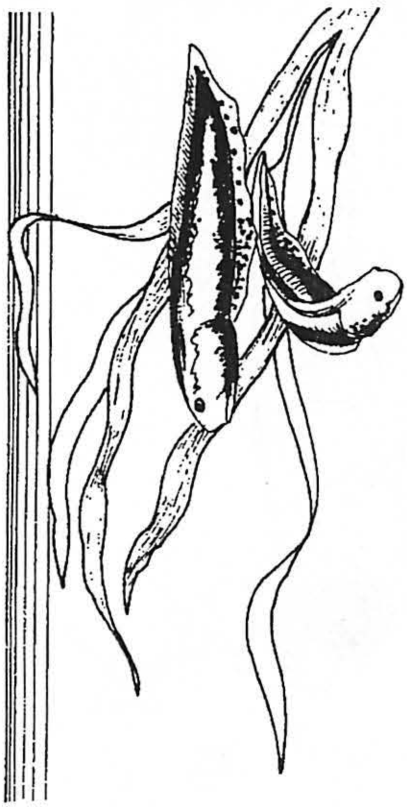


Butterflyfish

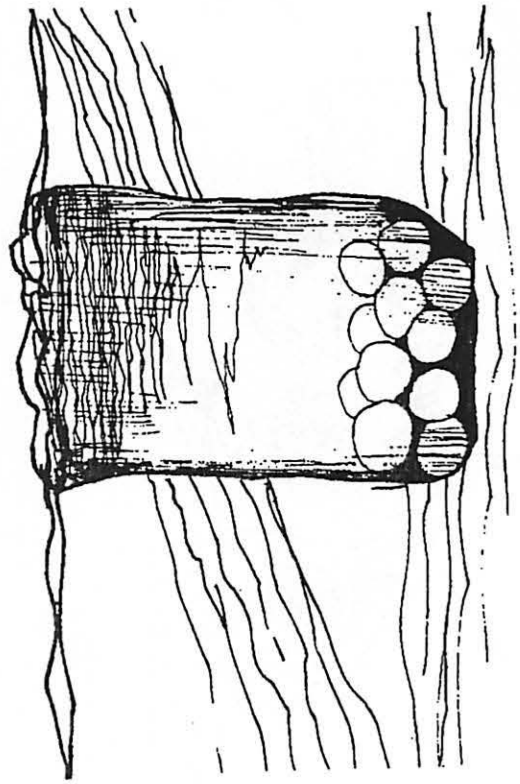


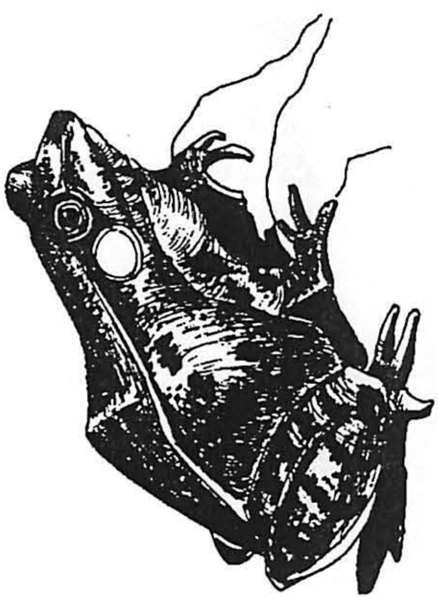
Billfish

Tadpoles

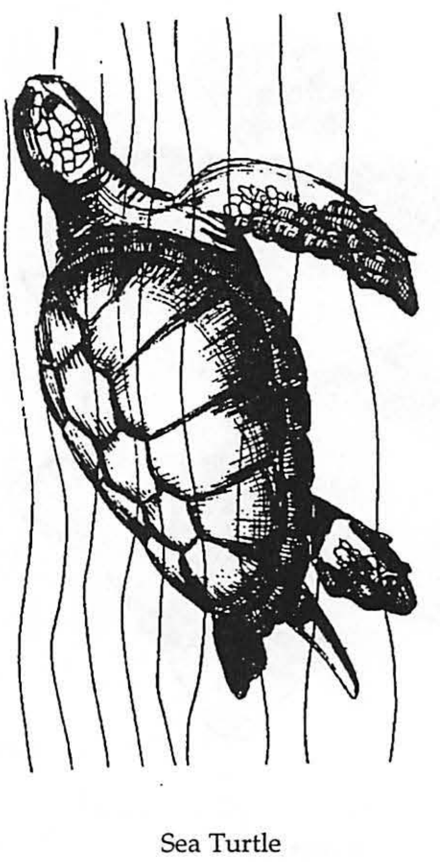


Sea Turtle Eggs





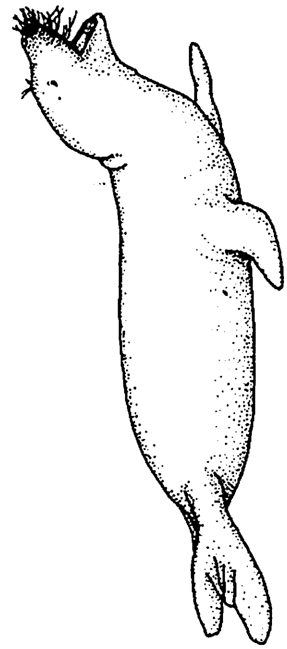
Frog



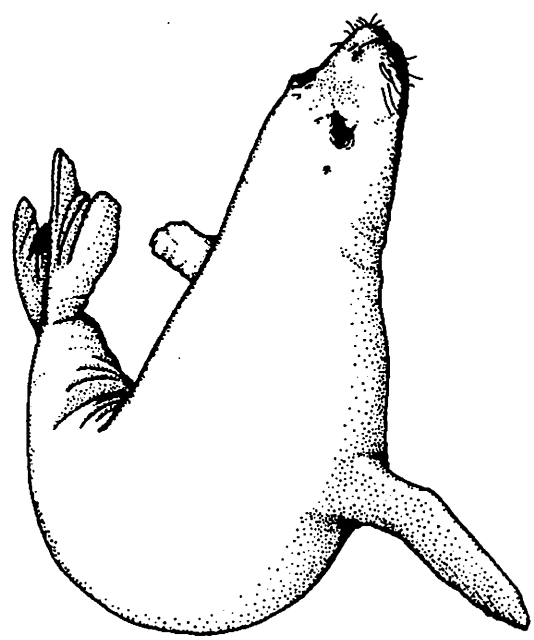
Sea Turtle

Young Dolphin

Young Monk Seal



Dolphin



Monk Seal

DESIGNING A HABITAT

OBJECTIVE
Students will be able to identify components of habitat essential for survival of aquatic animals.

METHOD
Students design a habitat suitable for aquatic wildlife to survive in an aquarium or Hawaiian fish pond or show how aquatic communities are grouped in a coral reef.

BACKGROUND
Zoos and aquaria are for the most part artificial habitats. The basic life-giving conditions of food, shelter, air, water and space in a suitable arrangement for animals to survive seem obvious enough when considering zoos.

However, in aquaria, water is a uniquely sensitive part of the habitat and it must serve to do far more than quench thirst. The surrounding envelope of water must meet specific requirements for different aquatic life forms. Slight changes in pH, salinity, dissolved oxygen, and the presence of a wide range of pollutants can spell disaster.

To successfully house aquatic wildlife in aquaria, careful attention must be paid to the range of conditions that each life form can tolerate. There are also certain physical requirements in terms of the shape and dynamics of the display that must be compatible with each creature.

For example, some fish require moving water or currents. Others prefer almost static conditions. Some prefer deep water and others shallow coral reef habitat. Sea turtles and seals need dry space on which to haul out. The variations are remarkable when one considers designing habitats for micro-organisms in pond water and mammoth habitats for orcas (killer whales) and monk seals.

Concern for the physical requirements of animals must go beyond meeting minimum survival needs. Attention should be given to the animals' comfort, creating conditions as similar to those in their natural habitats as possible. Would an animal be comfortable or live for very long all alone? Can certain animals, such as sea urchins, and sea cucumbers, be returned to the wild after short periods of capture? Why would this be a good idea?

In the growing practices of aquaculture (cultivation of freshwater organisms) and mariculture (cultivation of oceanic organisms) much research is conducted regarding habitat requirements. Often natural streams, anchialine ponds and even the ocean are used in these enterprises.

The early Hawaiians were well known for the creation of "fishponds" using the natural environment. Attention to water quality and disease control is just as important in these settings as it is in the confined habitats of aquaria.

Ethical concerns about the appropriateness or inappropriateness of housing aquatic wildlife in aquaria must also be considered. This activity is designed to address the complex physical needs of aquatic wildlife in order to be able to survive under conditions of captivity. The growing concern over the ethics of keeping large marine mammals in captivity can be addressed as an extension.

The major purpose of this activity is for students to recognize and appreciate the complex living requirements of aquatic wildlife. The strategy for learning is twofold: first, by researching the partitioning of the pond or reef environments by aquatic organisms, and then by applying this knowledge to construct an artificial habitat (aquarium) or graphic model or mural.

MATERIALS
3x5 cards; art supplies; writing materials; papier mache; modeling clay; gallon jars; string; card-

board; cardboard boxes (to use as frames for models); butcher paper.

PROCEDURE

1. Prepare cards (3x5) with the name of one of the following animals written on each card: tiger shark, butterflyfish, hermit crab, lobe coral, Moray eel, green sea turtle, monk seal, triton's trumpet, crown-of-thorns sea star, jack, black coral, damselfish, antler coral, decorator urchin, 7-11 crab, surgeonfish, mullet, milkfish.
2. Divide the class into groups of two to four. Have each group draw one card from a container.
3. Ask each group to be responsible for designing an artificial habitat in which their animal could live comfortably. Inform them that each team will be expected to conduct library research or consult reference materials or resource people to determine the life requirements of each creature. In addition, they must investigate and establish the characteristics of the natural habitat of the animals. If possible, they must also determine the Hawaiian name of their subject and what the name means.
4. When the research is complete, each team of students is to design and build a model or small replica of a pond or aquarium habitat which would be suitable for their animal's survival and comfort in captivity. Establish a scale for the exhibits (e.g., one inch = five feet for the large animals; actual size for the hermit crabs).
5. Once the models are complete, ask each team to report to the rest of the class. Each report should include a description of the basic biological needs of each animal, as well as a description of the characteristics of its natural habitat. The students should point out how their models are designed to meet the needs of the animal.
6. OPTIONAL: Once all the reports are finished, have the students arrange their models in a plan for a pond or an aquarium.
7. Ask the students to summarize the components of habitat that seemed to be necessary for the survival of the aquatic animals they studied. (Food, water, shelter, and space in a suitable arrangement would be the minimum necessary components.)

EXTENSIONS

1. Visit and aquarium and arrange for a staff person to explain how the aquarium staff addresses the same basic requirements for animals that the students did—that is, the components of the ecosystem.
2. Create a balanced aquarium for the classroom.
3. Discuss the reasons for and against keeping aquatic wildlife in zoos and aquaria.
4. Informative mural-making. For coral reef habitat, students can create a mural on a wall of the classroom (using butcher paper) with depth zonation from 0 to 100 feet scaled to fit from floor to ceiling. Using the same groupings of students as before, coordinate the placement of their artistic renditions of their research subjects onto the mural in the appropriate depth zone. They will use the information they obtained previously to help them determine the proper depth of placement on the mural.
For Hawaiian fish pond habitat, students can create a similar mural depicting the activities associated with this type of mariculture.

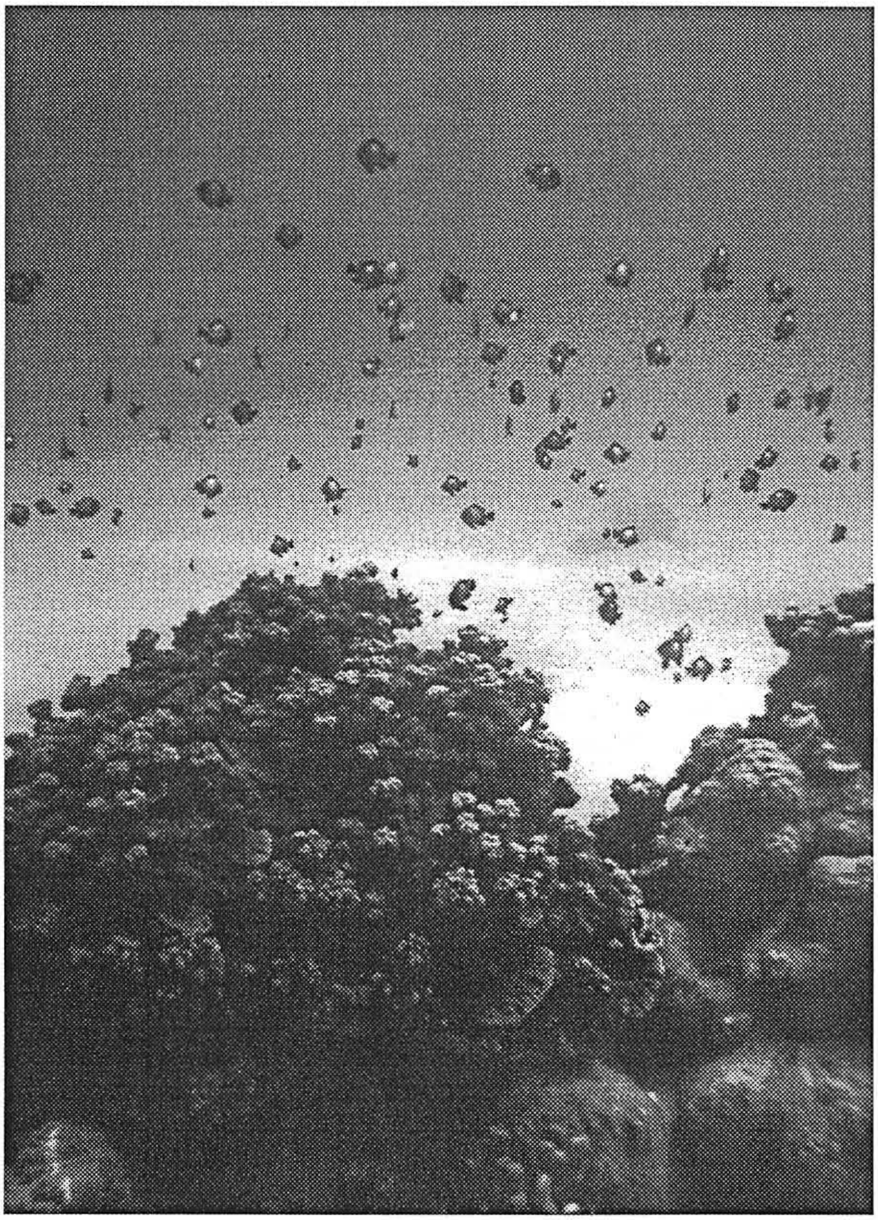
EVALUATION

1. List the components of suitable habitat that are necessary for most aquatic animals to survive.
2. Pick an aquatic mammal, fish, amphibian or other aquatic animal. Describe the biological characteristics of the animal and its habitat requirements. Compare similarities and differences between this aquatic animal and another aquatic animal. What things, if any, do they both need in order to survive? What things, if any, must be different in their habitats in order for each kind of animal to survive?

Age: Grades 3-12
Refer also to *Project WILD Aquatic* page 20

Distribution of Reef Slope Animals by Depth

Depth (feet)	Fishes	Invertebrates
10	Needlefish, blenney, goby, wrasse, surgeonfish, angelfish, butterflyfish	A'ama crab, opihi, cauliflower coral, lobe coral, armor urchin
20	Cardinalfish, barracuda, squirrelfish, surgeonfish, moray eel, blenney, goby	Hermit crab, spiny urchin, pencil urchin, lavender coral, lace coral
30	Damselfish, triggerfish, wrasse, blenney, goby, angelfish, grouper, papio	Lobster, collector urchin, lobe coral, polychaete worms
40	Parrotfish, angelfish, butterflyfish, triggerfish, surgeonfish, cardinalfish	Lobe coral, octopus, lobster, sponges, crown-of-thorns starfish
50	Snapper, damselfish, wrasse, squirrelfish, ulua	Finger coral, octopus, sea cucumbers, sponges
60	Goatfish, snapper, shark, parrotfish, angelfish, butterflyfish, wrasse	Rice coral, lobster, cowries
70	Mu, taape, goatfish, triggerfish	Finger coral, giant finger coral, nudibranchs
80	Grouper, goatfish, pualu	Octopus, sponges, flatworms
90	Wahanui	Wire coral
100	Kahala, longnose hawkfish	Helmet snail, wire coral, Kona crab, black coral, pen shells



WATER CANARIES

OBJECTIVES

Students will be able to: 1) Identify several aquatic organisms; 2) assess the relative environmental quality of a stream or pond based on the presence of diversity of organisms; 3) understand the qualities necessary to make a successful conservation plan and 4) discuss the problems that introduced species bring to the stream environment.

METHOD

Students investigate a Hawaiian stream using sampling techniques.

BACKGROUND

In the early days of coal mining, canaries were taken into mines. Since canaries were more sensitive than humans to the presence of toxic gases in the air, their discomfort or death indicated whether or not the air was safe to breathe. Although this practice no longer exists, it stands as an example of how animals with greater sensitivities to environmental changes can be used to warn humans.

It is generally acknowledged that biodiversity is greatest in the tropics. Because of their extreme isolation, however, tropical oceanic islands can be the exception. The Hawaiian Islands are the most isolated island group in the world. The Hawaiian marine fish fauna is compromised of only 400 species. Elsewhere in the Pacific basin, about 1,500 kinds of fishes are known from Australia's Great Barrier Reef, and over 2,000 species occur in the Philippine Islands. While Hawaii may have fewer total species than these other areas, we have more unique species, that is, endemics or those found nowhere else in the world.

There are only five species of fish, two species of mollusks and two species of crustacea native to Hawaii's streams. The loss of even one of these species would greatly reduce the diversity of Hawaiian fresh water systems.

Because of their low species diversity, island ecosystems are considerably less resilient than those of the continents. They are susceptible to adverse impacts from introduced species, and to other habitat changes brought about by human intervention (e.g. channelization, siltation, etc.)

Aside from five small naturally occurring lakes, most of Hawaii's fresh water habitat consists of relatively small mountain streams. These streams are the habitat of native fishes, mollusks and crustaceans, most found nowhere else on the planet. It is important that we preserve this very unique resource.

Stream flow regulates the life cycles of native stream animals. Increased stream flows, called "freshets", follow the first heavy rains of autumn, and carry larval stream animals out to sea. They spend several months developing and growing in the ocean. During this time they may drift to another island, or across the sea.

After spending several months in the ocean, young 'o'opu (hinana), 'opae and hihiwai head back upstream and, if they make it past predators and other obstacles, settle into adult life. Scientists do no know how these animals know when to head upstream, what stream to choose, and why they leave the brackish water. Each species settles at a particular level of the stream.

There are five different species of 'o'opu:

'O'opu nakea are the largest of the native stream fishes. They are the only 'o'opu that are not endemic, but are also found in other Pacific Island groups. They are a mottled brown-gray color, grow up to 14 inches long and are bottom dwellers that live at elevations up to about 1450 feet. They eat filamentous green algae, or animal matter like earthworms and snails. Nakea are a traditional Hawaiian food.

'O'opu naniha are small yellow-brown fish that are about 4 inches long . They live in the estuary section (lower stream), often burrow into the substrate, and eat plants and animal food.

'O'opu nopili grow to about seven inches, and are mottled brown color. Courting males become very dark with a white stripe on their side. Nopili live in the middle stream reaches. They feed by scraping algae with their underslung jaws.

'O'opu hi'ukole (alamo'o) are small fish, about two to five inches long. While courting the males are brightly colored, black from face to midsection and red from mid section to tail. They revert to a drab brown (for camouflage) when not courting. Females always retain the brown coloration. Hi'ukole are usually found at the highest reaches of the streams, up to 1800 feet.

'O'opu akupa are dark brown fish found in the lowest reaches of the stream. They are not true gobies, since their pelvic fins are not fused together to for suction discs. Akupa grow to about ten inches long and are carnivores. They eat invertebrates and other fishes. They have traditionally been used as bait by Hawaiians.

'O'opu have been used by Hawaiians as food and for ceremonies. Each species prefers a different area of the stream. All except the akupa are true gobies and use their fused pelvic fins as suction cups to get from the ocean upstream to their particular habitat.

The two native crustaceans found in Hawaiian streams are the 'opae 'oeha'a, which is found in the lower reaches of the stream, and the 'opae kala'ole (or 'opae kuahiwi), a shrimp frequently used for food and found in upper stream reaches. The two native mollusks are the hihiwai and the hapawai, both of which are also traditionally used as food.

The stream environment is more than just the water it contains. The vegetation bordering the stream influences water temperature, natural cover and food. The surrounding watershed can be the source of silt, road oil, fertilizers, pesticides and other toxic substances. Removing water from the stream for irrigation interrupts the normal upstream movement of stream animals. The introduction of exotics poses an additional challenge to native species.

It is important that while considering conservation of the 'o'opu, 'opae, hihiwai and hapawai, we consider the entire watershed. For any conservation effort to work it must be biologically sound, have public support, be compatible with local tradition and be enforceable.

MATERIALS

Paper, pencils, identification materials (Appendices 6 and 7), seine nets, assorted containers, white containers, magnifying lenses, eye droppers, and forceps. Optional: thermometer.

PROCEDURE

1. Select a sampling site where student impact will be minimal. Be sensitive to the impact students may have on stream banks, stream beds and vegetation. Have the students establish ethical guidelines for their sampling activities. Try to find a stream that has all of the different elevations that 'o'opu live in. Prepare yourself to do one section at a time. Be alert to the safety of the students. If the stream is not a public site, be sure to gain permission to visit. Advise the students in advance to dress for the setting. Old shoes, shorts or jeans would likely be best. NOTE: If a site visit is not possible, modify the activity to be conducted in the classroom.
2. Brief the students on habitat courtesies. Work from the students' own list of ethical guidelines for sampling activities. Alert them to ways to minimize the potential for damaging the habitat, and encourage care in their collecting techniques

(so everything can be returned to the stream).
3. Start by observing the water. Look for organisms on the surface and in the depths. Using the sampling equipment (nets, trays, assorted containers, etc.), have the students collect as many different forms of animal life as possible. Ask them to be alert to differing microhabitats near rocks, in riffles and in eddies. Place the animals to be observed in the white trays for viewing and drawing. The whiteness of the trays allows detail to be seen in the animals collected. Keep an adequate amount of water in the trays and place them in a cool shady spot. Change the water as often as needed to keep the animals cool. Use microscopes if they are brought along.
4. Have the students identify and draw the animals on the data collection sheet—those observed in their natural setting and those temporarily removed for observation in the collection containers. Ask them to fill in the number of each kind found and describe the actual location where the animal was found. Once these observations are completed, carefully return the animals to their natural habitat.
5. While outdoors encourage the students to discuss their observations. Were a lot of different aquatic organisms found? Introduce the concept of diversity of life—that is, a variety of different kinds of plants and animals is usually an indication of a healthy ecosystem. Discuss the problem of introducing exotic fishes into this system. Hypothesize the difference in the water temperature due to natural cover and vegetation. Notice any correlation between the number of organisms in an area and temperature.
6. Ideally, this activity should be repeated at other sites with different characteristics. The students should understand that biologists examine hundreds of sites in order to try to understand and predict what their evidence suggests is going on in natural systems.
7. Summarize the study with a re-emphasis that the diversity of specific animals is a useful indicator of environmental quality.

EXTENSIONS

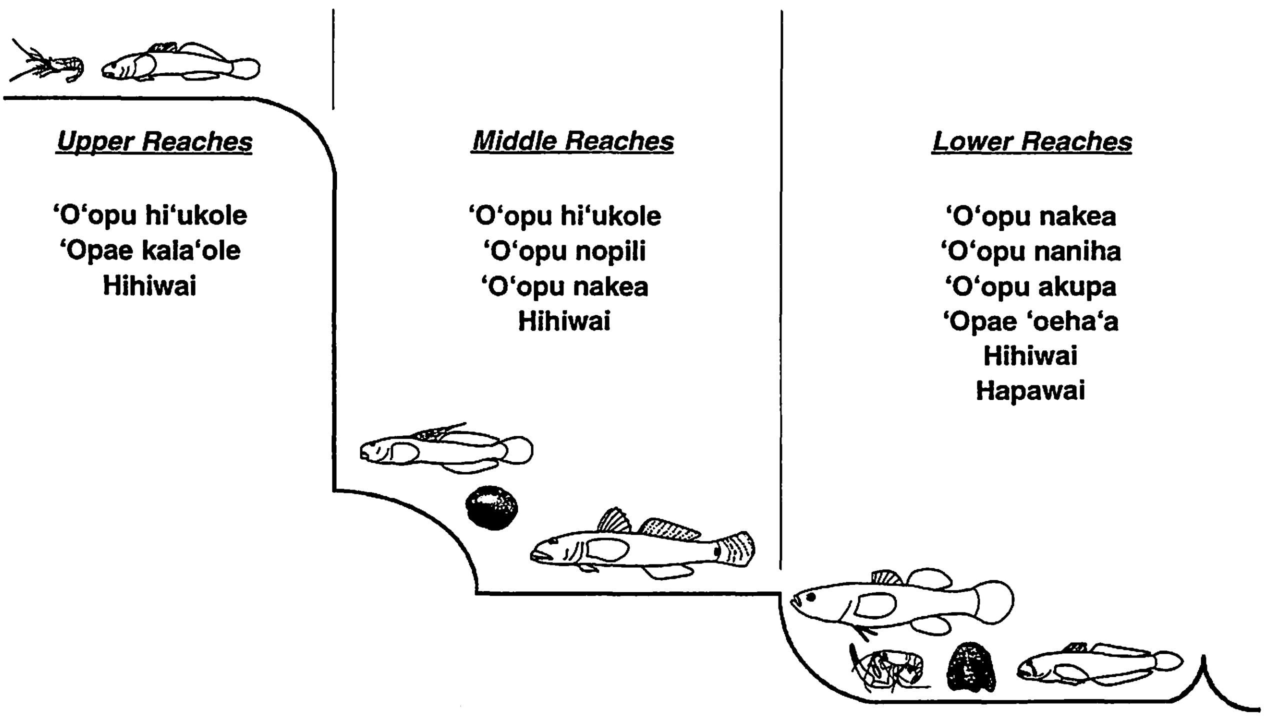
1. Measure and record the dissolved oxygen for the sites visited. Look at the relationships to the values for water temperature and pH.
2. Find the most diverse and least diverse streams in the area.
3. Contact local wildlife, environmental and conservation groups to find out what their concerns are regarding water quality. Determine what can be done as an individual and as a community to improve or maintain local water quality.
4. Sample streams above and below your local water treatment plant.
5. What do the conditions you discovered in your stream mean for wildlife in and out of the water?
6. Divide students into small groups. Have each group design a proposal to conserve Hawaiian streams. Each group must meet the requirements of a successful conservation effort: have public support, be compatible with local tradition and be enforceable. Each group presents their proposal and as a whole comes up with a class proposal.
7. Conduct a field trip to a natural stream and to a channelized stream. Compare and contrast the differences. Are native stream dwellers visible in either one? If a field trip cannot be arranged, ask students to make the trip on their own, and write down their observations.

EVALUATION

1. Draw a simple illustration of one or more of the following organisms: hihiwai, hapawai, hinana, 'opae kala'ole. Write the correct name beside the picture.
2. Create a mural (or hang a poster) in the classroom and have students place the 'o'opu in their habitats by stream elevations. Which species is found at the highest reaches of the stream? Which one at the lowest?

Age: Grades 6-12
Refer also to *Project WILD Aquatic* page 38

Distribution of Native Stream Animals by Elevation



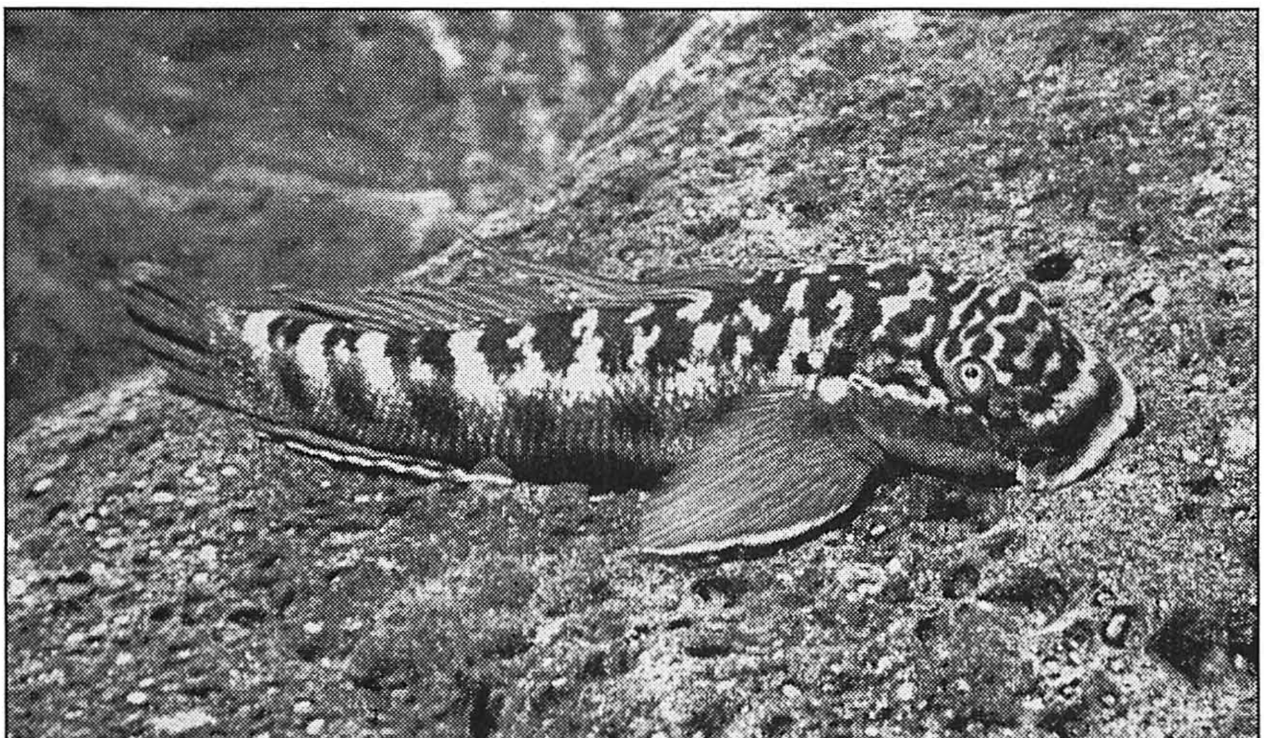
Water Canaries — Data Collection Sheet

Names:

Start Time ____________

Date: ____________ Location: __________________ End Time ____________

Drawing	Identification	No. Found	Location Found



27

LEAPIN' LIMU LUAU

OBJECTIVE
Students will be able to list and describe limu (seaweed) and the different ways that limu can be affected by humans, wildlife and the environment.

METHOD
Students research limu, create a three dimensional mural and prepare limu for consumption.

BACKGROUND
Limu is the Hawaiian name for all types of plants (seaweeds or macroalgae) living under water, both fresh and salt. People most commonly think of limu as edible seaweed.

The Hawaiian Islands have a wide range of seaweed habitat. Generally speaking, seaweeds are found in areas of water movement. This movement can be in the form of currents or waves.

Seaweed is held to the bottom of the ocean by a structure called a *holdfast* (see page 5). The holdfast anchors the plant to cobbles, large rocks, lava rocks and debris in sandy bottoms. It looks like a root but is not. The holdfast cannot absorb nutrients like true roots do; it serves only to keep the limu in place during storms, tides and normal wave action. Nutrients are absorbed through most of the limu's surface area.

The main body of a limu plant is called a *thallus.* As the thallus grows it may form a number of leaf-like structures called *blades.*

Great places to look for limu are: exposed rocky coastlines, tide pools, wave-swept cliffs, ledges, channels and reef flats. Some basic life support factors for limu are light, oxygen, carbon dioxide, and nutrients. These factors are further influenced by water depth, temperature, water clarity, salinity, degree of water movement and exposure to the air due to tidal fluctuations.

Some seaweed can live in sand, but most require a hard, solid bottom for attachment. A single species can dominate an area, but close inspection may yield a tangled complex of many species growing close together, so mixed-up it is hard to tell them apart.

Many times there is a larger limu species on top and a smaller species underneath. This is an example of different species requiring different amounts of light, temperature and water depth for survival. These adaptations enable limu to coexist in an environment that is conducive to all.

Growth of limu is limited by life support factors. For example, limu use carbon dioxide and produce oxygen during the day, through the process of photosynthesis. At night limu use oxygen and produce carbon dioxide through the process of respiration.

In tidepools, the oxygen produced by seaweed saturates the water during the day, but is lost as the water heats up. When photosynthesis stops at night, respiration by limu and marine animals in the tide pools use up much of the remaining dissolved oxygen, reducing its concentration to very low levels. This limits growth, particularly of the marine animals.

Nutrients also limit the growth of limu, nitrogen and phosphorus being the most important. The availability of nutrients is largely dependent on water movement. Currents can carry nutrients in and waste materials out. Fresh water runoff and streams carry nutrients (including fertilizers) from the land into the sea.

Sewage discharge is another source of nutrients for some forms of marine life, particularly algae. An over-abundance of nutrients, however, can result in an imbalance of the delicate reef ecosystem. Algal blooms are a phenomenon occurring with increasing frequency worldwide. Too much algae or seaweed growth can destroy coral reefs.

Land development or deforestation produces silt, a fine-grained soil carried and laid down by moving water, that ends up at the shoreline. This disturbance of the shoreline can block sunlight from limu, or cover the bottom with a soft and shifting surface leaving no place for the limu to attach.

Changes in salinity are most common in tidepools. As water evaporates the concentration of salt goes up. When the tide moves in the concentration of salt goes down. Heavy rain and runoff also decrease salt concentration. Pools farther from the sea are most influenced by temperature and salinity changes.

Some marine biologists suggest that seaweed beds provide habitat for as diverse a variety of wildlife as does a tropical rain forest on land. Both seaweed beds and rain forests do support a tremendous diversity of wild life.

Worms, snails, crustaceans and mollusks abound in seaweed beds. Fish live at all levels within the protection of seaweed beds. The dozens of aquatic species that live in seaweed beds attract predators. Sharks, sea turtles and humans find these beds to be attractive foraging areas.

Large, fleshy seaweeds are more abundant in flat areas, such as reef flats and limestone benches. These seaweeds tend to be the edible varieties. The wave surge environments, the reef crest and the steep, sloping seaward edge of reefs are dominated by stony coralline algae, seaweeds which deposit calcium carbonate and actually produce most of the reef through their growth.

Limu is harvested at low tides. Initial cleaning of the limu, during which all attached animals, coral sand, and other seaweeds are removed, takes place at the shore. Limu that does not deteriorate in fresh water is rinsed thoroughly.

The Hawaiian preparation of limu consists of chopping or mashing the fresh raw weed, adding salt and perhaps fresh chili pepper, and eating it as a relish in a fish and poi or rice meal. The most common edible seaweeds used are limu kohu, (*Asparagopsis taxiformis*, a red algae), limu ele'ele (*Enteromorpha prolifera* or other species of Enteromorpha, green algae), limu manauea (*Gracilaria coronopifolia*, red algae) and limu maneoeo (*Laurencia nidfica*, red algae).

Seaweed beds are threatened by pollution, sea urchins and over harvesting. Raw sewage dumped into sea water attracts sea urchins. The sea urchins feed both on the sewage and the seaweed holdfasts. Once the seaweed plants are cut adrift, they die and wash ashore.

MATERIALS

Paper, pencils, library reference including Hawaiiana resources, art materials for a mural.

PROCEDURE

1. Divide the class into groups of four or five students, Assign (or have the students choose) topics such as the following to research related to limu:
   - seaweed as a habitat for wildlife
   - aquatic weeds of the world (both marine and freshwater)
   - algae and the oceanic food chain
   - sea urchins
   - sea turtles (Hawaiian Honu)
   - limu as a food source (limu recipes)
   - the effects of development on seaweed beds
   - the effects of pollutants on seaweed beds
   - the effects of sewage or excess nutrient levels on seaweed beds
2. Along with research have each group be responsible for a seaweed mural .
3. Once the research is finished, have each group visually summarize its findings on a large sheet of paper .
4. When all groups are finished, have them place their art work on a wall and verbally report on their findings. As each group finishes, the next

should place its art work so that the edges of the paper overlap, producing a mural related to limu.
5. Lead a class discussion about limu, algae and the other freshwater and marine "weeds", inviting the students to react to the information and insights shared by each group.
6. Choose a limu recipe and prepare it to be shared by the class.
7. Using crepe paper streamers for limu and various marine animals made from poster paper and cardboard, hang a seaweed bed from the ceiling. Have one corner of the room be affected by sewer spillage, another by over-harvesting, another by development and deforestation and the last corner is pristine.

EXTENSIONS

1. Investigate other aquatic plants and their role in aquatic habitats.
2. Draw an accurate portrayal of a limu bed food web. Keep the animals and plants to their proportionate sizes in the drawings.
3. Visit an ocean beach where limu can be found. Identify its parts. If an ocean beach is not available, make a small collection of aquatic "weeds," from a local pond or stream. Try to identify these. See the Aquatic Wild Activity, "Water Plant Art."
4. Visit an aquarium that exhibits seaweed habitat.
5. Plan a Limu Appreciation Day, including a potluck meal where limu is part of each dish.

EVALUATION:

1. What is limu? Write a paragraph and draw a picture to illustrate your response.
2. Describe two ways that limu is helpful to each of the following: humans, wildlife, and aquatic habitats.
3. Describe two effects of the following on limu: humans, wildlife and environmental change.

CORRELATIONS

Additional background information and activities related to limu can be found in DOE's *Limu: Learning About Hawaii's Edible Seaweeds* and the Hawaii Nature Study Program *Reef and Shore* unit.

Age: Grades 6-12
Refer also to *Project WILD Aquatic* page 48 ("Kelp Help")

THE EDGE EFFECT

OBJECTIVES
Students will be able to identify patterns of distribution of organisms and sediment at a coastal site.

METHOD
Students collect data along a transect line at the water's edge.

BACKGROUND
Although we may not always realize it, zones are part of our everyday lives. We are literally surrounded by zones. Roadways, sidewalks, parks, and buildings are all zones designed and created by humans.

These zones have an intended purpose and are meant to separate different and sometimes incompatible activities. These man-made zones tend to be fairly obvious because of the different physical characteristics of each.

Less obvious zones can be found on your own school campus. Although the buildings may all look alike, the campus is probably zoned more or less according to grade levels or subject areas. Each zone has its own activities and interactions.

Zones also occur in nature. Streams, forests, and lava fields are all natural zones. Each zone has its own characteristic living and non-living components. An "ecosystem" is comprised of these components and the interactions that occur between them.

Zones and ecosystems can be large or small, depending on the perspective we take. For example, the entire planet earth could be considered a zone, as could a small pond. Zones within zones are called "subzones".

The area where two zones meet is called an "ecotone". This meeting is often more of an overlap than a definitive line. Ecotones have a relatively high diversity of life. Organisms associated with each zone may approach or even cross the border of their respective zones, increasing the diversity in the ecotone

The shoreline is a good example of an area where two very different zones and ecosystems meet. If we take a broad look at this area we will see that a great diversity of organisms have the potential of coming in contact with each other.

Let's take a step back though, and focus on the concept of zones. Within individual zones, organisms tend to be specialized and diversity is relatively low, depending on how the zones are identified. In harsh environments such as the shoreline, tides, waves, wind, rain and the sun constantly exert their forces. Here organisms tend to be even more specialized. Not many organisms can survive these extreme conditions. Those that can often inhabit only certain areas, dictated by their abilities to tolerate the conditions there. Therefore, it will be worthwhile to focus on this ecosystem and investigate the patterns that exist within this zone that surrounds us.

MATERIALS
Part 1: Chalk/marker board or large paper and three different colored chalks or pens; photographs or illustrations, one of shoreline and one of ocean (if done in classroom)
Part 2: (for each group of 2-5 students) clipboard, data sheet, pencil; measured string or rope, 50 to 100 feet long, marked at 5 foot intervals, and a stake or heavy weight to anchor it; meter sticks; identification materials

PROCEDURE
Prior to the shoreline field trip, give students a lesson on dangerous marine organisms, ocean safety and safety equipment required. Also review conservation practices; emphasize no col-

lecting and use care to avoid trampling and disturbance of habitat. Explain tides and the use of a tide chart.

Part 1: Ecotones (Can be done in classroom or at shoreline)

1. **Classroom:** Show the students a photograph or illustration of a shoreline area. The picture should show plants and animals on land and perhaps different substrates. Water related organisms should also be included or another picture of underwater organisms shown. (This is just to make suggestions to students on what organisms may be present.) **Shoreline:** Have students observe an area above and below the waterline for a few minutes.
2. Make three columns on a board or paper. Label the far left "terrestrial" and the far right "ocean". Define "terrestrial"; ask the students to give names of organisms that they consider terrestrial and list these in the appropriate column. Do the same for ocean organisms. Students can infer organisms they don't actually see.
3. Draw overlapping circles/semicircles around each list using different colored chalk or pens. Using both colors, shade in the overlapping area.
4. Explain that where the two areas overlap is called an **ecotone**. Ecotones are areas where two different types of communities or ecosystems meet. There is often a greater diversity of animals in these areas.
5. Illustrate this further. Label the the left line of the middle column "high tide" and the right side "low tide".
6. Ask the class which organisms from the terrestrial list may be found at the water's edge at low tide; list these in the shaded area. Ask them to name organisms from the ocean list that may be found up to the water's edge at high tide; list these in the shaded area.
7. There should be a number of organisms (if not all) representing both groups listed in the middle, illustrating a situation where a diversity of organisms from two very different ecosystems come together and perhaps interact. Discuss.
8. Inform students that the excursion to the shoreline will investigate what processes are going on in this ecotone. Let them discover on their own the zonation patterns that exist.

Part 2: Shoreline zonation

1. Select a safe shoreline area. (Zonation patterns may be most apparent along basalt coasts.) Select a date and time when the tide will be low. (Best to have a zero or below zero tide height. Plan to start your activity when the tide is falling and nearing it's lowest. You want to finish before the tide rises.)
2. At the site review safety procedures, set boundaries, etc. Ask students to survey the shoreline area for a minute, making note of substrate types, vegetation, and organisms.
3. Divide class into groups of 2 to 5 students. Have one person in each group be the data recorder and the others observers.
4. Have one person from each group anchor the transect line at the water's edge, being careful not to disturb or destroy evidence of animals (tracks, droppings, crab holes and mounds, etc.). If students are allowed to enter the water, the end of the line can be anchored several feet into the water. If results from different groups are going to be compared at the end of the activity, those groups should anchor their lines so the number of stations in and out of the water are consistent. Lay the rest of the transect line up the shoreline into the the splash zone. Groups should be spaced about 10-15 feet apart.
5. Have students start at upper end of the transect line, face the ocean and look a few (3-6) feet on each side of line. (The line is more of a reference to keep observers from wandering too far from their designated sites. The exact area need not be measured.) Each segment of line between two marks is considered a **Station**. The Station at the upper end of the line is Station 1.
6. Move along the line slowly toward the water. (It may be best to stand back of the points on the line to get a view of things in the area)

At each station, students collect the following data from the area adjacent to the line:

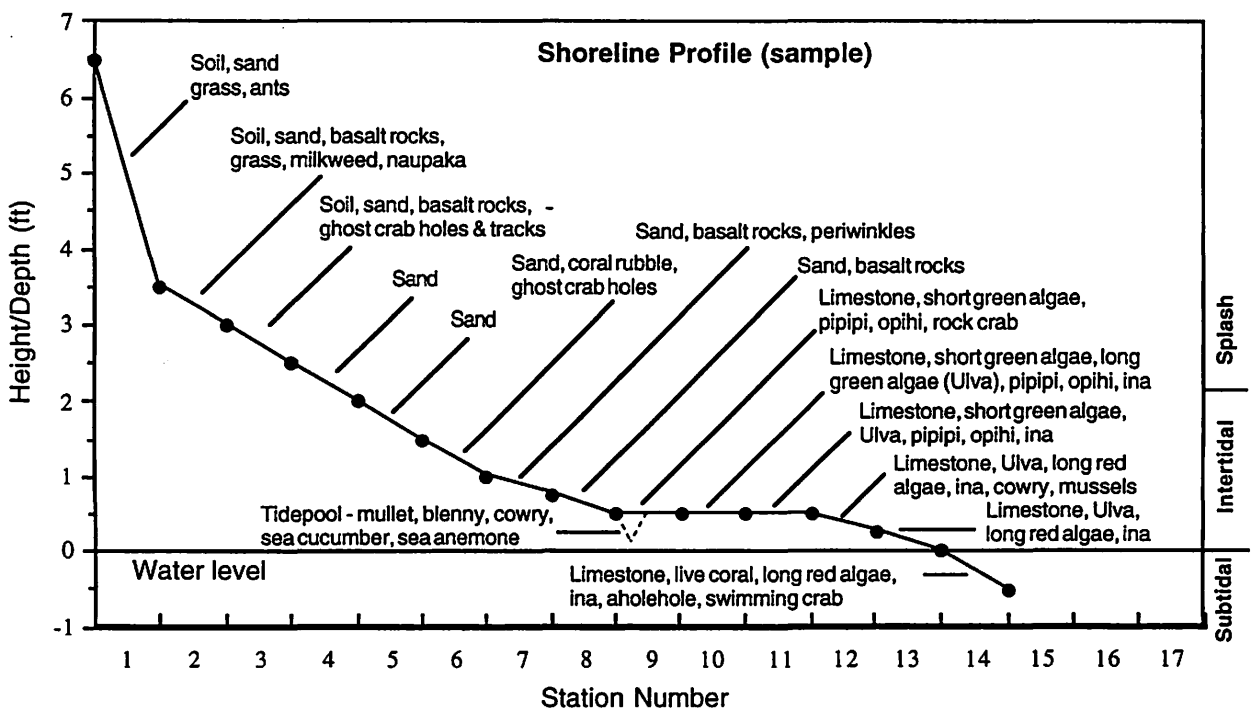
- Substrate type (basalt, limestone, sand, etc.)
- Plants (including attached algae)
- Animals, or signs of animals (droppings, footprints, burrows, etc. Students can use inference)

7. Upon reaching the edge of the water ask students to look into the water about five or ten feet (depending on water clarity) and record as above. Measure or estimate depth of water. If students are allowed to enter the water, they continue their observations to the end of the line.

8. Have students return to each marked point on the line and determine its height above, or below the low tide level. To measure depth, use a meter stick or measured rod, record the depth of each point below the surface. If students are not allowed to enter the water, depth can be estimated. To determine heights of points on the line that are above the low tide level, have one student hold the string down to the substrate at each point, starting with the one nearest the water. A second student should hold the meter stick at the water's edge and lift the line next to the meter stick until the line is level. A third student may want to stand on the side to determine when the line is level and record the height. This will be the height above low tide, of each point up the shoreline. Have students determine the high tide mark by looking for the debris line, and note this height as well.

9. Ask students to look at their data sheets and see if they noticed changes in substrate and organisms as they moved along the line. Did they notice any abrupt changes in the types of substrate and organisms? At which stations did these occur?

10. Gather the students around a portable chalk or eraser board. Using the data on heights of stations, reconstruct a portion of the shoreline profile using a line graph. Write the names or symbols of the various organisms and the substrate type (if more than one type) in their respective areas on the graph (see example below). Do not include tidepool systems initially. Ask students if they see any abrupt changes in types of organisms, which organisms were present or absent in certain areas.



11. Draw lines to indicate the apparent boundaries between significant areas.
12. Explain to students that this is called **zonation.** Ask them if they know why the shoreline has these zones. (Tides and waves)
13. Label high tide, low tide, splash, intertidal, and subtidal zones. Use a tide chart to illustrate. Discuss the conditions associated with each zone.
14. Indicate location and inhabitants of tidepools at this time. Discuss the significance of tidepools.
15. Have students return to their transect site and verify the zonation patterns. Have them take a broad look, maybe go on a beach walk to see if there is a consistent pattern or other areas where they see zonation. Teach students how to determine the high tide and low tide lines using vegetation, debris lines, erosion and organisms. Do these correspond to the zones identified? Have them imagine and discuss the conditions that occur when the tide rises and falls.

EXTENSIONS

1. Do further library research into shoreline zonations. What other zones exist which may not have been evident at the field site?
2. Discuss the harsh environmental conditions within the intertidal zone. Select an organism that lives in this zone and describe its adaptations for survival.
3. Assess the overall health of this section of shoreline. Take action to protect any aquatic habitats in danger of being damaged, degraded or lost.
4. Follow up this activity with a beach clean-up.

EVALUATION

1. Write several paragraphs about the zonation patterns observed, and the relationship between habitat and types of organisms found in a zone.
2. Choose a marine animal. Tell a story about its travels through several different zones. Explain how the animal's experience is different at each of the various locations.

Age: Grades 4-8
Refer also to *Project WILD Aquatic* page 68 ("The Edge of Home")

The Edge Effect — Data Collection Sheet

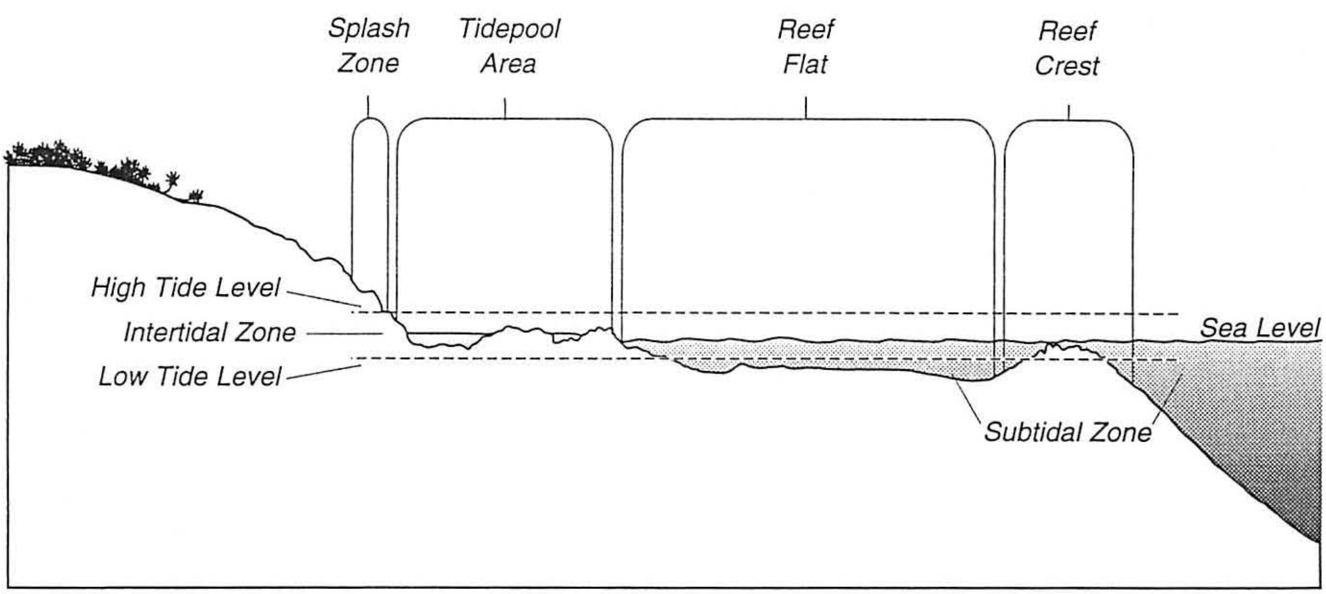
Names:

Start Time ____________

Date: ___________ **Location:** _________________ **End Time** ____________

Station No.	Substrate	Plants	Animals	Height/Depth

Typical Beach Profile



BLUE RIBBON NICHE

Ref: *Project WILD Aquatic* Page 72

OBJECTIVES

Students will be able to 1) identify different organisms that live in tidepool systems; 2) describe the ecological role of some organisms in tidepool habitats; 3) describe some basic characteristics of tidepool habitats; and 4) evaluate potential positive and negative effects from changes in tidepool habitats.

METHOD

Students create representations of animals that live in tidepool habitats.

BACKGROUND

Each animal in a community has a role—an "occupation" it performs as it lives out its biological life. This role or occupation is called its "niche". The niche includes such things as the animals preferences for food, shelter and space. If niche is an animal's "occupation", then habitat is its "address". This activity is designed to focus on tidepool niches and habitats.

Tidepool habitats are the fascinating pools of life found at the edges of the ocean. They are important and valuable areas supporting a variety of plant and animal life. Each plant and animal in the tidepool ecosystem has an important role, or niche. Some are predators, some prey. Some are producers, some consumers, some decomposers. Some are herbivores, some carnivores, some omnivores. The plants and animals in the tidepool habitat are interdependent, with each species contributing to the functioning of the overall system.

Traditionally, a tidepool zone has been defined as an area which is alternately covered and exposed by the tidal changes. In scientific terms, the intertidal or littoral (tidepool) zone can be broken down into subzones. The highest or splash zone is wetted only by splash waves. The next subzone is the upper intertidal zone which is covered by water at high tide. The middle intertidal zone is covered in moderate tides while the lower intertidal zone is uncovered only during the lowest tides.

Environmental conditions are severe throughout the zones, with the splash zone receiving the most in terms of severity. Elements include exposure (or lack of) to sun, rain and wind. Changes in the above can change the temperature, salinity (portion of dissolved solids) and oxygen levels in the seawater for each tidepool in each subzone.

Tidepool habitats are primarily aquatic, but include areas close to terrestrial habitats and are characterized by a wide diversity in life forms. For example, many fish fry will begin their lives in tidepools as eggs, drift out to sea, return to tidepools as fry and live in seclusion until large enough to defend themselves in the open reef areas. Other animals are dependent on and affected by fish in the tidepools. Birds, crabs, other fish and humans will feed off small fish in tidepools. It is the interrelatedness of all these "occupations" and "addresses" that contributes to the importance, uniqueness and beauty of tidepool zones.

Tidepool areas are easily affected by natural and human-caused changes. For example, vegetation and wildlife are dramatically affected by storms and flash floods. Excessive use of reefs and tidepools can result in destruction of tidepool vegetation and destabilization of shorelines can cause an increase in erosion and destroy pristine tidepool areas. Developmental and recreational pressure also threaten this unique habitat. Tidepool zones are fragile and can be destroyed easily.

Tidepool areas are important in many ways. They have aesthetic, ecological, scientific, social, economic, recreational and intrinsic value. Prized by the Hawaiians, they were cultivated, yet never abused. Often enhanced, some areas were turned into fish ponds, thus increasing the yield of some areas. By learning about the unique characteristics of tidepool areas, people may have more appreciation for their importance.

The major purpose of this activity is for students to become familiar with some of the characteristics of tidepool species, niches and habitats.

MATERIALS

A variety of art materials, e.g. paints, clay, papier mache, glue, wire, brushes; construction paper; nature magazines for photos (optional); books of references about tidepool habitats and wildlife (optional).

PROCEDURE

NOTE: This activity is designed to involve a visit to an actual tidepool site. If that is not possible, see the "Variation" for an alternative approach. **Follow the original Procedure** as written, substituting "tidepool" for "riparian" and "beach site" for "standing body of water". Note the following specific changes.

3. Don't hang artwork from branches—tidepool animals don't do that.

5,6. Find a flat area about the size of an average tidepool in the area; set artwork up in this area and compare with nearby tidepools.

9. Substitute the following "potential changes" for those listed.
   - construction of facilities on a beach site
   - landfill of a beach site
   - development of recreational parks on tidepool sites
   - introduction of an exotic plant/animal
   - clearcutting a slope above a beach producing siltation from increased runoff
   - disturbing of tidepools by people wading or hiking near tidepools
   - planting vegetative cover on a previously bare area near tidepools

10. Severe pollution would affect fish, crabs, sea cucumbers, etc.

VARIATION

1. Create a simulated tidepool area on the school grounds using chalk, paper cutouts, and other materials.
2. Limit the scale of a simulated tidepool area to the classroom—or even a tabletop. You may even want to make an aquarium tidepool setup with seawater.
3. Visit your local aquarium to study what they have in terms of tidepools.

EXTENSIONS

Add:

3. Have students research all Hawaiian names for their organism, ancient uses of their organism, and possibly a recipe using their organism (the older, the better).

EVALUATION

1. Identify and describe the habitat and niche of each of these organisms: rock boring urchin, sea hares, periwinkles, hermit crabs.
2. Name three other animals that are common in tidepool ecosystems in your area. What is the niche of each?
3. Describe two things that could have a positive effect on a tidepool habitat.
4. A beach and tidepool area is being evaluated for a resort/economic potential. What other values would you ask the owners of the land to consider before making a decision whether or not to develop the area?

Age: Grades 6-12

WILD WANDERINGS

OBJECTIVES
Students will be able to: 1) recognize that some fish migrate as part of their life cycle; 2) identify the stages of the life cycle of 'o'opu; 3) describe limiting factors affecting 'o'opu hi'ukole as they complete their life cycle; and 4) generalize that limiting factors affect all populations of animals.

METHOD
Students simulate 'o'opu hi'ukole and the hazards they face in an activity portraying the life cycle of these animals.

BACKGROUND
The 'o'opu are the only freshwater fishes native to Hawaii. There are only five species of 'o'opu, including four species which are true gobies. These are characterized by the presence of fused pelvic fins, which form a sucking disc that helps the 'o'opu adhere to the substrate as it swims upstream. A fifth species ('o'opu akupa) is not a true goby, and doesn't have fused pelvic fins.

The largest 'o'opu is the 'o'opu nakea *(Awaous guamensis)*, which reaches lengths of up to twelve inches or more. Other species, besides akupa, include 'o'opu hi'ukole, 'o'opu nopili and 'o'opu naniha. Although 'o'opu occur on every major island, their numbers have declined due to stream divergence, introduced predators and competition with other species.

'O'opu are diadromous fishes, requiring fresh and salt water conditions to complete their life cycle (see diagram on page 44). 'O'opu hi'ukole, endemic to Hawaii, live in the upper reaches of streams. During the spawning season, which extends from about August through November, the fish lay eggs in masses attached to rocks, which are then guarded by one or both parents. The eggs hatch within about 24 hours, and the newly hatched 'o'opu larvae ride flood waters (freshets) down to the sea. While passing through estuaries the larvae are vulnerable to aholehole, 'o'opu akupa and other predators.

The fry spend four to seven months in the ocean, where they are vulnerable to marine predators, then re-enter the streams and begin their upstream migration. Their sucking discs enable the *hinana*, as young 'o'opu are called, to climb waterfalls and other obstacles which predatory species cannot overcome. As long as there is even a trickle of water, 'o'opu hi'ukole have been known to climb waterfalls as high as 430 feet. After reentry into the freshwater habitat, the fish attain sexual maturity in a year's time.

'O'opu hi'ukole are too small for sport or subsistence fishing. However, fishing for 'o'opu nakea is a popular activity on Kauai throughout the year. Unlike 'o'opu hi'ukole, adult 'o'opu nakea ride freshets down to estuaries, where they lay their eggs. Fishing intensity increases and attains its peak during these spawning migrations. Commercial fishing for 'o'opu was prohibited in 1989, and other regulations to protect the species have been implemented over the years.

MATERIALS
large playing area (100 feet x 50 feet); about 500 feet of rope or string, eight traffic cones for marking boundaries; 100 tokens (3 x 5 cards, poker chips, etc.); jump rope

PROCEDURE
1. Begin by asking the students what they know about the life cycles of fish that live in their area, including both marine and freshwater species. Do any local fish "migrate" to spawn? If yes, which ones? (Marine: mullet; freshwater: 'o'opu.) This activity introduces students to the life cycle of the 'o'opu hi'ukole, so preliminary discussions should focus in that direction.
2. This is a physically involving activity! Set up a playing field as shown in the diagram, includ-

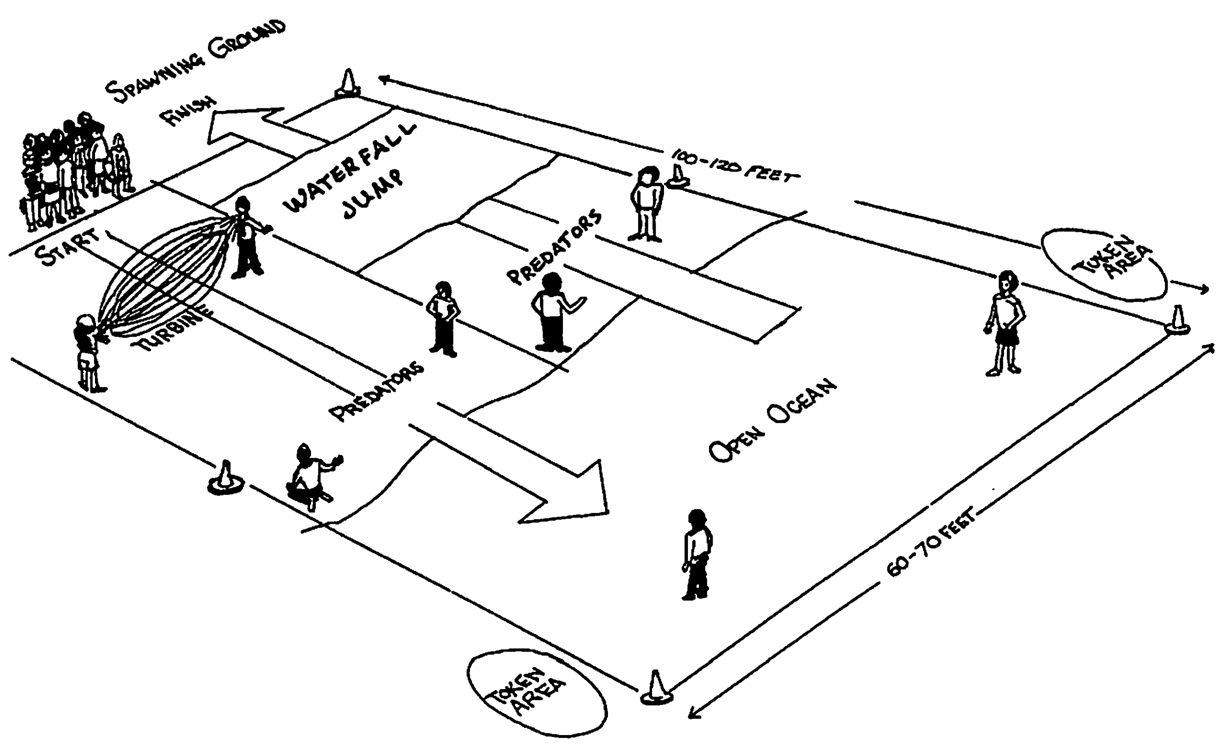
ing spawning ground, stream, estuary (downstream and upstream areas), waterfall and ocean. The area should be about 100 feet by 50 feet. Assign roles to each of the students. Some will be 'o'opu, others will be potential hazards to them. Assign the students roles as follows:

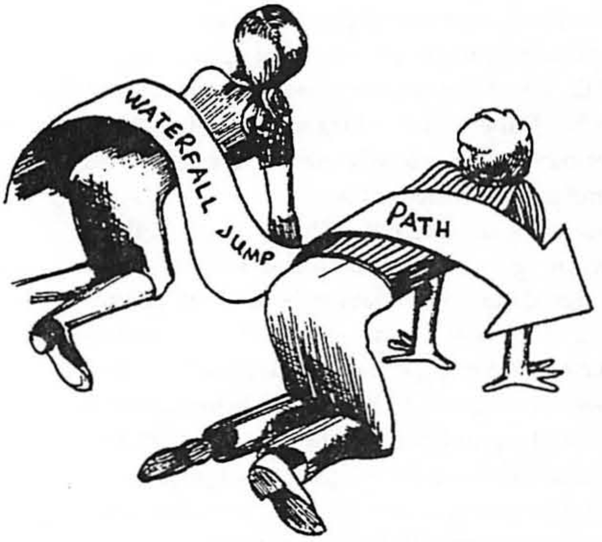
- Choose two students to be the turbine team. These are the ones who operate the jump rope which represent the turbines in a hydroelectric plant. Later in the simulation, when all the 'o'opu have passed the turbine going downstream, these students move to the upstream side to become the waterfall monitors. (See diagram.)
- Choose two students to be estuary predators. At the start of the simulation, they are below the turbines and catch 'o'opu headed to the ocean. Later in the activity when all the 'o'opu are in the sea, they patrol the area below the waterfalls. There they will feed on 'o'opu just before they climb the waterfalls.
- Choose two students to be marine predators, catching 'o'opu in the open ocean.
- All remaining students are 'o'opu.

NOTE: These figures are based on a class size of 25 to 30. If the group is larger or smaller, adjust the number of people who are estuary and marine predators accordingly.

3. Begin the activity with all the 'o'opu in the spawning ground, upstream above the turbine. At a signal, the 'o'opu larvae begin their downstream migration. A major hazard is the turbines. In Hawaii, hydropower plants are associated with stream diversions. 'O'opu that follow the diversion stand a good chance of being killed in the turbines. The student 'o'opu cannot go around the jump rope swingers, but they can slip under the swingers' arms if they do not get touched while doing so. An 'o'opu dies if it is hit by the turbine (jump rope or arms). The turbine operators may change the speed at which they swing the jump rope.

NOTE: Any 'o'opu that "dies" at any time in this activity must immediately become part of the





waterfall jump. Students who are the waterfall jump may kneel on the ground as shown above, a body-wide space between them.

4. Once past the turbines, the 'o'opu must get past some estuary predators. The predators must catch the 'o'opu with both hands—tagging isn't good enough. Dead 'o'opu are escorted by the predator to become part of the waterfall. Later, the 'o'opu who survive life in the sea will use the waterfall to return to the spawning ground.

NOTE: Both the estuary and marine predators must take dead 'o'opu to the waterfall site. This gets the predators off the field regularly, helping to provide a more realistic survival ratio.

5. Once in the open ocean, the 'o'opu can be eaten by marine predators. The same rules for catching 'o'opu apply, and captured 'o'opu are escorted to the waterfall. The 'o'opu must move back and forth across the ocean area in order to gather four tokens. Each token represents one month of growth. Once an 'o'opu has four tokens, it can begin migration upstream. The month tokens can only be picked up one at a time on each crossing. The 'o'opu must cross the entire open ocean to get a token. The "four months" these trips take make the 'o'opu more vulnerable and more readily caught by predators. This creates a more realistic survival ratio on the population before the 'o'opu begin their upstream migration. You may wish to have someone on each side of the ocean passing out tokens, so the students don't take more than one at a time.

6. Once four tokens are gathered, the 'o'opu can begin to move upstream. They must pass through one more group of estuary predators. At this point, any captured 'o'opu are escorted off the playing field and are out of the rest of the simulation.

7. 'O'opu that make it past the predators must go up the waterfall broad jump. Be sure the jumping distance is challenging but reasonable. The two former turbine students will monitor the jump. 'O'opu are safe from predators once past the first jump. If an 'o'opu fails to make a jump, it must return to the bottom of the waterfall and come up again.

NOTE: When playing indoors or on a hard surface, the broad jump waterfall may be done on mats for safety purposes. Alternatively, the migrating 'o'opu may just tap the heads of the waterfall students as they "ascend".

8. The activity ends when all the 'o'opu are gone before the spawning ground is reached, or when all surviving 'o'opu reach the spawning ground.

9. Next engage the students in a discussion. Explore topics such as:

- the apparent survival-mortality of 'o'opu
- the students' feelings throughout the activity
- the role of the turbine
- the role of the predators
- where the losses were greatest
- where the losses were least
- what the consequences would be if all the larvae made the journey successfully
- what would happen if we altered the natural conditions of the stream (e.g. channelizing the stream with concrete)
- what seemed realistic about this simulation and what did not

10. Ask the students to summarize what they have learned about the life cycle of 'o'opu, its migration, and limiting factors. Make sure the students have a clear working definition of limiting factors. Encourage them to make the general-

ization that all animals—not just 'o'opu—are affected by limiting factors. Ask the students to give examples. They might mention availability of suitable food, water, shelter and space; disease; weather; predation; changes in land use; stream diversions, and other human activities.

EXTENSIONS

1. Write a report on the life history of one of the species of 'o'opu (akupa, naniha, nakea, nopili, hi'ukole). Create a mural showing the life cycle of the native goby.
2. Investigate and discuss dispersal of various species. The Tahitian prawn was introduced into three streams in the state in 1956. Today it is found in virtually every watershed throughout the island chain. Tahitian prawns are diadromous; eggs hatch in the stream and are carried downstream and out to sea. The larvae are transported by ocean currents until they can settle in the vicinity of stream discharges. What other organisms go through diadromous dispersal? How did they spread so far? Are there special biological features that the animal must have in order to be dispersed from one island to the next?
3. Take the class on a field trip to a channelized stream and to one that has not been so severely altered. Examine the stream beds for signs of life. Have students record their observations.

EVALUATION

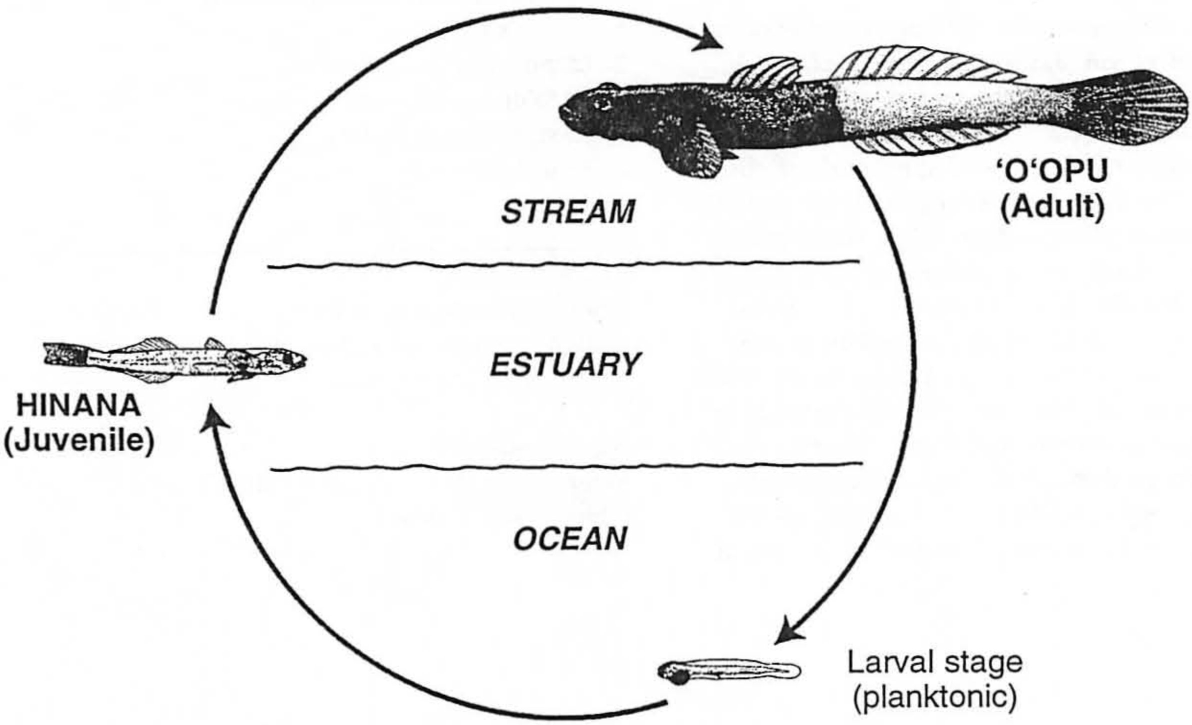
1. List, describe and illustrate the major stages in an 'o'opu's life cycle.
2. Identify and describe some of the factors that affect 'o'opu as they complete their life cycle.
3. Identify and describe some limiting factors that might affect other animal populations.

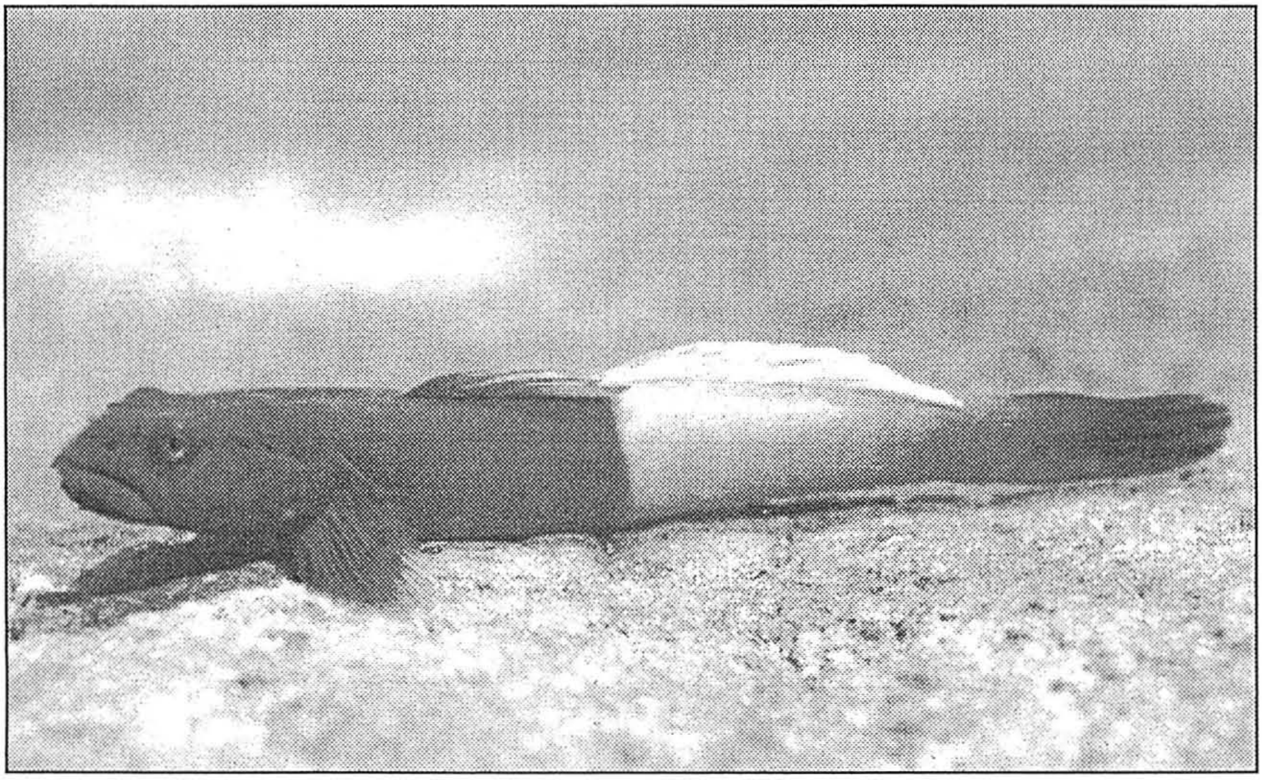
CORRELATIONS

Additional background information and activities related to 'o'opu are included in DOE's *Kauai: Streams and Estuaries* unit.

Age: Grades 3-9
Refer also to *Project WILD Aquatic* page 76 ("Hooks and Ladders")

'O'OPU LIFE CYCLE





FASHION A FISH

Ref: *Project WILD Aquatic* Page 88

No change to:
OBJECTIVES
METHOD
BACKGROUND
PROCEDURE

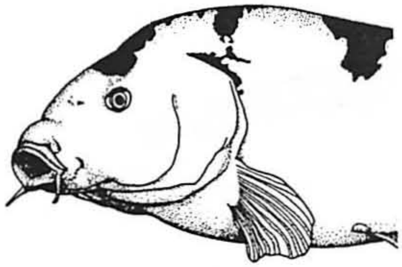
MATERIALS
Use the supplemental masters provided for this activity, which make more use of local (and more familiar) species. Substitute the table below for the one on page 89.

CORRELATIONS
Additional activities and information related to form and function in fish can be found in the Hawaii Nature Study Program *Reef and Shore* unit.

Age: Grades 3-12

ADAPTATION	ADVANTAGE	EXAMPLES
Mouth		
sucker shaped mouth	feeds on small plants and animals	carp
elongate upper jaw	powerful jaw muscles	shark
elongate lower jaw	feeds on prey it sees above	barracuda
spearlike upper jaw	slashes prey	sailfish, marlin
extremely large jaws	surrounds prey	grouper, bass
Body Shape		
torpedo shape	fast moving	ono
flat bellied	bottom feeder	catfish, goatfish, anglerfish
vertical disc	fits into small spaces	butterflyfish, bluegill
horizontal disc	bottom dweller	flounder
slender shape	fits into small spaces	eel
Coloration		
light colored belly	hard to see from below	tuna, perch, mackerel
light all over	hide in sand or surf	moi, weke
vertical stripes	camouflage near coral	manini, mamo
bright coloration	warning or recognition	wrasse, butterflyfish
mottled coloration	camouflage near bottom	hawkfish, rockbass, trout
Reproduction		
eggs deposited on surface	hidden from predators	mamo, trout
eggs deposited in nests	protected by adults	bluegill, bass
floating eggs	dispersed in high numbers	mahimahi, striped bass
eggs attached to vegetation	stable until hatching	tucunare, perch
live bearers	high survival rate	guppies, some sharks

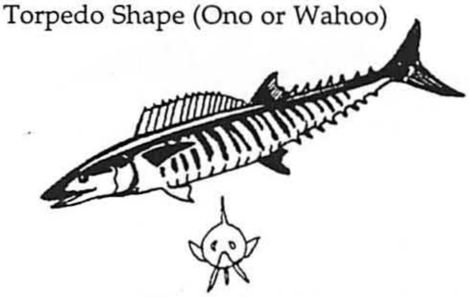
Mouth/Feeding



Sucker Shaped Mouth (Carp)

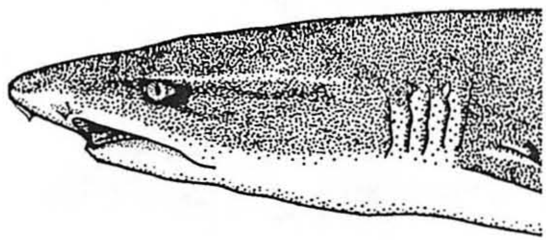
Body Shape

Torpedo Shape (Ono or Wahoo)

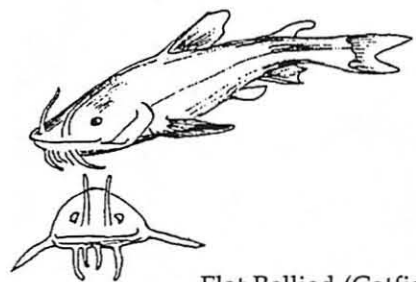


Mouth/Feeding

Elongate Upper Jaw (Shark)



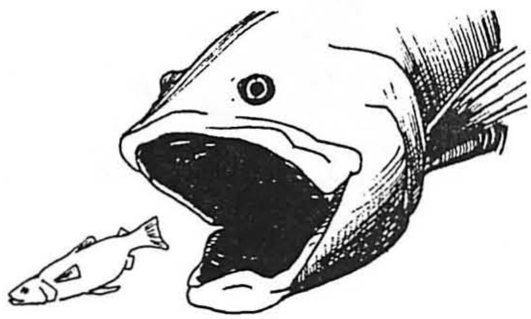
Body Shape



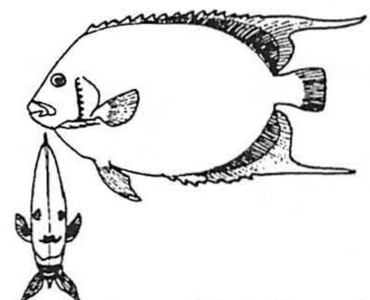
Flat Bellied (Catfish)

Mouth/Feeding

Extremely Large Jaws (Grouper)



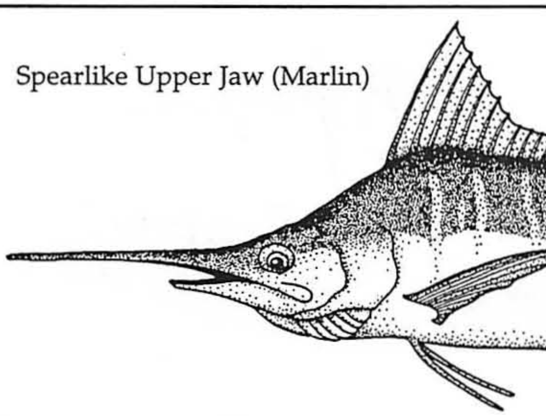
Body Shape



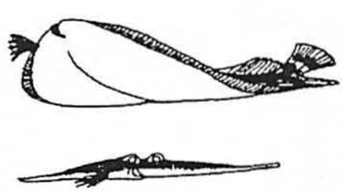
Vertical Disc (Butterflyfish)

Mouth/Feeding

Spearlike Upper Jaw (Marlin)



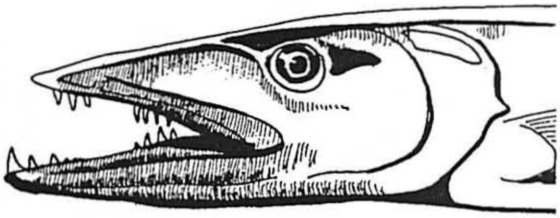
Body Shape



Horizontal Disc (Flounder)

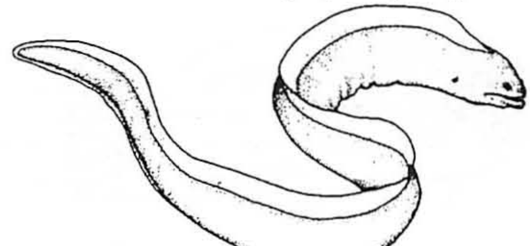
Mouth/Feeding

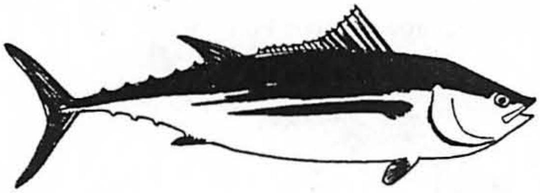
Elongate Lower Jaw (Barracuda)



Body Shape

Slender Shape (Moray eel))

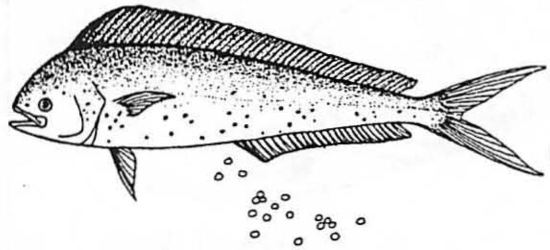




Light Colored Belly (Tuna)

Coloration

Floating Eggs (Mahimahi)

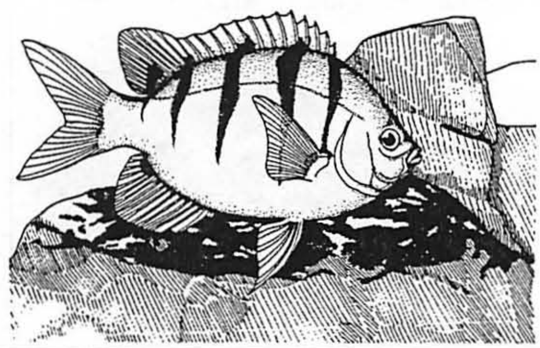


Reproduction

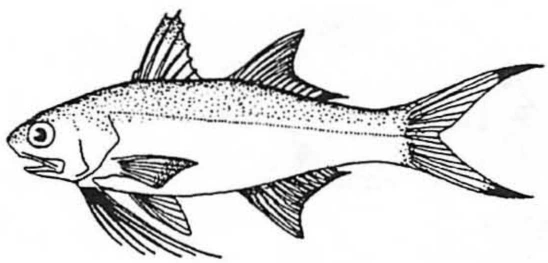
Vertical Stripes (Manini)

Coloration

Eggs Deposited on Surface (Mamo)



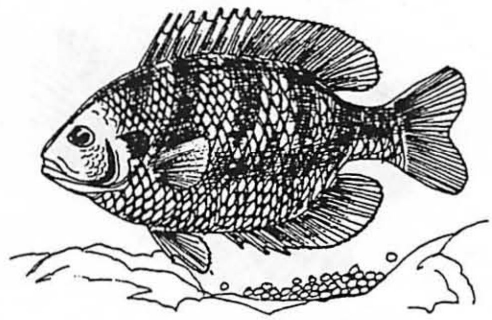
Reproduction



Light All Over (Moi)

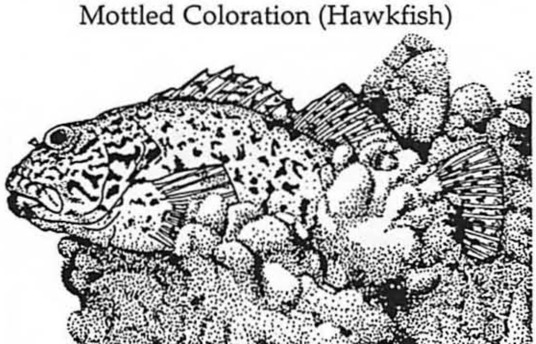
Coloration

Eggs Deposited in Nests (Bluegill)

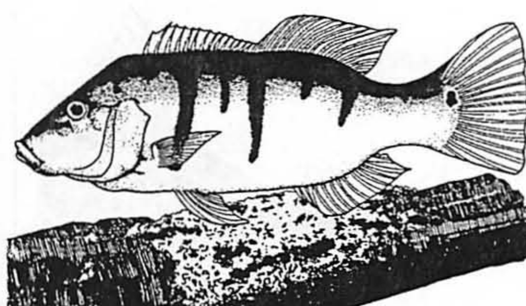


Reproduction

Mottled Coloration (Hawkfish)



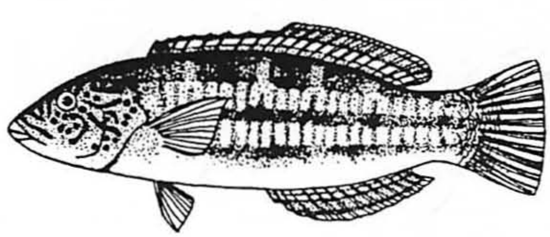
Coloration



Eggs Attached to Vegetation (Tucunare)

Reproduction

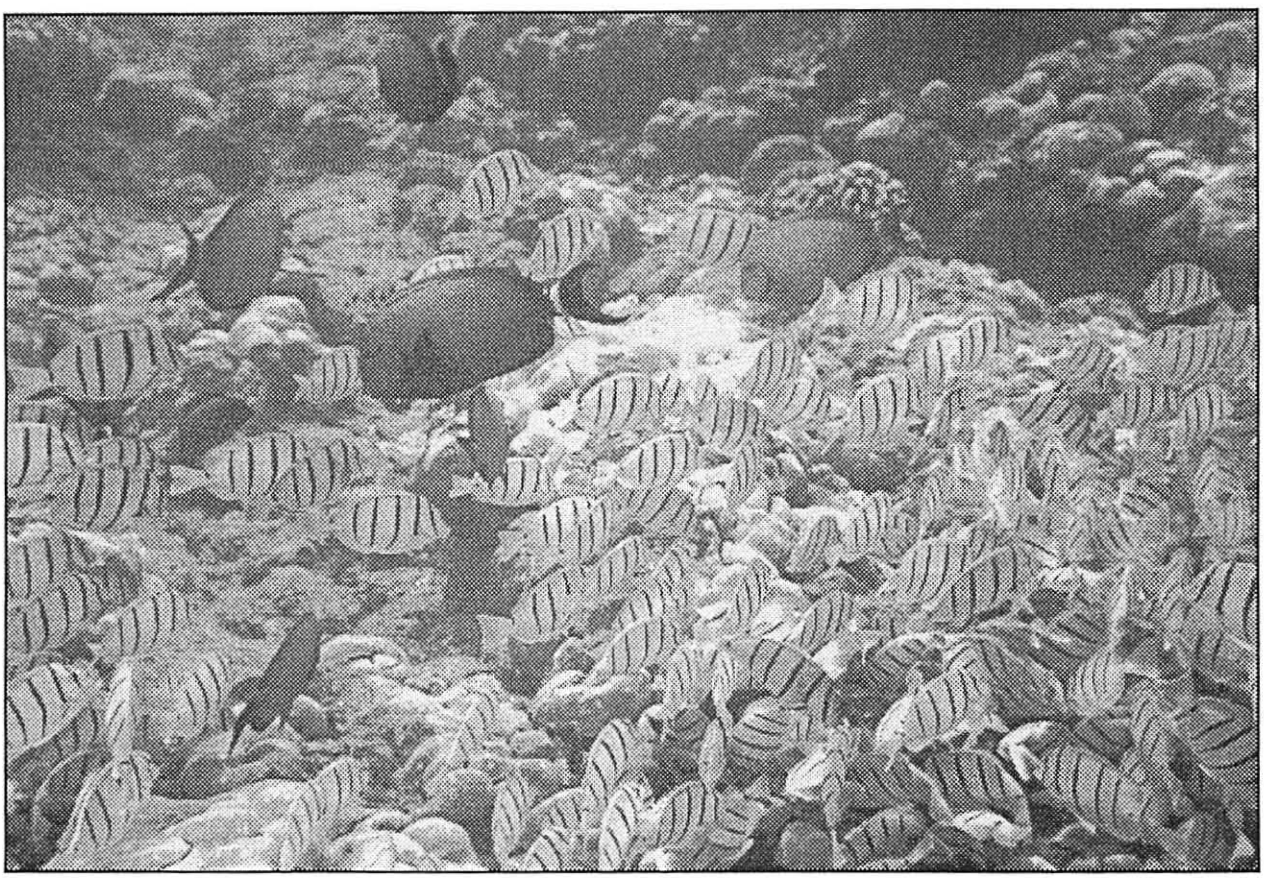
Bright Coloration (Wrasse)



Coloration

Live Bearer (Guppy)

Reproduction



MIGRATION MIRACLE

OBJECTIVES

Students will be able to: 1) list limiting factors affecting populations of migrating shorebirds; 2) predict the effects of such limiting factors; 3) describe the effects of habitat loss and degradation on populations of migrating shorebirds; and 4) make inferences about the importance of suitable habitat for migrating shorebirds.

METHOD

Students role-play a migrating shorebird, the Pacific golden-plover or *kolea*, traveling between nesting habitats (the Arctic, Alaska) and wintering grounds (Hawaii). They experience hazards at either end of the migration path as well as along the way.

BACKGROUND

Migration is a mysterious phenomenon. How do birds, fish, mammals and insects travel the immense distances they do with such exactness? Some travel at night, some during the day, some in skies and others deep within the seas. Yet unerringly they locate habitat necessary for the continuation of their species.

Scientists have proposed that they use the stars, the sun, even the earth's magnetic field for guidance. Some animals, such as salmon, seem to use smell to guide them home from the sea. Most likely, migrating animals use a combination of means to guide their fantastic journeys.

Each year, the Hawaiian Islands are home to a number of migratory birds. Perhaps the most common seasonal visitor is the Pacific golden-plover, or kolea. These little birds cross the vast Pacific Ocean to spend the winter here after breeding in the Arctic during the summer. Their incredible voyage usually takes less than two days! Many of them spend the whole year here and are easily spotted from the shoreline to the top of Haleakala.

The populations of some species of birds, such as the kolea, are healthy; however, there are many more populations of birds on a long-term downward trend. Among the species that are listed as endangered in Hawaii are the Hawaiian duck *(koloa)*, black-necked stilt (*ae'o*), American coot (*'alae ke 'oke'o*), common moorhen (*'alae 'ula*) and Laysan duck.

There are international treaties and national laws affecting migratory species, including water birds. In the United States, the U.S. Fish and Wildlife Service has principal legal responsibility for managing migratory wildlife at the federal level. State wildlife agencies share some responsibilities with the U.S. Fish and Wildlife Service in protecting migratory animals.

The primary threats to the survival of migratory waterfowl are the loss and degradation of habitat. With reduced habitat, dozens of species of ducks, geese, swans and other birds have nowhere to rest, nest and feed.

Many federal, state and private groups recognize the importance of habitat to the very survival of wildlife. For example, millions of acres of wetlands have been purchased and protected to actively preserve and restore habitat for local wildlife and the vast flocks of migratory birds that span the continents and oceans on their journeys.

Agriculture, development and industry are all reducing the availability of natural habitat. Pollution, through pesticides and heavy metals, takes its toll. On the positive side, the use of lead shot by waterfowl hunters has been outlawed nationwide since 1991. Lead pellets that missed their mark would sometimes be mistakenly consumed as food by the birds and their predators, resulting in lead poisoning and death. Shotgun pellets used on wetlands are now made of steel.

There is new evidence suggesting that "acid rain" may be affecting insect populations upon which the birds feed. Natural conditions also affect the migratory birds and/or their prey. Predators, weather, disease and fire influence both the animals and their habitats.

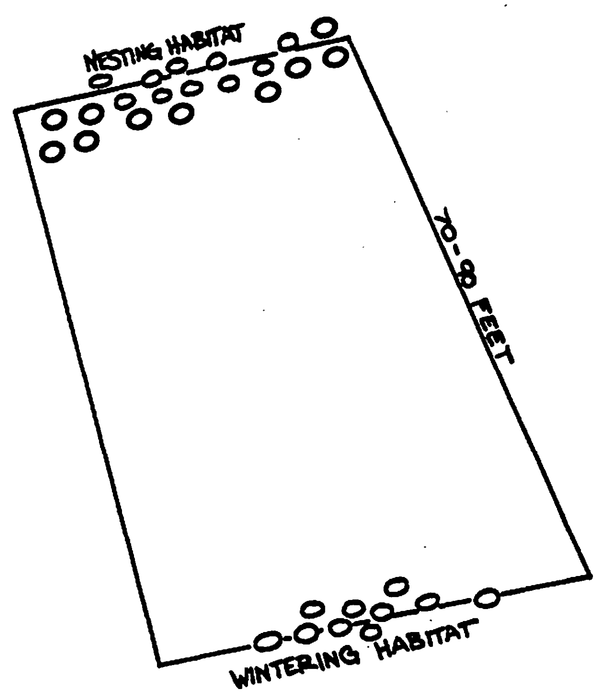
Because the life cycle of migratory birds is somewhat complex and migration itself is still such a mystery, we have greatly simplified the chain of events for this simulation. Many of the hazards of the migratory cycle are encountered en route. We guide the teacher to emphasize these hazards in discussion rather than during the simulation.

Each student (assuming a class size of 30) represents thousands of birds. Thus, occasional losses to predation and other events of relatively minor magnitude during the course of migration are downplayed.

The major purpose of this activity is for students to dynamically experience some of the important factors which affect the survival of migratory bird populations.

MATERIALS
Large playing field or gymnasium; paper plates, or 12" by 12" carpet samples available at no cost from most carpet retail stores.

PROCEDURE
1. Review background information on kolea with class. Distribute copies of fact sheet on page 55. Emphasize that the kolea depends on <u>two</u> kinds of habitat: breeding grounds in the Arctic and wintering grounds in the tropics (e.g. Hawaii). They need healthy habitats and good food supplies in both places.
2. Select a large playing area about 70 feet in length. Place the paper plates in two groups at either end of the playing field as shown (you may wish to staple or glue several paper plates together so they're not blown away as easily by the wind). Choose the number of plates so that you have somewhat fewer plates at each end of the field than there are students. Use your discretion, depending on the effect you want to demonstrate.
2. Explain to the students that they are the Pacific golden-plover or kolea, and will migrate between these two areas at your signal. Tell them that the plates represent suitable habitat for water and shorebirds. At the end of each journey, the students will have to claim a plate and have one foot on it in order to continue. If they cannot find a plate, that means they have not found suitable habitat. They "die" and have to leave the flock.



3. Begin with all students at the nesting grounds. Signal for them to migrate (without running) over to the wintering grounds. They can "flap their wings" for effect. Those who cannot find a plate are "dead". Move these students to the center of the field. The remaining birds wait at the wintering habitat until the "dead" birds are arrayed in a line, holding hands. Explain to the entire group that these students are now a storm and the migrating kolea must pass through it on their way back to the nesting grounds. The "storm" will try to encircle and stop the migrators from

making it across the field. This exercise may have to be timed. After a count of about 10, those who have not freed themselves from the storm are considered "dead" or lost.

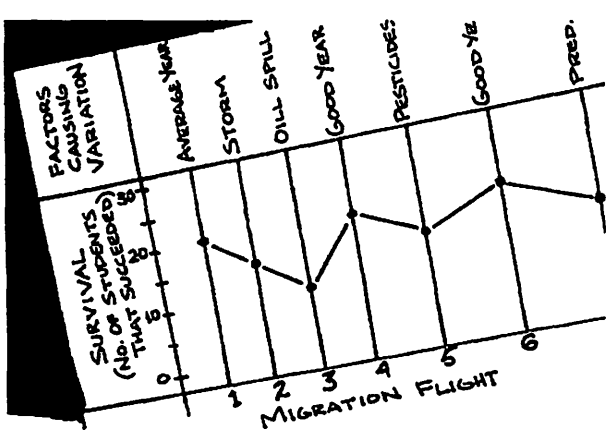
4. Count how many have made it to the other side (the nesting grounds). Call the whole group together and summarize what has occurred.

5. Clear the field of the "dead" birds; have them rejoin the group at the nesting grounds as new hatchlings. Adjust the number of plates at the wintering grounds so there are again fewer plates than surviving birds. Explain to the entire group that this represents an overuse of pesticides at the wintering grounds, severely reducing food supplies.

6. Repeat the process until eight or ten migratory flights have been completed, to illustrate changes in habitat conditions with resulting effects on the numbers of birds. Continue to provide opportunities for "dead" birds to re-enter as hatchlings, as appropriate.

NOTE: The series of migration cycles can be graphed as shown below. Make the graph big enough for students to see it while on the field. Many teachers have chosen this method to record the cycles.

7. Give examples of factors that might influence the birds' survival. (See the following table for suggestions.)



Factors Limiting Survival of Populations of Kolea

- pesticides (insufficient insect food)
- drought
- oil spills at breeding grounds
- snow doesn't clear at breeding grounds
- trampling of nest sites (musk ox, reindeer)
- urban expansion
- predation (foxes, bears, squirrels, caribou, reindeer, dogs, cats, mongooses, etc.)
- insufficient food stored up for migration
- illegal hunting
- migratory mistakes (timing, direction, etc.)
- storms (blown off course)
- disease

Factors Favoring Survival of Populations of Kolea

- creation of new wintering habitat
- abundant prey
- restoration of habitat
- dynamic balance with predators
- public education efforts
- regulation of hunting

Some limiting factors are a natural dynamic part of any environment. This is true of factors favoring survival as well. However, the significant difference in the case of the survival of populations of migratory shorebirds seems to be the loss or degradation of huge areas of suitable habitat, much of it as a result of human intervention, e.g. draining wetlands, polluting water supplies.

Be sure to create one or more "disaster" years to illustrate catastrophic loss of large areas of available habitat. Remember that, overall, the availability of suitable habitats for migrating shorebirds is diminishing—the activity should end with fewer areas of available habitat than can accommodate all the birds. There is general agreement that the greatest long-term threats to the survival of migratory shorebirds are loss and degradation of habitat.

8. In discussion, ask the students to identify the apparent causes of the birds' population decline

from year to year. Ask them to try to imagine what seem to be the major factors contributing to habitat loss and degradation. Ask them to make predictions about the effects of these factors. Distinguish between short-term and long-term effects. Distinguish between catastrophic effects and gradual changes. Ask the students to support their hypotheses with evidence, seeking additional information through research if necessary.

9. Ask students to summarize what they have learned about some of the many factors that affect the success of bird migration. List and discuss human-caused factors and environmental factors. Compare similarities and differences between these limiting factors. Highlight those which the students identify as posing the most significant long-term threat to the survival of migrating shorebirds.

10. What kinds of things can and should be done to protect and restore habitats for migrating shorebird populations? Discuss potential trade-offs related to any recommendations.

EXTENSIONS

1. Teach students how to identify the kolea using field guides and photos. Conduct a field trip to a known wintering habitat, such as Kanaha Pond on Maui, or another state or federal preserve. Ask students to keep a log of sighting locations for the kolea (they can be seen around lawns, golf courses and beaches).

2. Explore the major factors affecting habitat loss and degradation, or gain and restoration, in your area. Research the causes for long-term habitat loss, as well as any major efforts underway to prevent these increasing losses.

3. Using a map, plot the migratory routes of the kolea and several other shorebirds.

4. What other animals migrate? Restructure the exercise using humpback whales (*Megaptera novaeangliae*) as the example. Are the problems they face similar to those of migratory birds?

5. There are national laws and international treaties protecting migratory species. Find out about some of these. What is their history? Are they effective? Are there problems enforcing them? What migratory species, if any, are unprotected by such laws?

EVALUATION

1. Name two human activities and two environmental factors that might interfere with shorebird migration. For each activity and factor, describe the possible effects on the shorebirds.

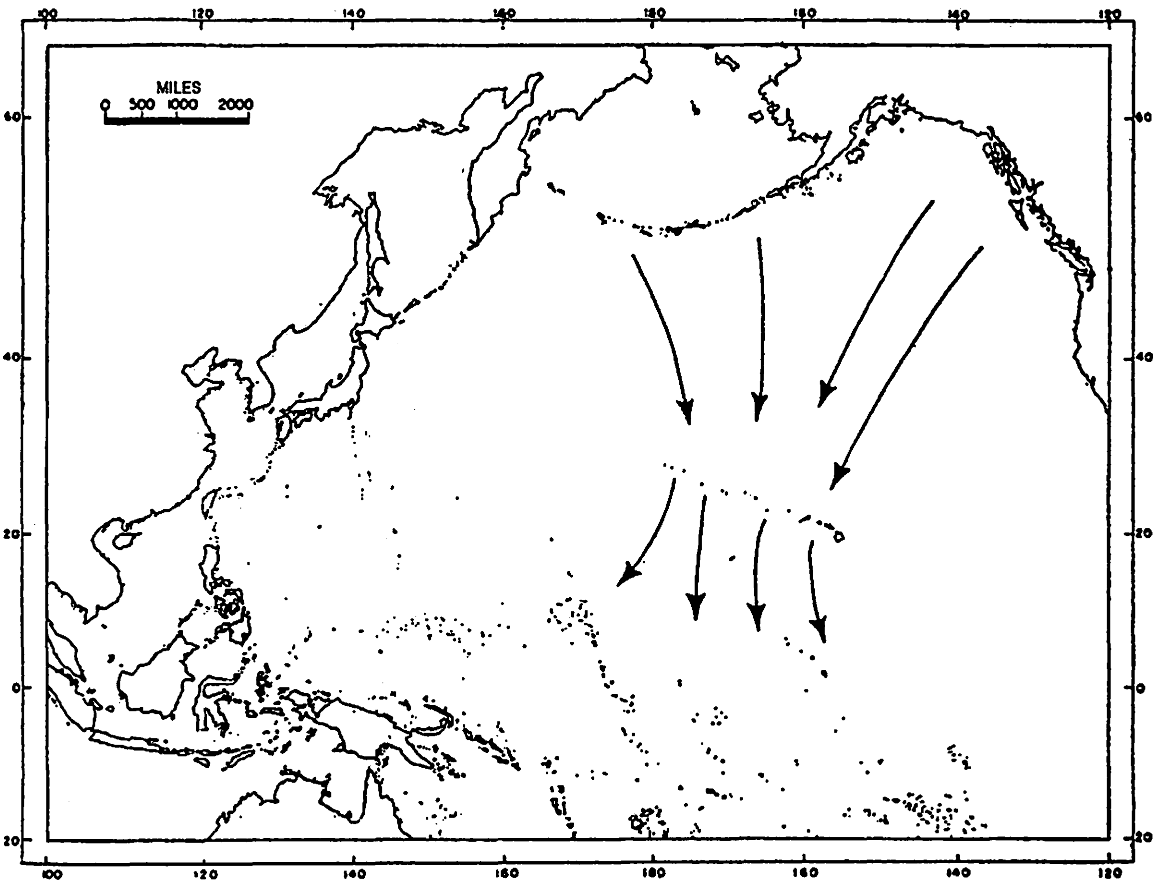
2. Distinguish between effects on individual birds and effects on populations of birds. Indicate if an effect is short-term or long-term.

3. Why is suitable habitat important for migrating shorebirds? Include in your response a description of the different kinds of habitat that are needed by migrating water birds.

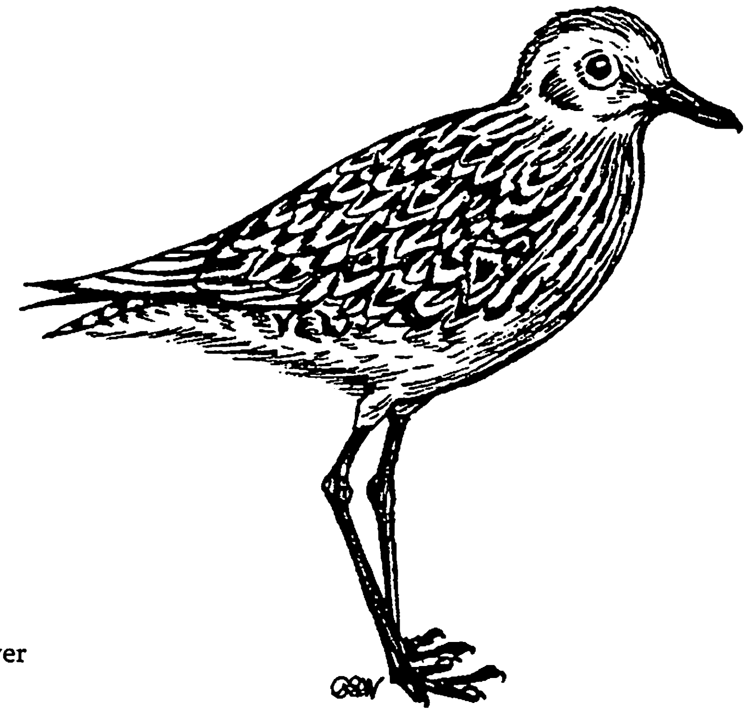
4. True or false: Habitat loss is a greater threat to the survival of migrating populations than for stationary populations of wildlife. Explain your answer.

Age: Grades 6-12

Refer also to *Project WILD Aquatic* page 94 ("Migration Headache")



Southward migratory route of kolea, the Pacific golden-plover.



Kolea

Pacific Golden-Plover
Pluvialis fulva

DISTRIBUTION: Migratory to the Hawaiian Islands. One of the world's foremost long-distance fliers, makes annual nonstop flights between the arctic and tropics. Breeding grounds along western coastline of Alaska. Hawaiian Islands are on the northern edge of winter range.

Adults arrive in Hawaii in mid-August through early September. Juveniles arrive in October; first-year migrants to Hawaii (and beyond) suffer high mortality en route. Found on all islands on mudflats, lawns, fields, beaches and grassy mountain slopes. Close cropped grass, which resembles tundra on breeding grounds, is favored. Northward migration back to breeding grounds occurs in late April and early May. Flight between Alaska and Hawaii takes 50 to 72 hours. A few kolea (less than 1%) do not migrate back to the north and stay for the summer, often due to illness or injury; these never attain full breeding plumage. Individuals return to the same wintering and breeding sites each year.

DESCRIPTION: Coloration is dark brown, spotted with gold above, paler below. Sexes are similar in winter plumage. Prior to leaving the Hawaiian Islands in April, the kolea molts into breeding plumage: white band over the forehead and down the sides of the neck, with the cheek, throat, breast and abdomen black. Length is 11 inches, weight about one-half pound. Life span estimated at 8 years.

VOICE: Clear, melodious whistle.

NESTING: Nests in Alaska and the arctic. Lays four eggs, one every other day, totaling two-thirds of female's body weight. Generally arrives in the Hawaiian Islands in flocks, which soon disperse. Many kolea establish their own territories which they defend from other kolea, while ignoring other species of birds. Some kolea (usually young birds) are non-territorial. Wintering birds often roost on offshore islands or rooftops at night to avoid predators like cats, dogs and mongooses.

DIET: Winter diet consists exclusively of insects. Non-territorial kolea feed in groups. Kolea can usually be seen running for a few steps then stopping; they listen and peer at the ground in search of food.

OTHER NOTES: Kolea is the most abundant of Hawaii's migratory shorebirds. An indigenous species, it is protected by both federal (Migratory Bird Treaty Act) and state law (Wild Bird Law).

AQUATIC ROOTS

Ref: *Project WILD Aquatic* Page 100

No change to:
METHOD
MATERIALS

OBJECTIVES
Regarding Hawaii's aquatic animals and plants, students will be able to: 1) trace the origins of various species; 2) categorize them as native or exotic; and 3) evaluate the appropriateness and positive or negative effects of introducing new species.

BACKGROUND
Hawaii's temperate and relatively pleasant climatic conditions have nurtured and fostered the growth, development and proliferation of a multitude of native and exotic species. But competition for resources has led to "survival of the fittest"; in combination with other effects, this has resulted in extinction to some native species and the placing many others on the "endangered species" list.

Native animals and plants arrived in the islands without the help of humans. The early Hawaiian settlers, and later the Europeans and other ethnic groups, were responsible for introducing new, exotic species.

Exotic introductions have been classified as intentional (for pest control, food, sport, trade, etc.) or accidental (e.g. pests, aquarium fishes in streams, etc.). Research has shown that surviving "aliens" usually affect other animals, plants and the entire ecosystem. These effects have ranged from detrimental to beneficial, depending largely on the perspective taken. Some introduced species appear to have had little or no noticeable effects.

Among the introduced aquatic animals, some serve useful purposes, such as food or sport fishing. These include groupers, snappers, basses, trout, prawns, etc. Others, whether intentionally or accidentally admitted for various reasons, have caused some major concerns. Varying points of view debate whether the crayfish, *Procambarus clarkii,* or the tilapia have resulted in any useful purpose.

Many fishes classified as ornamental aquarium types, such as the swordtail, convict cichlid, armored catfish, and freshwater silver needlefish, have become widespread and established in our streams, ponds and reservoirs. Tropical fish hobbyists have released them without apparent concern for the possible negative effects and disruption of stream-life ecosystems. Release of illegal fishes, such as piranha, into local waters causes serious concerns for human safety and the health of existing fish populations.

Alien plants have also found their way into Hawaiian waters and have played a commanding role in the environment, either benefiting or disturbing the normal habitat of native flora. Many have survived and thrived.

The taro (or *kalo*) and some mangrove have proven to be beneficial. Taro is a staple food source; mangrove builds and protects land areas while its wood has been utilized for fuel. Other species have been admitted for ornamental or aesthetic reasons, but have escaped their cultivated areas and overcrowded natural stream or pond environments. Among these have been the water weed, water lettuce, lotus, water hyacinths, etc.

Many marine flora (seaweed or limu), whether native or exotic, have been known for their nutritive food value. Others have no apparent value at all. Certain cultural uses have included medicinal or adornment purposes. Over the years new saltwater species have appeared in the isles. Among the rhodophyta or red seaweeds, ogo *(Gracilaria parvispora* and *Acanthophora spicifera)* have been here since the 1900's and have become firmly established. The former species is perhaps the most widespread in terms of popular use and harvesting. The latter has not served any useful purpose, and displaced other algal species.

An example of an introduced seaweed which went seriously awry is the red alga *Hypnea musciformes*. Researchers, hoping to find a way to extract colloids from *Hypnea's* cell walls, brought the alga illegally into Hawaiian waters around 1974. The *Hypnea* escaped and spread around Oahu and to parts of Maui and Lanai. Surfers nicknamed the alga "hookweed" because the sharply curved branch tips cling to wetsuits. *Hypnea* also hooks onto the native seaweed *Sargassum* (limu kala), and drags it up to shore. This harms the *Sargassum* as well as fish and other animals that depend on it for food and shelter. Recently, masses of *Hypnea* have occasionally bloomed and washed up on west Maui beaches.

Earlier in Hawaii's history no known legal proceedings regarding introduction of species had been enforced. Our state, as well as other states, has now developed rules and regulations to prevent possible detrimental "mistakes" from occurring. Introductions of some of these exotic species, whether animals or plants, have proven positive. In other cases they have proven negative or detrimental over the course of time. A significant focus of this activity is to study and explore the role these introduced species play in our environment and to develop an awareness of the need to carefully regulate any admittance of these aquatic flora and fauna.

PROCEDURE

1. Review vocabulary words: marine, flora, fauna, native, exotic, endemic, indigenous, introduced
2. Distribute worksheet "Native or Exotic? Marine or Freshwater?" Have students fill in sheet to the best of their knowledge. Discuss and follow up with a slide presentation of the flora and fauna listed on the worksheet.
3. Have students form pairs to select and research 1-2 exotic plants or animals (see Appendix 10 for examples). Reports on the selected topic could include (if available) a) year, place(s), reasons for introduction to Hawaii; b) general information and impact on the ecosystem; c) sketches, snapshots or illustrations; d) decisions whether the introduction was beneficial or not and reasons why or why not. Provide students with bibliographic references and other local resource information to assist them.
4. Suggest that each pair prepare a report to be shared orally using one or a combination of the following methods: illustrated chart or mural; diorama, aquarium or terrarium; stick puppets; movie roll; mobiles; etc.
5. On a large map of the Hawaiian Islands, students may want to share their discoveries of what islands their species was introduced to, year introduced, and what the introduction has led to in our environment. For example:

Spotted grouper (roi), *Ephinephelus merra*, was brought to Coconut Island, Oahu on October 10, 1956 and to Anini Reef, Kauai on October 17, 1956 for commercial and sport fishing.

Asiatic clam was first discovered on Kauai (an illegal introduction) and is now found in Waipahu streams on Oahu.

6. Following the oral reports, divide class into small groups. Have students brainstorm and write down all ideas as to how and why introductions occur. Encourage investigations, debates and general discussion on issues that have or might arise with intentional, accidental or illegal introductions. How can potentially dangerous, illegal introductions be prevented or coped with? How would they handle a case where one might suspect someone of harboring an illegal entry? What social and ethical responsibilities are important to keep in mind regarding these issues?
7. Have the class globally summarize findings on a world map. Using strips of colored yarn, link Hawaii with the state or foreign country from

which the introduced species originated.
9. Divide class in half. Form two teams selecting a captain and a recorder for each team. Recorder is to write down all major concepts learned in this activity. Allow 5 minutes. After time is called, captains are to orally discuss what concepts teams derived.

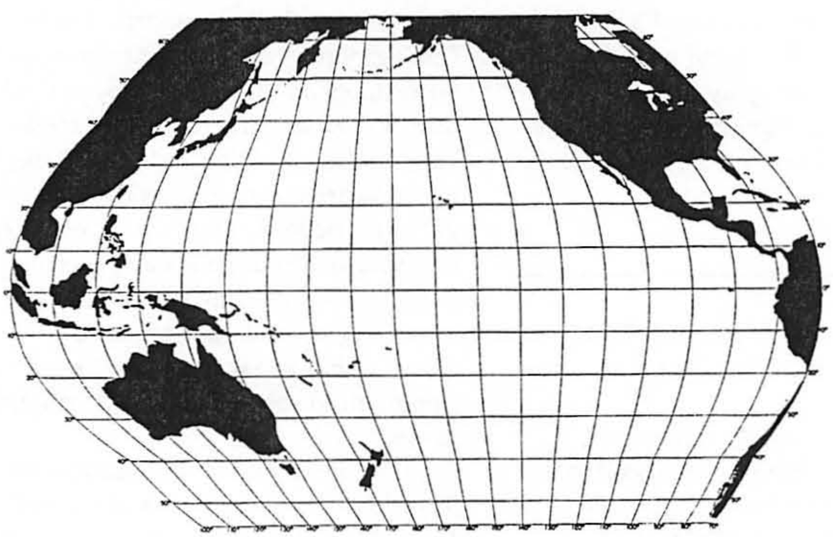
EXTENSIONS

1. Invite resource speaker(s) to class or arrange for a visitation to agencies that discuss rules and regulations on illegal introductions or how to prevent potentially dangerous "accidental" introductions from occurring in Hawaii. Have them explain what to do with illegal animals you may have.
2. Construct a time line listing introductions of foreign species to Hawaiian waters by date, from earliest to most recent times.
3. Take a survey of what aquatic native or exotic flora and fauna are found in the students' homes or neighborhood.
4. Have groups of students write and perform an imaginary short dramatic play or puppet show on topics such as "From Aquarium to Stream—What's Happened With Tropical Fish" or "How (plant or animal) Journeyed to Hawaii".
5. Construct a scrapbook or portfolio of items related to topic of study. Make a collection of the following: a) newspaper or magazine article clippings on issues related to native/exotic aquatic animals and plants in Hawaii; b) identified dried/pressed native and introduced seaweeds, or leaves and flowers of other aquatic flora.
6. Observe what is in the classroom: aquaria, etc. Take a walking tour of the school campus. Identify and record some of the plants and animals observed. Research and list whether these are native or exotic species.

EVALUATION

1. Return worksheet, "Native or Exotic? Marine or Freshwater?" to students. Have them put in corrections, if any, and discuss paper with class.
2. Of the aquatic animals or plants discussed, name two or more native and exotic species not given on the worksheet. Find several reasons for why a species might be introduced to our islands. Name some negative and positive effects of what might happen.
3. Play a "Native or Exotic Trivia" game with the class. Divide class into teams. Score one point for each team that answers a trivia question correctly on topics discussed in their studies.

Age: Grades 5-12



Name ____________________

Native or Exotic? Marine or Freshwater?

DIRECTIONS: For each organism listed, check whether it is an animal or plant, native or exotic, fresh-water or marine.

Name	Animal	Plant	Native	Exotic	Freshwater	Marine
Crayfish						
Bullfrog						
Water hyacinth						
Swordtail						
Taro *(kalo)*						
'Opae kala'ole						
'A'ama crab						
Guppy						
Ogo						
Limu manauea						
Tilapia						
Catfish						
'O'opu						
Mangrove						
Hihiwai						

NET GAIN, NET EFFECT

OBJECTIVES
Students will be able to: 1) describe the use of nets for fishing from early to contemporary times; and 2) describe the effects of different net mesh sizes on species and size of fish taken, and subsequently on fish populations.

METHOD
Students conduct a simulation to explore the effects of differing mesh sizes on fish populations.

BACKGROUND
In the days of old Hawaii one type of gear fishermen used was nets. Back then, nets were made from natural materials. Plant fibers were twisted into cord, then woven into various types of nets. "Dip" or "scoop" nets were used for catching small fish and crustaceans in shallow water. Larger nets, some over 100 feet long, were used in deeper water to catch larger fish. Sometimes several nets were connected to catch large amounts of schooling fish.

Later, other natural materials such as linen and cotton twine were used to make better nets. More recently, though, these natural materials have been replaced by synthetic materials. In particular, the use of nylon monofilament line ("sugi") in net making has become more common. Nets made from this material are lighter, stronger, more durable, and less visible to fish than previous types of nets.

Gillnets are made to entangle fish when they swim into one of the "eyes" or openings of the net. Different mesh sizes are used depending on the size and species of fish sought. Fish caught usually get stuck right behind their gill plates depending on their body shape and position of their fins. Floats along the top and weights along the bottom keep the net upright in the water. The net resembles and funtions like a fence, and so it is often referred to as a "fence net".

Today's fishermen use these nets in a variety of ways. One popular method is to "set" or "lay" the net in front of a cave or across a bay that fish frequent. The fishermen leave the area and return later to collect their net and fish. Fish that attempted to enter or exit the area are entangled. Another variation is to set the net then scare or chase the fish into the net. This is done by slapping the surface of the water or making other loud sounds (pa'epa'e).

Surround nets are used to encircle a school of fish after they have been located. These nets are usually 100 feet or more in length and can be up to 20 feet in height. Several nets may be connected if the school is large. The net is spread in a circle around the school of fish. Once "corralled" the fish usually get gilled or are bagged. To bag the fish, a separate bag-shaped net (enclosed net with a single opening) of usually smaller mesh is attached to an opening in the circle. The fish are then chased into the bag, which is then closed.

Thrownet fishing was introduced from Japan to Hawaii about 1890. The thrownet is a circular net with weights around its circumference. It is usually 10 to 12 feet in diameter, and used mainly in shallow coastline areas. The net is carried by the fisherman and when fish are spotted he throws or casts the net over them.

Thrownet fishing requires much patience and skill. Providing he knows how to throw his net, the fisherman must locate the fish, maneuver into range and wait for the right moment to make his cast. Any movement at the wrong time will surely spook the fish. After throwing he must then enter the water and close off any escape routes under the net, then retrieve his net and catch.

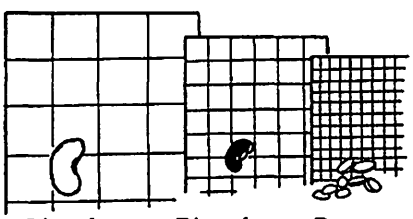
Drift gillnetting is a controversial method of fishing practiced mainly by some Asian countries. In this large-scale commercial method of fishing, more than 20 miles of 30-50 foot wide nets may be set out and allowed to drift in the open ocean.

Commercial fishermen are able to catch many fish using this method.

The problem with these huge driftnets is that while drifting they may also inadvertently catch other non-target species of fish that the fishermen aren't seeking (by-catch). Because the nets are not very visible, other wildlife like turtles, seabirds and marine mammals may also get entangled in them and drown. It is illegal to use or possess drift gillnets in Hawaii.

MATERIALS

nets or mesh bags of differing mesh size (see illustration below); styrofoam poi bowls; about two pounds each of large lima beans, pinto beans; about one pound each of popcorn, rice; writing materials; container large and deep enough to hold the beans and grain; smaller containers (e.g. paper cups and paper bowls) to transfer and hold netted "fish"



PROCEDURE

1. Prepare the "ocean" by mixing the beans and grains together in the large container. Divide the students into groups of four. Have one member of each group collect a cupfull of "fish" and return to the group.
2. Ask the students to decide what each bean or grain will represent for the purposes of this activity. Fish can be hypothetical or could represent actual fish. For example:
   - lima beans may become uhu, papio or kala
   - pinto beans may become kumu or moano
   - popcorn may become menpachi or aholehole
   - rice may become kole, mamo or manini

Make a chart matching the beans and grains with the fish they represent. Post the chart in front of the room or any place where it is easily visible to the students.
3. Discuss how fish are caught. "If you catch fish, how do you do it? Have you seen people catch fish? How were they catching their fish? Could large numbers of fish be caught if all fish were caught with rods or poles? What are some ways to catch large groups of fish at one time?" After a general discussion of ways people fish, tell the students that they will now simulate the catching of fish using nets.
4. Pass out the netting materials, which should be cut to about six by six inches. One net of each mesh size should be given to each group. Also give each group two poi bowls with the bottoms removed, and two containers (such as paper bowls) to serve as the "ocean" and a "boat".
5. Show the students how to make a "sieve" with the poi bowls and coarse netting, then ask the students to "fish". They are to slowly dump the "fish" in the paper cup through the net and into the "ocean" bowl. You may wish to demonstrate first.
6. Have the students dump their "fish" into the "boat" bowl as needed to keep from plugging up the net. All "fish" caught by the net go into the "boat", all "fish" that pass through the net go into the "ocean". Count the number of each type of fish caught. Record the numbers. Counting or estimating may be used. The worksheet shown on the next page may be helpful. Have them return the fish to the paper cup and repeat the process, if desired.
7. Draw the students' attention to the species they have netted. The smaller popcorn and rice, and most pinto beans, often will slip through the netting and escape capture. The larger species—the lima and some pinto beans—are the most likely to have been caught. Ask them what they could do to catch more fish. Discuss possible options with them.

8. Ask students to again return all the fish they caught to the paper cup. Now have them make two fishing efforts with the medium-mesh net, returning all the fish to the cup before making each effort. Tabulate and discuss the results.
9. Ask students to fish two more times, now with the fine-meshed net. Tabulate and discuss the results. Return all the fish to the cup.
10. Work with the students to construct a bar graph showing the numbers of fish caught using the different nets. Ask the students to think and talk about what happens when the different kinds of nets are used. What might happen if people took all the fish from one part of the ocean? How can nets be used in order to catch certain kinds of fish in the ocean?
11. Now announce a different perspective. Tell them that all the fish, beans through rice, are of the same species. Tell them that no fish can be caught that is smaller than the popcorn species size.
12. The groups are now to represent commercial fishing operations. Have each group select a mesh size that they feel will allow them to catch the largest number of legal-sized fish.
13. Have each group make one "fishing" effort with the mesh size of their choice. Tabulate the results as before. Without returning any fish to the ocean, have them make a second effort with the same size net. Tabulate these results.
14. Tell the students that each lima bean is worth two points, and each pinto bean worth one point. Each popcorn or rice is a penalty of two points. Have each group calculate the number of points scored for each fishing effort. The group with the highest combined total wins the coveted "Riches of the Sea" award.
15. Discuss the comparison between the first and second fishing efforts in this part of the activity. Why were the fish not returned to the ocean prior to the second effort? What will happen in successive fishing efforts if fish are not returned? Why is there a penalty for catching smaller fish? What would happen if fish of any size could be taken?
16. Ask the students to summarize what they have learned. Review the history of net fishing in Hawaii. From both economic and conservation perspectives, what are the advantages and disadvantages of using nets, especially gill nets, to catch fish. What kinds of regulations on net use should be implemented in order to maintain fish populations?

EXTENSIONS

1. Create an illustrated history of the use of fishing nets in Hawaii.
2. Investigate the current status of the problems surrounding the netting of tuna. How successful have efforts been to develop, use and enforce use of new nets and technologies to prevent the accidental netting of dolphins?

	COARSE NET		MEDIUM NET		FINE NET	
SPECIES / *TRIAL:*	*1*	*2*	*1*	*2*	*1*	*2*
Lima Papio						
Pinto Kumu						
Popcorn Menpachi						
Rice Manini						

3. Who "owns" the fish in the sea? In streams? Who is responsible for conserving and protecting fish species?
4. Find out about regulations on recreational, subsistence, and commercial fishing in freshwater and marine environments in Hawaii.
5. Explore issues related to gill net use in the open ocean, particularly in reef areas. How do Hawaii's gill net practices compare with those of other coastal states or Pacific Island nations and territories?
6. Discuss the role of aquaculture (freshwater) and mariculture (marine) aquatic farming. How will this emerging field affect commercial fishing? What possible positive effects, if any, on fish populations and habitat might there be from a change to aquaculture and mariculture? What possible negative effects, if any?
7. Investigate commercial fishing in Hawaii. How big an industry is it? What fish are primarily targeted, and how are they taken? What are some significant current trends in landings of commercially important species? What new regulatory measures are under consideration? You may wish to invite a representative of a regulatory agency to speak to your students on these issues.
8. Find out about international treaties and organizations dedicated to conserving and protecting oceanic habitats.

EVALUATION

Describe how fishing has changed from early times to the present. How have these changes affected fish populations?

Age: Grades 7-12
Refer also to *Project WILD Aquatic* Page 104

WHERE HAVE ALL THE REEF FISH GONE?

Ref: *Project WILD Aquatic* Page 110
("Where Have All the Salmon Gone")

No change to:
OBJECTIVES
METHOD
MATERIALS
EXTENSIONS

BACKGROUND
In 1971 the state Department of Land and Natural Resources (DLNR) developed a fisheries management concept of rotating the opening and closing of certain shoreline areas to fishing as a means of replenishing marine life and improving fishing.

Initially the Department suggested establishing eight zones or management areas around the island of Oahu. At any time, four zones would be open to fishing with the remaining four zones closed on an alternating basis.

This idea, however, was vigorously opposed by many fishermen for a variety of reasons, such as the zones being too large and the cause of resource depletion attributed to reasons other than overfishing (pollution, habitat degradation, etc.). Moreover, there was no assurance the nearshore marine life would be replenished in closed areas if fishing in these zones was eliminated. As a result, the Department deferred establishing the fisheries management areas on Oahu.

However, in 1975 the State Legislature appropriated funds to assess the feasibility of establishing such a statewide management scheme. As a result of the study, the Department established the Waikiki-Diamond Head Shoreline Fisheries Management Area (SFMA) on Oahu to test the concept of fisheries management by area, beginning in July, 1978.

All fishing along the designated shoreline was suspended for a two-year period (Fiscal Years 1979-80, July 1, 1978 to June 30, 1980), followed by a one-year period open to pole-and-line fishing and hand harvesting only (FY 1981, July 1, 1980 to June 30, 1981), and a second one-year fishing period open to all legal fishing methods (FY 1982, July 1, 1981 to June 30, 1982). The SFMA was then closed for a second two-year no fishing cycle on July 1, 1982.

Biologists from the DLNR's Division of Aquatic Resources monitored fish stocks during the open- and closed-to-fishing cycles by conducting fish counts on a regular basis. After analysis of the data from several cycles, it was concluded that the fish stocks recover sufficiently after a year's closure to permit fishing, but that certain fishing methods (especially gill nets and night spearing) should not be permitted as they result in more rapid depletion.

The Waikiki-Diamond Head SFMA is currently open to fishing during even-numbered calendar years, and closed during odd-numbered years. Fishing with nets (other than thrownets) and night spearing are prohibited during the open to fishing part of the cycle.

The SFMA approach has proven to be a successful fisheries management concept, and may be expanded to include other areas statewide in the relatively near future. However, there continues to be opposition within the fishing community to regulations affecting particular areas for various reasons.

PROCEDURE
1. Provide students with the fish count data from 1977 to 1988 and blank graphs (give them copies of pages 67-68). Have them graph the data for the four species on the graph on page 67, using

different colored pens or pencils for each species. They should include a legend to indicate what each color represents. Students should then graph the data for the total of all species on the second graph (page 68).

2. Provide students with the historical data and information on selected species on page 66. Have them indicate years that are closed to fishing on the graph (perhaps by shading). Ask them to list and explain whatever inferences they can draw from the data provided. Do the graphs show any trends? Is there a relationship between the population abundance of each species and the historical information?

3. Have students consider more closely the fish descriptions, paying particular attention to information on schooling and fishing methods. What major factors may be affecting the population levels? Do the graphs seem to show any of these situations in relation to historical events? Do each of the interpretations seem to explain or fit the information and data? If faced with making a management decision about this type of open and closed fishing period, would you recommend more of these areas? Do you think it works? Should the time intervals be lengthened or shortened, or kept as they are? What kinds of local opposition to such restrictions might be encountered, and how could this be dealt with?

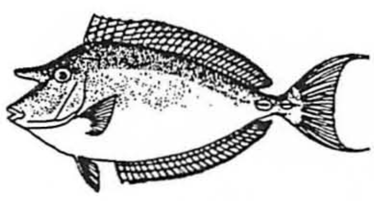
4. Wrap up with a discussion of the changes made to the Waikiki-Diamond Head SFMA (after 1988) as a result of this data.

Age: Grades 7-12

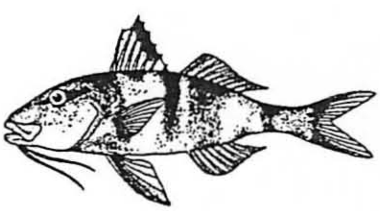
Historical Data

Fiscal Year (FY)	Status
1978	Prior to closure of Waikiki-Diamond Head SFMA
1979, 1980	Closed to fishing
1981	Open to fishing with pole-and-line and hand harvest only
1982	Open to all legal fishing methods
1983, 1984	Closed to fishing
1985	Open to fishing with pole-and-line and hand harvest only
1986	Open to all legal fishing methods
1987, 1988	Closed to fishing

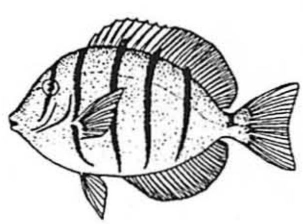
Descriptions of Selected Fish Species



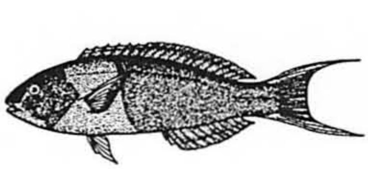
Kala, Unicornfish *(Naso unicornis)*
Description: Dusky olive, with light blue on fins and around caudal spines; horn protruding from front of head, lengthens with age; two fixed caudal spines on each side. **Size:** Length up to 2 feet. **Habitat:** Inshore reef areas and along rocky shores. **Feeding:** Diurnal; algae, especially more leafy varieties. **Schooling:** Schools; large adults sometimes found at edge of reef. **Fishing methods:** Net, spear, pole and line.



Moano, Manybar goatfish *(Parupeneus multifasciatus)*
Description: Reddish with shades of yellow and white; black marks behind eye, at base of pectoral fin, and black saddle areas in front of first dorsal fin, between dorsal fins, below soft dorsal fin, and in front of tail; deepness of color varies with light intensity, becoming lighter in bright light. **Size:** Length up to 14 inches. **Habitat:** Rocky areas, sandy bottoms near coral heads. **Feeding:** Diurnal; crustaceans, small fish. **Schooling:** Solitary or small groups. **Fishing methods:** Handline, spear, pole and line.



Manini, Convict tang *(Acanthurus triostegus)*
Description: Silvery, may have yellowish tinge; six black vertical bars, first passing through eye and last near base of tail; single small retractable caudal spine on each side. **Size:** Length up to 1 foot. **Habitat:** Most reef areas, from shore to depths of about 90 feet. **Feeding:** Diurnal; mostly fine algae. **Schooling:** Large schools, but also seen singly or in small schools. **Fishing methods:** Net, spear.

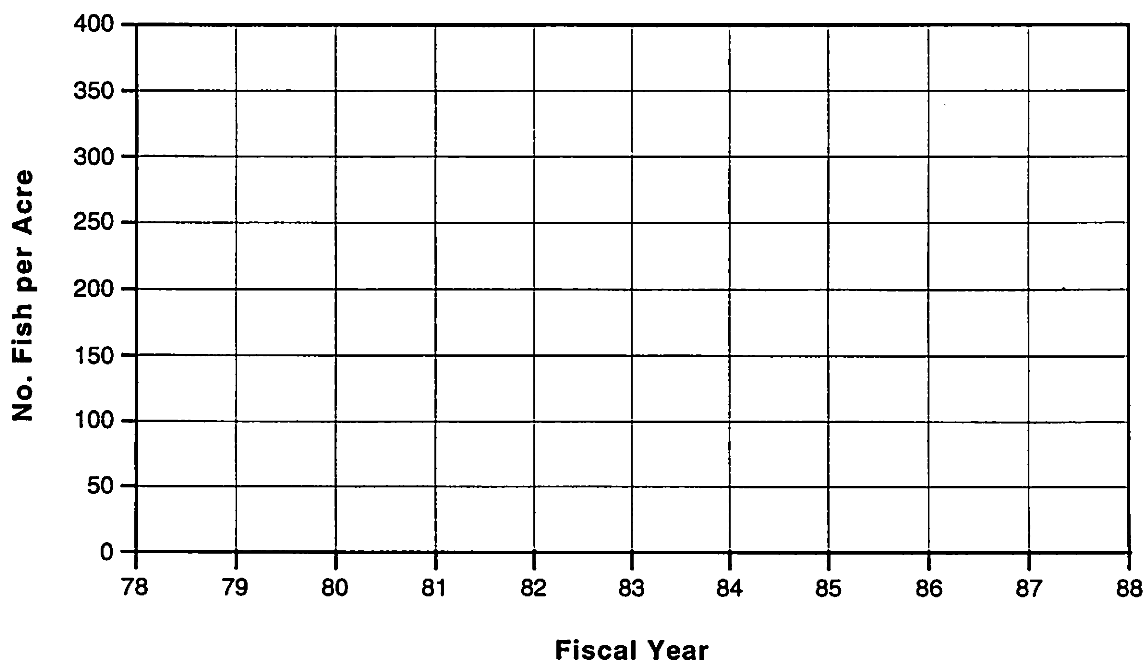


Hinalea, Saddle wrasse *(Thalassoma duperrey)*
Description: Green with vertical purple-red bars, purplish blue head and wide orange saddle surrounding body just behind head. **Size:** Length up to 1 foot. **Habitat:** Very abundant along shallow rocky shorelines and reef areas. **Feeding:** Diurnal; seaweed, crustaceans. **Schooling:** Solitary or small groups. **Fishing methods:** Pole and line, handline.

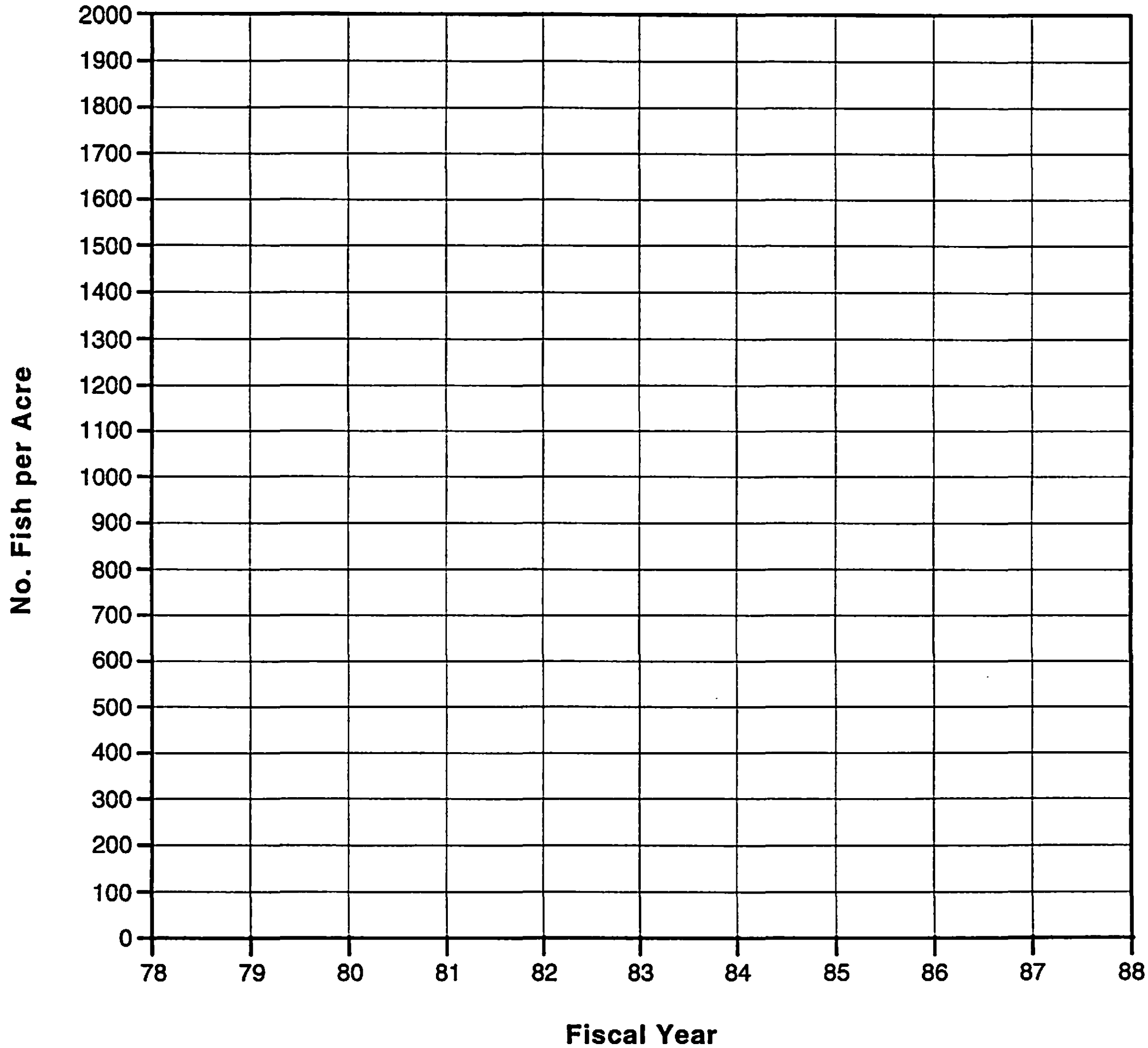
Fish Transect Data
Abundance by Year of Four Selected Species and All Species
Estimated Number of Fish per Acre

Fiscal Year (FY)	Kala	Moano	Manini	Hinalea	Total All Species
1978	30	8	229	101	730
1979	67	24	283	140	1050
1980	102	32	323	187	1490
1981	67	27	400	162	1470
1982	33	28	168	156	880
1983	70	32	269	185	1340
1984	112	36	335	232	1830
1985	97	22	256	200	1480
1986	48	28	179	173	1080
1987	85	54	256	224	1460
1988	96	65	328	232	1770

Waikiki-Diamond Head Fish Transects
Average Yearly Abundance
Selected Species



Waikiki-Diamond Head Fish Transects
Average Yearly Abundance
Total All Species



WATER WE EATING?

Ref: *Project WILD Aquatic* Page 120

OBJECTIVES

Students will be able to: 1) identify foods derived from aquatic sources and their geographic origins; 2) describe the importance of aquatic environments as food sources; and 3) gain an understanding of how much or how little island inhabitants such as ourselves depend on the sea for food. NOTE: Younger students may not identify geographic origins of foods.

METHOD

Students visit a local supermarket or grocery (optional), and survey their own homes to compile a list of products that originate in aquatic habitats.

BACKGROUND

Those of us living in Hawaii should know we live on the most remote land mass in the world, in the middle of the biggest ocean on the planet. We are at least 2500 miles from the nearest continent and 1500 miles from our nearest island neighbors.

When the Hawaiian Islands were first settled nearly 2000 years ago, before diesel-powered ships and air cargo, people were more dependent on the surrounding waters for sustenance than we are today. Despite our isolation, many of us consume foods that do not come from the surrounding waters, but from hundreds, even thousands of miles away. Whether imported from other places or grown locally, the foods we eat are grown or produced in association with some form of water during their life cycle, whether it is the ocean, rain, irrigation canals or ponds.

Aquatic habitats (oceans, estuaries, marshes, lakes, rivers, etc.) provide humans with a wide array of products which are sold commercially. Some of these are obvious; e.g., fish, shellfish, taro and rice. Other items like fertilizer, soup stock, watercress, water chestnuts and vitamins are not so well known.

While many people in Hawaii consume locally harvested seaweed or limu, few know that seaweed is a common additive in a wide variety of products because of its rich supplies of algin, carrageenan and agar. These naturally occurring compounds are used as stabilizers, thickeners and emulsifiers in such surprising items as ice cream, shampoo and chocolate milk!

Another source of aquatic food products is aquaculture. Aquaculture is an ancient form of cultivating aquatic plants (in Hawaii, taro is one of our most important products of aquaculture) and animals for food. Mariculture is a term usually used to refer to the cultivation of aquatic plants and animals in seawater.

For millennia, humans have raised fish for food in small ponds. Early and modern Hawaiians created fish ponds by altering the shape of the shallow reef environment, enclosing an area of salt water or anchialine pools with walls of lava rock. By utilizing fish ponds to raise fish, the early Hawaiians could conserve the wild fish stocks or ensure an abundant supply of fresh fish was on hand for special celebratory feasts.

Today, the trend in Hawaiian pond mariculture of fish has been more a reflection of cultural awareness and subsistence usage rather than for commercial purposes. The fish most often raised today are mullet ('ama'ama) and milkfish (awa). There is a newly emerging program for cultivation of seaweeds for commercial production in restored fish ponds.

Agricultural uses of water account for 33% of human use of water in the United States. That means that over 600 gallons per day for each person in the United States is being diverted by irrigation and livestock use from the natural aquatic sources. It takes about 40 gallons of water to produce a single egg, 80 gallons per ear of corn, and 2500 gallons for one pound of beef.

Hawaii's abundant rainfall and mountainous geography result in many lush rainforests and streams. The majority of these streams have been diverted into irrigation canals to supply us with fresh water for crops such as sugar cane, pineapple and taro.

This activity does not specifically address potential ethical questions which may be raised concerning human aquaculture and mariculture practices. It is designed to focus on students' recognizing the role of water in the production of foods, especially in an island habitat.

The major purpose of this activity is for students to increase their awareness of food products that are derived from aquatic sources. An additional exercise for the students will be the determination of how much of these foods are derived from our local waters.

MATERIALS

Pencil and paper; world map; map of the Hawaiian Islands; magazines or newspapers if field trip is not possible. Optional: clipboard.

PROCEDURE:

For Younger Students:

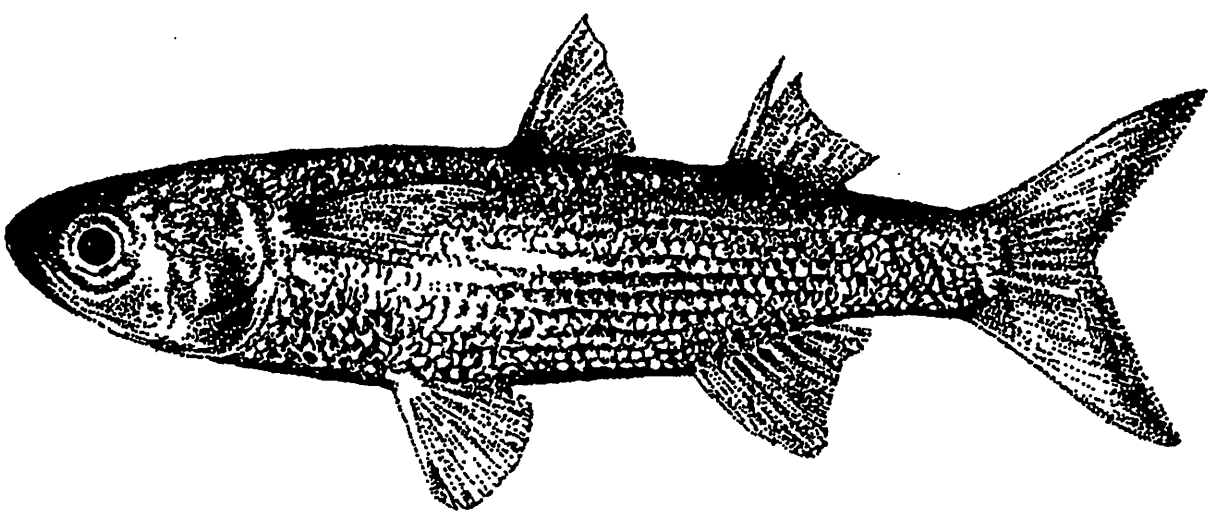
Replace:

3. Compile a master list of aquatically-derived products. If necessary, do research to answer the following: Where do they come from? How many (what percentage) come from Hawaiian waters? How are they obtained? Where and how are these products processed? How are they used?

4. On a world map locate the origins of as many items on the list above as possible. On a map of the Hawaiian Islands, locate how many items come from neighbor islands.

Add after Step 6:

NOTE: If a field trip is not possible, have the students arrange to accompany their parents on a family shopping trip. Do they shop at a local market or do they obtain their own food from the



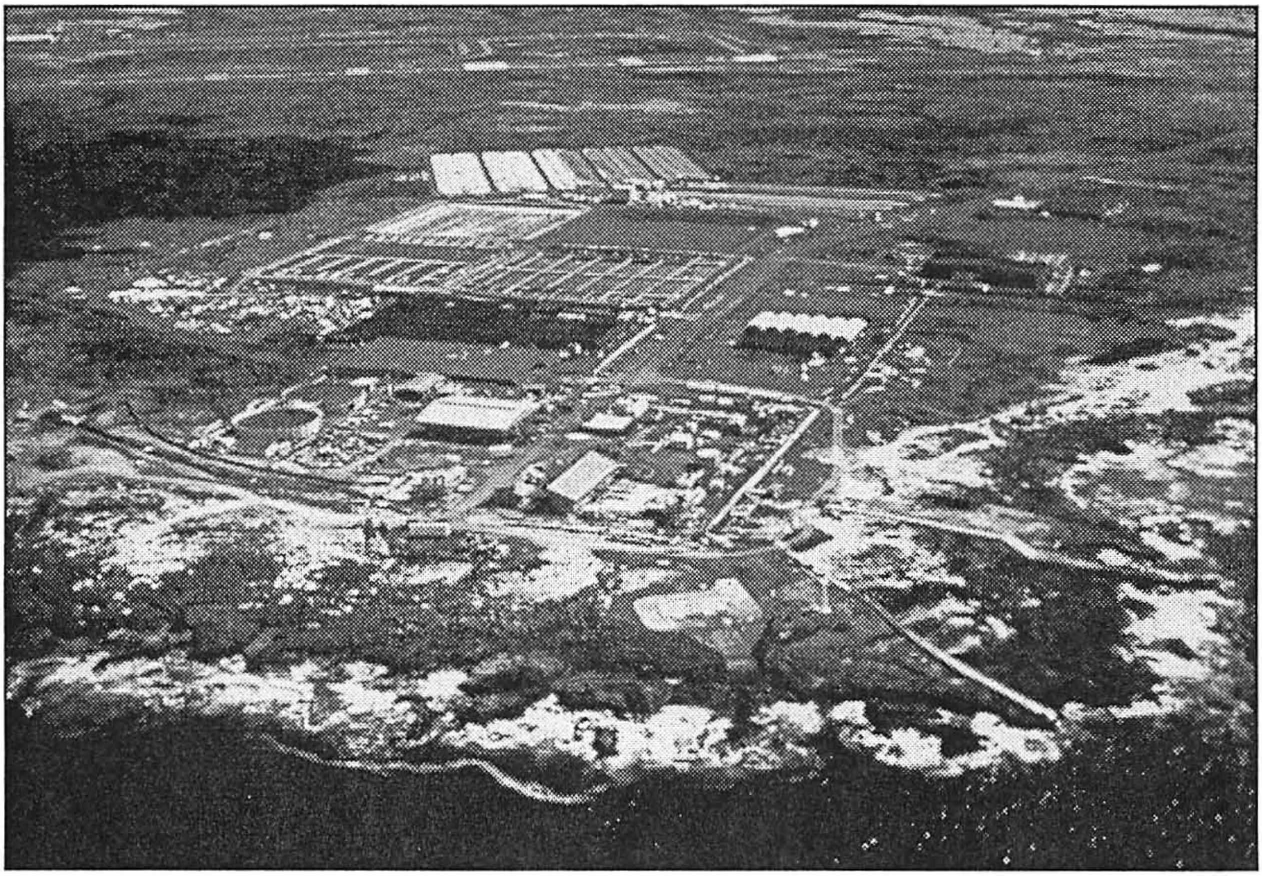
sea or ponds? Cupboards and pantries at home could be another source. You and/or the students might bring a representative variety of items to school to show the diversity of foods and other goods people use from aquatic environments. Or, use photos from a variety of magazines.

For Older Students:
Replace this NOTE at the end of Step 2:
NOTE: If a field trip is not possible, you might use supermarket advertisements in newspapers as a source of aquatic products. Have the students arrange to accompany their parents on a family shopping trip. Do they shop at a local market or do they obtain their own food from the sea or ponds? Cupboards and pantries at home could be another source. You and/or the students might bring a representative variety of items to school to show the diversity of foods and other goods people use from aquatic environments. Or, use photos from a variety of magazines.
Replace:
4. On a world map locate the origins of as many items on the list above as possible. On a map of the Hawaiian Islands, locate the origins of as many items on the list above as possible. How many come from neighbor islands?

EXTENSIONS
Replace:
3. Compare aquatic products found in conventional markets in the United States with products found in markets specializing in foods from Asia. (Japan, China, Philippines, Vietnam, etc.) Have students interview parents, grandparents or neighbors to discover how they may have obtained foods from the sea or streams when they were young. Do they still?

EVALUATION
Add:
5. What products are raised through mariculture in Hawaii? What products through aquaculture?

Age: Grades 6-12



TO DAM OR NOT TO DAM

Ref: *Project WILD Aquatic* Page 134

No change to:
OBJECTIVE
METHOD
MATERIALS

BACKGROUND
Hypothetical situation: The town of Puulani, population 900, is located along the Wailupe River at the edge of the forest reserve three miles from the city of Lohi, the island county seat. The mayor and city council of Lohi have proposed that in conjunction with the state's commitment "to expanding its use of indigenous, renewable energy resources to replace imported petroleum" a dam and hydroelectric power plant be constructed two miles upriver of Puulani. In the Environmental Impact Statement (EIS) written by the county engineers, the following information was identified (see diagrams pages 76-77).

The proposed project would consist of two stream diversion structures being built, one on the Hihiwai Stream, the other on the Wailupe River. A diversion structure would transmit water from the Hihiwai Stream south to the Wailupe River and the combined flows would form an artificially created lake behind a dam.

At the dam, a 10-megawatt hydropower plant with an estimated average annual output of 35 million kilowatt-hours would be constructed. The dam would meet the area's electrical power demand, provide some water for irrigation for sugar cane crops, and also help with flood control problems downriver.

The proposed project would consist of building a stream diversion structure, a concrete dam, a power house, access roads and transmission lines. The elevation at which the planned structures would be built would be 1400 feet above mean sea level. The area of land required to construct the project would be 52 acres.

The diversion structure on the Hihiwai Stream would not exceed ten feet in height and require no pondage except within the stream channel. The diversion structure and dam on the Wailupe River would be fifteen feet in height, and require the use of ten land acres.

The project construction would take five years to complete and would employ over 1,000 workers. After completion of the project, approximately 100 workers would be required to maintain the plant and other supporting facilities.

The following impacts would be felt:
- blockage of upstream and downstream movement of 2 native aquatic species, 'o'opu hi'u-kole (*Lentipes concolor*, a diadromous fish) and 'opae kala'ole (*Atyoides bisulcata*, a shrimp)
- loss of 52 acres of rain forest vegetation (ohia lehua, koa, tree ferns, understory shrubs, vines, epiphytes) including the Newell's ohia lehua, and introduced species of swamp mahogany and Alexandra palms
- disturbance and loss of habitat for two indigenous, migrant bird species, the Pacific golden-plover and the wandering tattler;
- disturbance and loss of habitat for threatened species such as the Hawaiian hawk *(io)*, Hawaiian duck *(koloa)*, Newell's shearwater *(ao)* and the Hawaiian hoary bat *('ope'ape'a)*
- increased access into rain forest areas for pig hunting
- possible development of water recreation
- change in scenic waterfalls downstream
- increased water available for drinking and irrigation
- reduced water supply downstream for taro and rice growers
- possible flooding of Hawaiian archaeological sites
- higher electrical rates to pay for project costs
- cleaner source of electrical power
- flood control for residential areas

The people of Puulani are concerned about the problems and benefits from the number of people that would come to their town during and after construction. For example, they project the arrival of 1000 workers plus their families during construction for five years, and 100 permanent workers and their families may stay after the dam is completed.

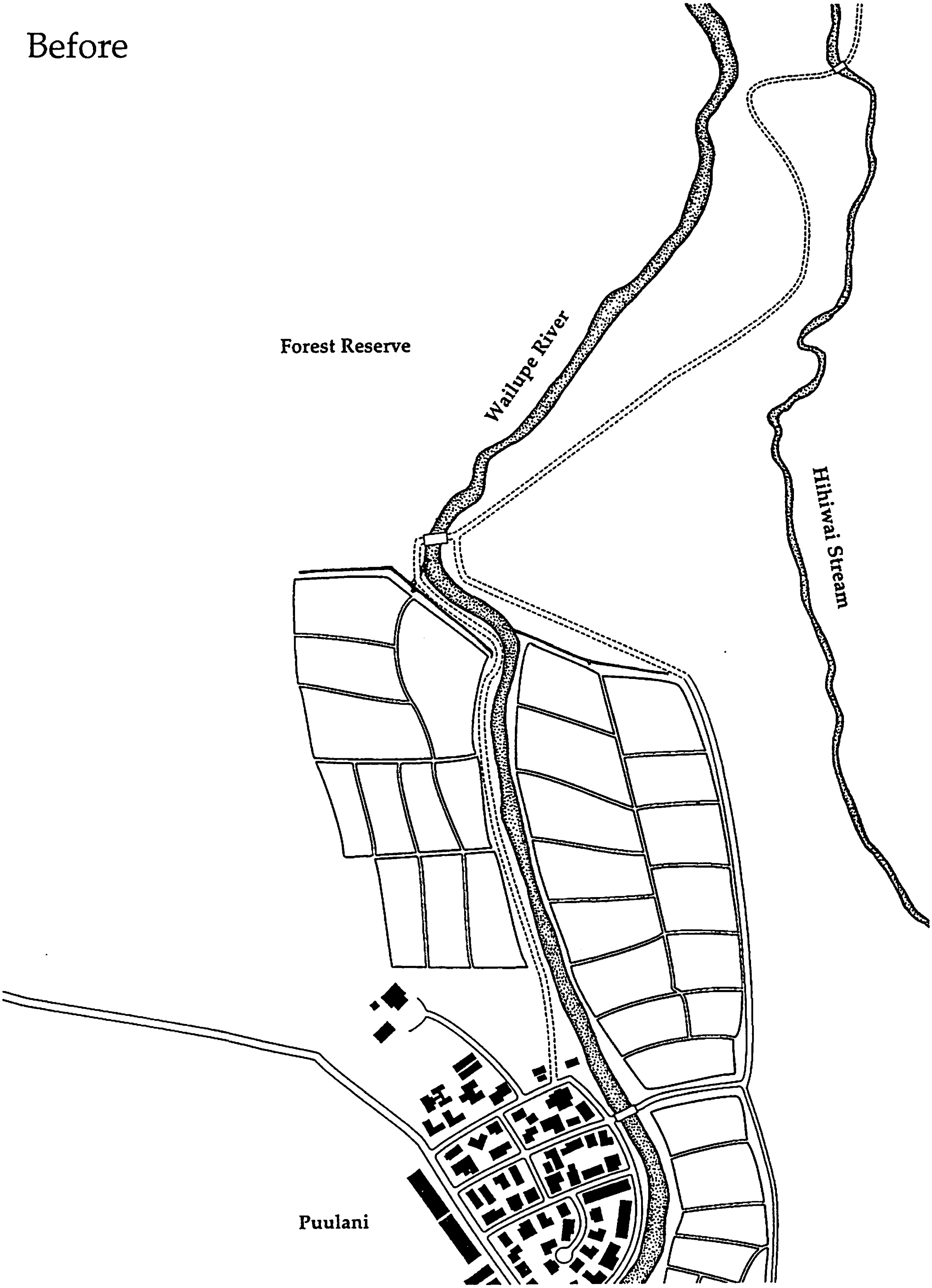
They are concerned about effects on schools, sewage disposal, roads, homesites, property values, loss of rural atmosphere, as well as police, fire and hospital emergency capacities.
But they also see some potential benefits from the developments, such as creation of jobs for their own community, new recreation opportunities for their people as well as the residents of Lohi, which is only about a half-hour away (water skiing, fishing, swimming, boating, picnicking, and other lake-related sports).

PROCEDURE

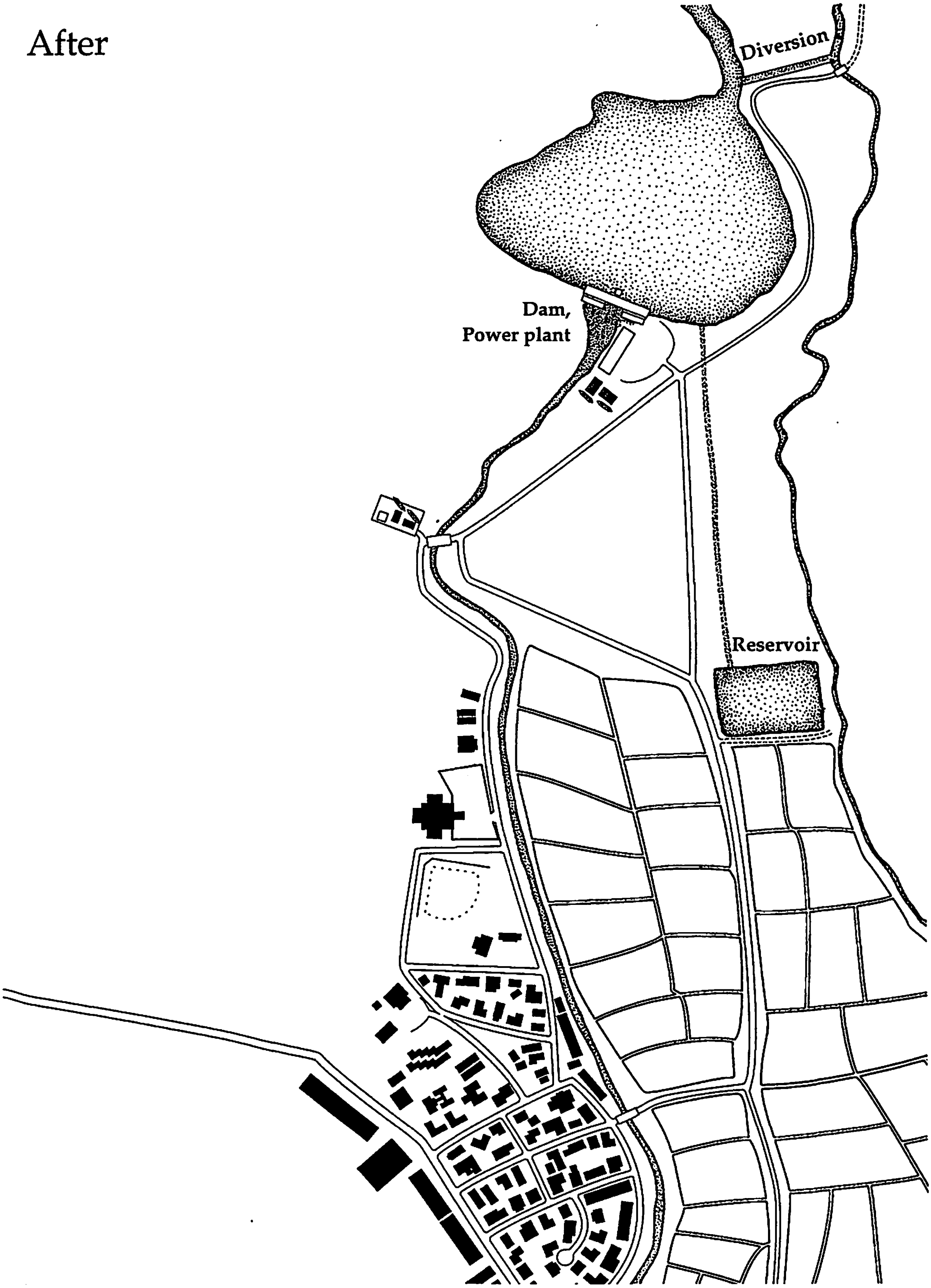
Substitute the examples of roles on page 78 for those on page 136 of *Project WILD Aquatic.* For smaller classes, reduce numbers of roles, but try to maintain a balance between interests favoring and opposing the project. Students should sign up to speak, and indicate whether "pro" or "con". The council should also balance the number of speakers from each side. The number of students on the council may be adjusted according to the class size, but should be an odd number, including the chair. The chair votes only to break a tie. Allow students to make up their own characters' names if they wish.

Age: Grades 5-12

Before



After



A. G. "Rick" Ulture: a representative of diversified agriculture interested in the irrigation potential of the dam.

Lotta Power: a lobbyist for the electric power company interested in developing the dam.

C. Ira Klub: the president of the "Save Our Native Plants and Wild Animals" organization.

Archie O. Logis: an archeology professor from the local university who has done research on Hawaiian archaeological sites in the area.

E. Conomy: a local businessperson who is optimistic about the short- and long-range business potential of the area if the project goes through.

Kala Boose: the local town sheriff concerned about maintaining police protection, peace, health and safety with limited staff in the region.

H. M. Owner: a representative of all homeowners in the area below the dam who would like to see more flood control.

Lehua Koa: a furniture maker who is concerned with loss of local woods.

Myna Byrd: the president of "Coots Unlimited" who believes that with the dam more habitat will be created for native waterbirds.

Lynn Dripper: the director of the board of water supply attracted to the dam's potential for providing more water for the city.

Cy N. Tist: a respected biologist who is prepared to testify about potential effects on wildlife from the building of the dam.

Hana Pa'a: a local sporting goods store owner who would like to see sport fish stocked in the new reservoir.

O. L. Slick: a salesperson for boats, jetskis, and other recreational equipment.

Kam A. Aina: an outspoken representative of a local Hawaiian cultural group that believes it is against "the life of the land" to change a natural stream flow.

Violet or Victor Vigil: a local representative of a group of retired people who are concerned about the rise in power bills.

C. D. Minium: a wealthy land developer who is interested in subdividing, developing, and building condominium or home sites.

I. Lan Style: a resident who is concerned about loss of a unique, rural way of life.

Prince Sepal: an educator concerned about the increase in the number of school-age children and the lack of facilities.

C. L. Nik: head of the town health clinic concerned about the need for a larger facility and increased staff.

Taro N. Ryce: a representative of the farmers' group concerned about loss of water downstream in rice and taro growing areas.

C. Nick Torres: local tour guide interested in the potential for new water activities and tours made possible by the dam.

FACTS AND FALSEHOODS

OBJECTIVES

Students will be able to: 1) develop criteria for evaluating the quality, balance and fairness of an informational presentation; and 2) evaluate the balance and fairness of informational presentations designed to represent points of view about an environmental topic.

METHOD

Students analyze and evaluate print material according to criteria they establish for quality, balance and fairness; then develop their own informational presentations using such criteria.

BACKGROUND

People have many different points of view, particularly concerning political and environmental issues. It is difficult at times to discern fact from falsehood, objectivity from subjectivity, and accuracy from exaggeration. Sometimes people are knowingly selective in what information they present about a topic. Other times they do not realize that they are presenting only a narrow view of the topic—that the way they see the world is not the only possible way to see it.

There is really no escaping some amount of subjectivity. That is, everything is subject to an individual's personal filters and perspective. Objectivity is one goal of science. Yet even in the precise world of scientific measurement and observation, pure objectivity without some influence on the part of the observer may be beyond reach. So objectivity is a goal; it is difficult, if not impossible, to achieve in a pure and technical sense.

If objectivity is so difficult to achieve, what can we do to develop our own skills of objectivity? One way is to become more discerning about balance and fairness. When you hear a speaker presenting information on a topic—is that person making an effort to describe the topic as a whole? Or, is the speaker selectively describing only his or her view? Does the speaker acknowledge that there are any other differing points of view? Is the speaker presenting accurate information or opinion as if it were fact? These are some of the questions this activity is designed to address. To provide a focus, the activity will emphasize the kinds of informational presentations that students might encounter in public settings—especially those related to the environment and specifically aquatic environments.

Providing information about the environment is a widespread activity in settings as varied as classrooms, national parks, excursion vessels, industrial complexes and wilderness preserves. Some information is provided by the distribution of printed materials. In other cases the information is provided through a presentation, possibly using many media and involving audience participation. The latter often combines people's passion for entertainment and recreation with their desire for self-education (sometimes called "infotainment").

Hawaii is economically dependent on tourism and many groups have recognized the need to educate the public about natural and cultural sites of interest. Prepared lectures, exhibits, and handouts contain ecological, recreational, scientific and historical information. The main purpose of those who prepare the materials and presentations is to inform the public. Part of the effort to inform in such settings may also focus on justifying the site or the development of the site and what this offers. The result may be a mixture of information, entertainment and subtle justifications of policy offered in a palatable form.

Sometimes the exhibits, programs and materials offered at such sites—even those under the administration of public agencies—become fairly one-sided and possibly even closed about other options or viewpoints. Clearly this may not be intentional but the effect may be more to propagandize than to inform or educate.

Sometimes the distortion of information, or at least its lack of completeness, may be intentional. At other times, the limitations are a reflection of emerging and conflicting perspectives about what is accurate concerning the topic. Science itself is hardly non controversial. Physicists argue about whether light is a wave or a particle. Biologists debate whether or not sharks should be eradicated in Hawaiian waters, or whether whales should be killed for scientific purposes. Aquatic biologists are on both sides of the fence regarding the introduction of exotic fish species; for example, controversy exists about those fish introduced to Hawaiian streams from other parts of the world. Those who sponsor the construction of dams, canals, aqueducts and locks, and those who propose large-scale diking and dredging projects, all must wrestle with the impact that the project may have on the aquatic habitat and its life forms.

The major purpose of this activity is for the students to develop and use their own set of criteria for evaluating the quality, balance and fairness of informational presentations. Special emphasis here is placed on information concerning aquatic environments; however, the process also applies to other topics.

MATERIALS

Collections of sample print informational brochures and publications, especially concerning the aquatic environment (many are available through the Department of Land and Natural Resources, National Marine Fisheries Service and various conservation groups); sample advertisements and articles from popular tabloid publications; art materials; markers, poster paper, display boards, a display area. OPTIONAL: video or still cameras; darkroom facilities.

PROCEDURE

1. Assemble a file of sample informational brochures from various public or private agencies and organizations. The brochures may cover a range of topics. Make sure some address aquatic topics or issues. Examples might include algae blooms, water pollution, conservation (e.g., whale watch programs), sewage treatment and hydroelectric power. Articles concerning water issues —including water quality, the development of aquatic resources, and water use—from local news media would also be of potential use.

2. Also before beginning this activity with students, obtain several issues of popular, sensational, tabloid publications. These are widely available at the check-out counters of convenience stores and supermarkets. We do not recommend that you take any of these publications in their entirety to school. Cut out selected articles, feature stories, and even advertisements from these tabloids. Choose those that deal with science; health; the environment; new technology; new products or inventions; and discoveries as being most suited to this activity. Prepare a student assignment sheet with some of the following questions (feel free to add others suited to your setting):

- Does the article or advertisement cite or list facts? What are they?
- Does the item make a claim? Is the claim based on or supported by facts or by some sort of evidence? Describe the claims and the supporting facts and evidence.
- Does the item or article base its claim or story on some part of science or technology? Is a scientific law or principle used to support the claims? If yes, what are they? Is a scientist or engineer or other expert cited as an authority? Who is he or she and how is his or her expertise established? Which fields of science or engineering are employed?
- Is there any indication that the writer of the article stands behind its accuracy or validity? Will the publisher or editors of the tabloid support the claims? Will the advertisers back up their products?
- How could you go about checking or verifying the claims and facts in the article?

• What is your overall assessment of the accuracy of the article or advertisement? Exceptionally accurate? Generally accurate? Somewhat accurate? Generally inaccurate? Exceptionally inaccurate? Flagrant falsehoods?

3. Divide the class into pairs or teams. Give each group an article from the tabloid and a student assignment sheet listing the questions. Ask the students to review the article or item and to answer the questions on the sheet. Encourage the students to develop any other questions that they think might usefully be asked. Discuss the students' results. What do they think about the overall quality of what they read? Do they believe the article? Would they buy the advertised products? Why or why not?

4. Next distribute the samples of informational brochures, handouts, or pamphlets that were collected and are related to aquatic and other environmental topics. Provide at least one brochure to each of the teams. Ask the students to analyze and evaluate these materials in the same way they did the tabloid items. Provide the students with another copy of the assignment sheet with the same questions. Again encourage them to add questions of their own. In addition, ask the students to consider:

- whether or not the publication acknowledges different points of view or opinions about the topic, where these exist
- whether information or facts have been selected in order to support a view or develop a perspective. Does the material try to persuade the reader in some way or is the reader invited to make up his or her own mind? What evidence can the students find to support their viewpoints?

5. Ask each group to report on their findings. They can summarize their findings by giving the brochure an overall rating—using the five categories from "exceptionally accurate" to "flagrant falsehood". Ask them to support their evaluation with some evidence and reasons for their view.

6. Now have the students work as a whole group to develop a "checklist" that they can use to evaluate informational materials, exhibits or presentations. What, in their view, should be the characteristics of an informational presentation of quality? Of balance? Of fairness?

7. After the checklist has been developed in draft, open discussion to a few more questions. For example, ask the students whether or not it is possible to be forceful and effective in expressing one's view without becoming unfair or biased. Is it possible to separate one's own viewpoint from a publicly neutral position? To what extent do government agencies, citizens groups, businesses, interest groups and individuals have a responsibility to acknowledge other points of view concerning their policies and practices? After discussion, see if the students want to make any changes in their "Checklist for Quality, Balance and Fairness in Informational Presentations." Make any changes that they recommend. Post the final checklist in a visible place in the classroom. Also provide each student with a copy of the final checklist for personal use.

8. OPTIONAL: Send a copy of your final "Checklist for Quality, Balance and Fairness in Informational Presentations" to the national offices of Project WILD, 5430 Grosvenor Lane, Bethesda, MD 20814. This is a challenging and important topic. We'd love to get to share in your thinking!

9. OPTIONAL: Prepare a set of assignments in which groups of students are to act as the designers and developers of an informational brochure or program. Have the students draw assignments at random. Each team will prepare an informational presentation having two components:

- a verbal presentation (10 minutes maximum)
- a display or prepared print brochure

In each case the remainder of the class will apply the criteria from the checklist for quality to the presentations. Following each presentation, the other class members will suggest improvements and changes to add to the quality.

EXTENSIONS

1. Visit a site where information is provided that is related to the environment in some way. Using your criteria, evaluate whether the programs, exhibits and printed materials appear to be balanced and fair.
2. Choose an aquatic wildlife issue in your own community. Write an article for a newspaper or develop a presentation to make in informal educational settings (garden club, Kiwanis, Chamber of Commerce, etc.). Make sure your article or presentation reflects your standards for quality, balance and fairness.
3. Think of five things you could do to enhance the public's understanding of aquatic wildlife and habitats in your own community without using propaganda.

EVALUATION

1. Select one of the following topics and describe the types of information that should be included in an informational presentation designed for students your age: recreation area, sewage treatment plant, whale museum.
2. Why is it, or is it not, important for informational presentations to be accurate, balanced, fair and of quality?
3. The visitor area of a popular land-based whale watch viewpoint has two informational displays. One explains how much we have learned about the whales through the efforts of researchers who may be out there right now observing the humpbacks. The other shows how much we all enjoy watching the whales aboard boats, or from kayaks, etc. What other information, if any, should be provided for visitors?

Age: Grades 7-12
Refer also to *Project WILD Aquatic* Page 138

DEADLY WATERS

OBJECTIVES

For Younger Students

Students will be able to name and describe different kinds of pollution that can affect water as well as animals and plants that live in water.

For Older Students

Students will be able to 1) identify major sources of aquatic pollution; and 2) make inferences about the potential effects of a variety of aquatic pollutants on wildlife and wildlife habitats.

METHOD

Students analyze the pollutants found in a hypothetical bay. They graph the quantities of pollutants and make recommendations about actions that could be taken to improve the habitat.

BACKGROUND

Our planet is the water planet, although named for the land upon it. Mostly covered by ocean, it is like an oasis in the desert of outer space. In Hawaii, our islands form a freshwater oasis in the midst of the biggest body of saltwater on Earth. Our lives are especially intertwined with water. Water is precious and all life on this planet is linked to it. And yet, all the water that has ever been available to our planet is on or in the earth right now.

Waterways like rivers, lakes and streams are a vital expression of the water cycle. All the rain and snow that falls on the land either seeps into the water table or is carried to the sea. In addition, all along the way, water evaporates or finds its way through plants and transpires back into the atmosphere to form clouds and precipitate again.

Early Hawaiians parceled the land into ahupua'a, or pie-shaped wedges extending from the mountain tops down into the nearshore area. They recognized the importance of the entire watershed, from freshwater source fed by rain, to its end in the sea.

With this picture of the scale and interconnectedness of our planet's freshwater resources in mind, it is apparent how fragile this vital substance is. Yet each day water is being damaged by pollution that stresses ecosystems beyond their capacities to support life. Illness and death in humans and wildlife due to pollutants has been overwhelmingly documented.

Even though its effects may seem obvious, pollution is a complex topic. Most current resource books include four definitions.

Chemical Pollution The introduction of toxic substances into an ecosystem, e.g., acid rain, contamination of water supplies by pesticides.

Thermal Pollution Varying temperatures above or below the normal condition, e.g., power plant turbine heated water, lava flow into ocean.

Organic Pollution Oversupplying an ecosystem with nutrients, e.g., fertilizer inflow.

Ecological Pollution Stresses ordinarily created by natural processes; i.e.,
1) adding a substance that is not a naturally occurring substance in the ecosystem (adding something that is not usually there), e.g., extreme tides pour saltwater into habitats ordinarily protected from sea water, lava flows into the sea;
2) increasing the amount or intensity of a naturally occurring substance, e.g., abnormal increase in sediments in runoff water to produce silt as occurs during catastrophic storms, landslides or avalanches;
3) altering the level or concentration of biological or physical components of an ecosystem (changing the amount of something that is already there), e.g., introduction of aquatic plants via bird droppings, shifts in oceanic currents, etc.

It is no secret (ask any child) that pollution is predominately human-related. In the definitions above, chemical pollution through the introduction of toxic substances is clearly human caused. Organic pollution in reefs and streams typically results when the growth of certain organisms living there is enhanced by chemical fertilizers used in agriculture. Thermal pollution is predominately human caused through nuclear power plants, fuel-based electrical power production (common in Hawaii), and other industries. Some dams also produce unnaturally cooled water with bottom discharge of water.

Surprisingly, these three forms of pollution—chemical, thermal and organic—can take place without human intervention. When this pollution occurs, it is most often ecological pollution. (At times, human activity can also increase pollution via naturally occurring substances. For example, roadbuilding and harvesting of native forests can increase siltation.)

Natural ecological pollution, in the larger view of things, may be beneficial rather than harmful. Whether beneficial or harmful or neither, ecological pollution—which is predominately derived from natural processes—does affect wildlife and wildlife habitat.

Obviously, many substances naturally occurring in water are also beneficial as well as harmful to aquatic life and habitats.Yet all that is known of ecological or nonecological pollution points to humans as the greatest source of damage to habitat. Today, habitat degradation is perhaps the single greatest threat to wildlife worldwide. If we can understand the effects of pollution and know that we are the primary cause, then we can take constructive action now and in the future to protect and maintain a healthy environment.

Surely no one is happy about the amount of pollution around us. Economics drives pollution, in that short-term gain is usually weighed against long-term risks or costs. One researcher called pollution the "chosen disease." It is usually difficult to measure the effects of pollution in the short-term with the exception of catastrophes such as Chernobyl, Russia and Bhopal, India.

The effects of DDT took years to manifest in such animals as the brown pelican and the peregrine falcon, and it took years to link the thinning eggshells of these birds with the presence of DDT in the food chain. Pollution can be invisible and insidious; it often takes a long time to display its toxic destructiveness. Since the effects of most pollution are long term, we must develop long-term views about its effects on our world.

Ground water is continually being affected by toxins we cannot see. Some pollutants enter water from a localized source, like a chemical discharge from a factory or sewage outfalls. This is called **point source pollution**. Other pollutants enter from a variety of less easily identified sources; for example, when rain washes motor oil from parking lot and road tops into city storm drains it re-enters the water supply via the sea. This is called **non-point source pollution**.

In its circuitous journey, water may be contaminated by thousands of different substances and conditions. For the most part, these substances and conditions alter water in such ways that it becomes a hazard to wildlife, wildlife habitat and humans as well. Some effects are direct; others are indirect.

The major purpose of this activity is for students to increase their understanding of water pollution and its potential effects on human and wildlife habitats.

MATERIALS

nine different colors of construction paper (2 sheets each); writing or graph paper (1/2" grid); scotch tape or glue; Pollutant Information Sheets (one for each student); 1/4 teaspoon measure (for paper punch tokens); 1 tablespoon measure (for 1/2" square tokens)

PROCEDURE

1. Before the activity begins make 100 tokens of each of the nine colors of construction paper. The construction paper may be folded in quarters to speed up the process of cutting or punching. For younger students, cut the paper into 1/2" squares using a paper cutter. For older students, punch tokens with a paper punch. Put all the different tokens, either squares or punches, in a container. Stir them so the colors are thoroughly mixed. Make one copy of the Pollutant Information Sheet for each student.

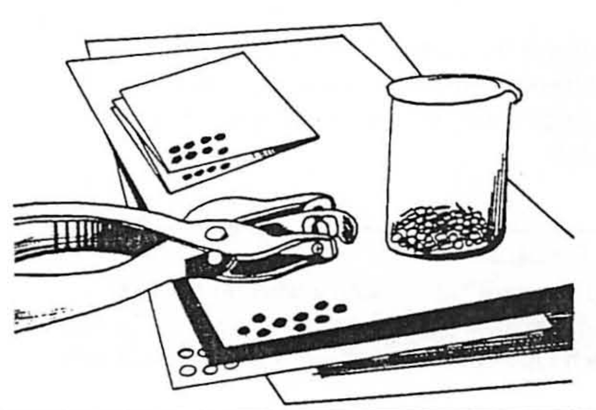
2. List the 4 major categories of pollution on the chalkboard and discuss each. They are: chemical, thermal, organic and ecological. Refer to the background for a description of each.
NOTE: The first 3 are predominately caused by humans, although there are rare cases where natural processes can cause them. Ecological pollution is typically natural, although there are cases where it is caused by humans.

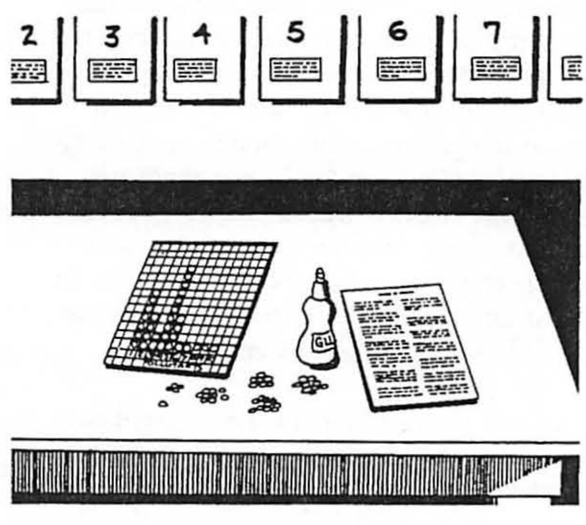
3. Pass out the Pollutant Information Sheets. Review each kind of pollution with the students. Talk about how some of these can fit into more than one of the 4 major categories of pollution. Code each of the nine types of pollution with a different color of construction paper. Post each sheet of colored paper with its corresponding description of the kind of pollution it represents in a convenient place.

4. Once the nine kinds of pollution have been discussed, and the students understand that each kind of pollution will be represented in this activity by one of the objects, divide the students into teams of 3. These will be research teams; each team will analyze the pollution content of a hypothetical bay. Provide each team with a piece of graph paper. Distribute the colored paper tokens that have been cut or punched from the construction paper. Pass the container with the tokens for each research team to measure out for themselves 1/4 teaspoon of the paper-punched tokens or one tablespoon of the 1/2" square tokens. Also provide each team with a piece of graph paper.

5. The teams must separate the tokens into piles; using the color key. Once this is done, they should count the number of each kind of pollutant they have identified and then use graph paper to construct a simple bar graph showing the whole array of pollutants. Arrange the pollutants in the same order as they are displayed in the color key that is posted in the classroom. This makes it easy to compare each team's findings. Remind them that each has a different bay. Their results are not likely to be the same!

6. When they have the bar graphs completed and have compared the teams' results, tell them that



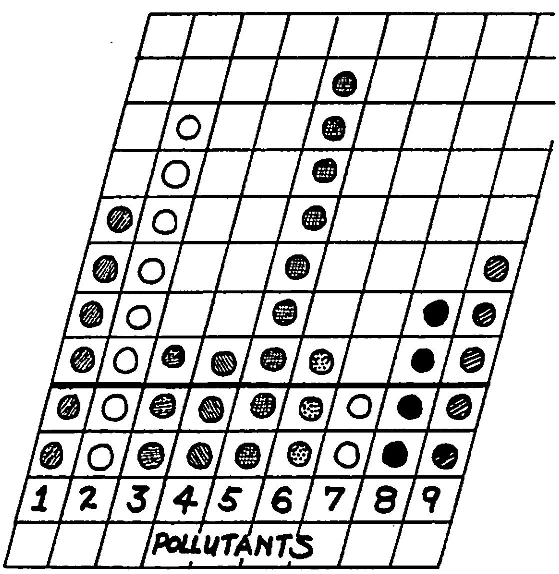


any quantity above two units of each kind of pollutant is considered damaging to wildlife habitat. In their hypothetical bays, what pollutants would be likely to cause the most damage to wildlife and habitat? Give examples and discuss the kinds of damage that could be caused.

7. OPTIONAL: Invite the students to match the pollutants with the four categories of pollution listed at the beginning of the activity. Some seem to fit rather easily; others could fit in more than one category, depending on the source of the pollution. For example, is the thermal pollution human or naturally caused (power plant water effluent or lava flow)?

EXTENSIONS

1. List five things you can do—starting today—in your own life to reduce the number of pollutants you add to the environment. A list of alternatives to toxic cleaning products can be obtained from local environmentally friendly stores and from environmental groups.



2. Have each of the teams of students choose a real bay in the Hawaiian Islands that they will research to determine if it is in jeopardy from pollution or not.

3. Conduct a field trip to a local waterway and attempt to identify what, if any, kinds of pollution are affecting it.

4. Get information about current national and state laws protecting water quality in the United States. Write a short history of the U.S. Clean Water Act.

5. Is DDT being used on crops here in Hawaii? What kinds of pesticides are being used?

EVALUATION

1. Describe the effects that large quantities of the following things might have on an aquatic environment. Consider short term and long term effects: hot water, fertilizer, soil (silt), heavy metals, etc.

2. Water is taken in from a river, treated, used by people of a community, sent to a city sewage treatment plant, and put back into the river. Is this aquatic pollution? Defend your response.

Age: Grades 4-12
Refer also to *Project WILD Aquatic* Page 146

POLLUTANT INFORMATION SHEET

SEDIMENTS

Particles of soils, sand, silt, clay and minerals wash from land and paved areas into streams, human-made channels and onto coral reefs. In large unnatural quantities, these natural materials can be considered a pollutant. Development projects often contribute large amounts of sediment. Certain lumbering practices (like logging off the native forests) allow erosion of the land with sediment runoff. Sediments may fill stream channels and harbors that later require dredging. Sediments suffocate fish and coral reefs. The coral polyps and the gills of bottom fish and shellfish can cleanse themselves of small amounts of sediments, but not overwhelming amounts.

PETROLEUM PRODUCTS

Oil and other petroleum products like gasoline and kerosene can find their way into water from ships, oil drilling rigs, oil refineries, automobile service stations and streets. Oil spills kill aquatic life (coral, fish, birds and seaweeds). Birds are unable to fly when oil loads the feathers. Coral and small fish are poisoned. If it is washed on the beach, the oil requires much labor to clean up. Fuel oil, gasoline and kerosene may leak into ground water through damaged underground storage tanks.

ANIMAL WASTE

Human wastes that are not properly treated at a waste treatment plant before releasing into the water may contain harmful bacteria and viruses. Typhoid fever, polio, cholera, dysentery (diarrhea), hepatitis, flu and common cold germs are examples of diseases caused by bacteria and viruses contaminating water. The main source of this problem is sewage. People can come into contact with these microorganisms by drinking the polluted water or through swimming, fishing, or eating shellfish in polluted waters. Hawaii has been plagued with breakage of sewer lines (Maui, Oahu) and location of sewage injection wells too close to the sea. Animal and human wastes can also act as fertilizer and lead to algae blooms through increasing nutrients in the sea.

ORGANIC WASTES

Domestic sewage treatment plants, food processing plants, paper mill plants and leather tanning factories release organic wastes that bacteria consume. If too much waste is released, the bacterial populations increase and use up the oxygen in the water. Fish die if too much oxygen is consumed by decomposing organic matter.

INORGANIC CHEMICALS

Inorganic chemicals and mineral substances, solid matter and metal salts commonly dissolve in water. They often come from mining and manufacturing industries, oil field operations, agriculture, toxic wastes dumped in harbors and natural sources. These chemicals interfere with natural stream purification; they destroy fish and other aquatic life. They also corrode expensive water treatment equipment; and increase the cost of boat maintenance.

DETERGENTS, AND FERTILIZERS

Many of these substances are toxic to fish and harmful to humans. They cause taste and odor problems and often cannot be treated effectively. Some are very poisonous at low concentrations. The major source of pollution from agriculture comes from surplus fertilizers in the runoff. Fertilizers contain nitrogen and phosphorous that can cause large amounts of algae to grow. The large algae blooms cover the water's surface. The algae die after they have used all of the nutrients. Once dead, they sink to the bottom where bacteria feed on them. The bacterial populations increase and use up most of the oxygen in the water. Once the free oxygen is gone, many aquatic animals die. This process is called eutrophication.

HEATED OR COOLED WATER

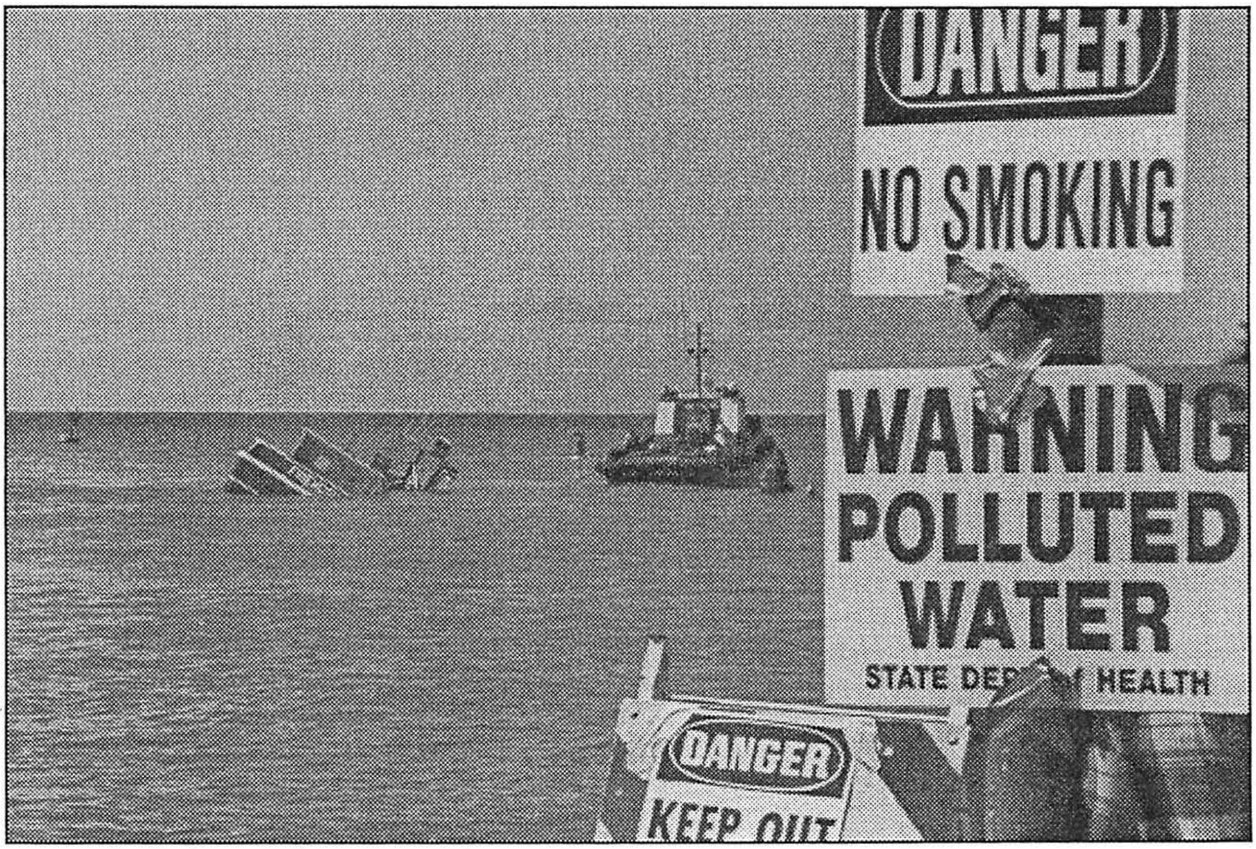
Heat reduces the ability of water to dissolve oxygen. Electric power plants use large quantities of water in their steam turbines. The heated water is often returned to streams. lagoons, or reservoirs. With less oxygen in the water, fish and other aquatic life can be harmed. Water temperatures that are much lower than normal can also cause habitat damage. Deep dams often let extra water flow downstream. When the water comes from the bottom of the dam, it is much colder than normal.

ACID PRECIPITATION

Aquatic animals and plants are adjusted to a rather narrow range of pH levels. pH is a measure of the acidity of a solution. When water becomes too acid, due to inorganic chemical pollution or from acid rain or sometimes from lava flows, fish and other organisms die.

PESTICIDES, HERBICIDES, FUNGICIDES

Agricultural chemicals designed to kill or limit the growth of life forms are a common form of pollution. This pollution results from attempts to limit the negative effects of undesirable species on agricultural crop production. Irrigation, groundwater flow and natural runoff brings these toxic substances to rivers, streams, lakes and oceans.


DANGER
NO SMOKING
WARNING
POLLUTED
WATER
HEALTH
DANGER
KEEP OUT

WAIKAHE ("FLOWING WATER")

OBJECTIVES
Students will be able to: 1) evaluate the effects of different kinds of land use on wetland habitats; and 2) discuss and evaluate lifestyle changes to minimize damaging effects on wetlands.

METHOD
Students work together on a simulated land-use activity involving wetlands.

BACKGROUND
Land and water use in Hawaii have always been political and social issues. Our population is increasing, yet land and fresh water are limited resources. What we do with these resources affects our economy, lifestyle and health.

During ancient Hawaii, land was used to fulfill man's basic needs: food, shelter and clothing. Each island, or *mokupuni,* was ruled by an *Alii Nui.* Each mokupuni was divided into individual *mokus.* And each moku was further divided into the *ahupua'a.* Each of the land divisions generally was pie-shaped, from the mountain spreading out to the sea.

People living in one ahupua'a used whatever resources grew there. In the mountains grew the tall ko'a, pili grass and olona. The valleys were cultivated and planted with taro *(kalo).* The sea contained food resources such as fish and other marine life.

To preserve their resources, there were certain kapus or practices that were forbidden. In the higher part of the stream, water was restricted for drinking. Below that came the use for irrigation. Near the mouth of the stream, they could wash utensils and bathe.

The Hawaiians were strict in enforcing and practicing conservation rules. People lived in harmony with all wildlife, taking only what they needed to survive, and preserving their abundant resources for future generations.

Much of the ahupua'a in the activity is the wetland area which many consider as "swampy wastelands". But wetlands serve as nurseries for many forms of wildlife—fish, mollusks, migratory birds, crustaceans, insects and plants. Some organisms depend on both fresh and salt water habitats to complete their life cycles. They need a continuous flow of streams and rivers. These animals include the Hawaiian gobies ('o'opu), shrimp ('opae), Tahitian prawns and some species of snails.

Much of Oahu's wetlands have been converted to landfilled resorts, homes or golf courses (e.g. Waikiki, Kaneohe and Makalena). Very rarely, the natural environment is somewhat preserved and yet is able to turn an economic profit, like Sumida's watercress farm near Pearl Ridge.

Land use today does not only satisfy people's basic needs. It goes beyond, into recreational activities, as well as the biological and moral issues of land and wildlife preservation. Since land is limited and valuable, there are many groups that want to promote their special interest in our remaining "unused" land. For whatever the interest, there will be some positive and some negative outcomes for each proposed use.

In the activity to follow, the student will be aware that a lot of planning and analysis goes into land use and rezoning of our limited land. People need to consider not only their own economic, recreational, social and aesthetic needs, but the needs of all life forms that will be affected by changes in the environment.

Students will be invited to explore options, design a proposal, promote its view, and take an active interest in land use in Hawaii. Social interaction, critical thinking, inquiry and awareness in social problems will stimulate these activities.

"Waikahe (Flowing Water)" will encourage students to investigate and understand the social issues involved in land use planning. The simulated activity will allow them to become aware of conflicting interests and the need to work together in an attempt to solve problems.

The fate of the wetland areas is important. Wherever water flows in a natural environment, it gives life to the land. The land, in turn, nurtures all that it touches. If water is the substance of life, how vulnerable are our wetlands and the plants and animals that depend on them?

MATERIALS

for each group: copy of Waikahe Ahupua'a, chart papers, broad tipped markers of various colors

---

PROCEDURE

1. Review the ahupua'a concept. Ask your kupuna to share the chart of the ahupua'a from Hawaiian Studies. If the kupuna can help students visualize the concepts of water rights and how each member shares the labor and benefits within the ahupua'a, then your students will understand some of the values of the Hawaiian culture.
2. Divide your class into small groups, provide each group with a map of Waikahe Ahupua'a, and have them work as teams to see how effectively they can utilize the land to fulfill the needs of the ancient Hawaiians: food, shelter, clothing. You may need to allow time for researching the following: timber, fiber (olona), fishing/fish ponds, pili grass, clothing (wauke or mamake). Students should also be aware of water usage for drinking, washing clothes and bathing. Have them decide what symbols would represent the activity/product and draw them where they would be functional, yet ecologically safe for the environment. Allow time for each group to share their ideas.
3. Tell them that the state is giving up a parcel of land, the Waikahe Ahupua'a, to be developed to meet the needs of its citizens. Discuss with them what the land could be used for. Consider all needs: economic, social, ecological.
4. Discuss the name of the ahupua'a ("Waikahe" means "flowing water"), its topography, river, etc. Go over the scale. Predict how long 10 meters might be. Measure your classroom in meters. Now, estimate how long 100 meters might be (a football field).
4. Share the following information with them: Whenever man changes the wetland environment, he affects the way the water runs off to the sea. Cutting into the land and grading loosen the soil and allow silt and mud to rush into the sea during rainy periods. Erosion is also a major concern. Building concrete water drainage/flood control systems may prevent erosion, but cannot replace the natural habitat many organisms need to grow and reproduce. Filling in the land may give you a drier area to work with, but provide an unstable ground to build your foundation. Sinking and shifting of the building may occur later.
5. Divide the class into groups of 4 or 5 students, with each group representing one of the interest groups (see below). Questions each interest group should answer during the presentation will help them in their planning.

a. How would you need to alter/change the land to carry out your proposal?
b. Where on the map of the ahupua'a would you build your project?
c. How will the people benefit from your project?
d. What impact/consequences will this project have on the land itself?

Possible interest groups and additional questions:

residents—want to live in the area
Q. Why should this area be opened to building new homes? How will you take care of the sewage problem?

farmers—want to use the land to raise food
Q. Why is this area ideal for farming? What will you grow or raise? Will you divert water from

the stream to use? If so, will the water quality be changed in any way?

business interests—want to see the land converted to a shopping center for commerce and economic growth

Q. How many stories high will the complex be? How many stores will there be, and how much parking will be available?

parks/recreation personnel—want people to have a place for a variety of recreational activities

Q. What types of activities will be offered? What types of facilities would be built to accommodate these activities?

utilities—island electric company wants to build another power plant to provide better service to nearby residential areas

Q. If water is diverted from the stream to generate power, how will the discharged water be affected? If water is going to be used to cool generators, how will the water be discharged? Where will the warm water go? How will this affect the environment?

NOTE: Add others that you think may be locally important.

6. Pass out chart papers and markers so that students can web or chart information. They should a) state interest of group as a proposal (refer to worksheet "Preparing a Proposal/Position Statement); b) list the pros and cons of the proposal; and c) list supporting detail(s) to each pro/con.

7. Inform them that each group is expected to a) give a presentation of their proposal (students may use the worksheet in step 6 above); b) have a picture of the proposed project after development; c) address the questions raised in step 5; d) have everyone participate somehow; and e) offer no rebuttals.

8. Give the class ample time to work together. Guide them in their planning. Allow them time to practice their presentations.

9. Have the groups deliver their proposals to the class. Be sure each group covers the advantages and disadvantages of their proposed project.

10. As a class, focus on the consequences of the proposed project after each presentation.

11. Can a compromise be reached? Could several interest groups share the proposed sites without adversely affecting each other and their environment? Are there some trade-offs that are inevitable?

EXTENSIONS

1. Have the class look into undeveloped wetlands near your community. (Those on Oahu may find *Sites of Oahu* a valuable source. Others may want to contact the Department of Land and Natural Resources or U.S. Fish and Wildlife Service on their respective island.) If possible, take a field trip to this site. If no wetlands are accessible in the vicinity, look for a vacant parcel near your school. What are the possible uses for the area?

2. Keep an eye on the newspapers. Bring in articles on controversial land use issues. See if the students can identify the real issues behind each controversy. Have them poll the public on their reactions to these issues.

3. Learn more about environmental impact statements. Try to obtain actual copies of statements about wetlands in your area. See what concerns are addressed in these documents.

4. Learn about the national wildlife refuge system. Are there any wildlife refuges in your area? What animals find refuge in them? Visit a national wildlife refuge.

5. Find out about private organizations that work to protect wetlands. Two examples are the Nature Conservancy and Ducks Unlimited. Find out about what they do and how they do it.

6. Find out about zoning laws and land use regulations in your area. Would the plan your group proposed for Waikahe be allowed in your community?

EVALUATION

1. Name three things that people can do to reduce or prevent damage to wetlands. Under what conditions, if any, do you think actions to

reduce damage to wetlands would be **appropriate?**
2. Under what conditions, if any, do you think actions to reduce damage to wetlands would be **inappropriate?** Select any action that you personally think would be appropriate and that you could take to reduce or prevent damage to wetlands. Describe what you would do.
3. Have the student react to his/her personal views on the land use in this activity. Is (s)he concerned about the diminishing wetlands on our island? Can (s)he express a need for balance between progress and preservation of our environment?
4. Or... the student could respond to step 10 in a written activity. Can (s)he see a compromise with several interest groups sharing the wetland? How well can (s)he support his ideas?

Age: Grades 4-12
Duration: Four to six classroom periods
Refer also to *Project WILD Aquatic* Page 154 ("Dragonfly Pond")

WORKSHEET: PREPARING A PROPOSAL/POSITION STATEMENT

NAMES OF MEMBERS: ______________________________

____

____

Purpose: to make a strong statement for or against a controversy and support with details.

GOOD MORNING LADIES AND GENTLEMEN. OUR GROUP IS CALLED

____
(NAME OF GROUP)

AND WE ARE FOR/AGAINST (CIRCLE ONE)

____
(CONTROVERSY)

WE BELIEVE (list supporting statements from weakest point to strongest point):

1.

2.

3.

4.

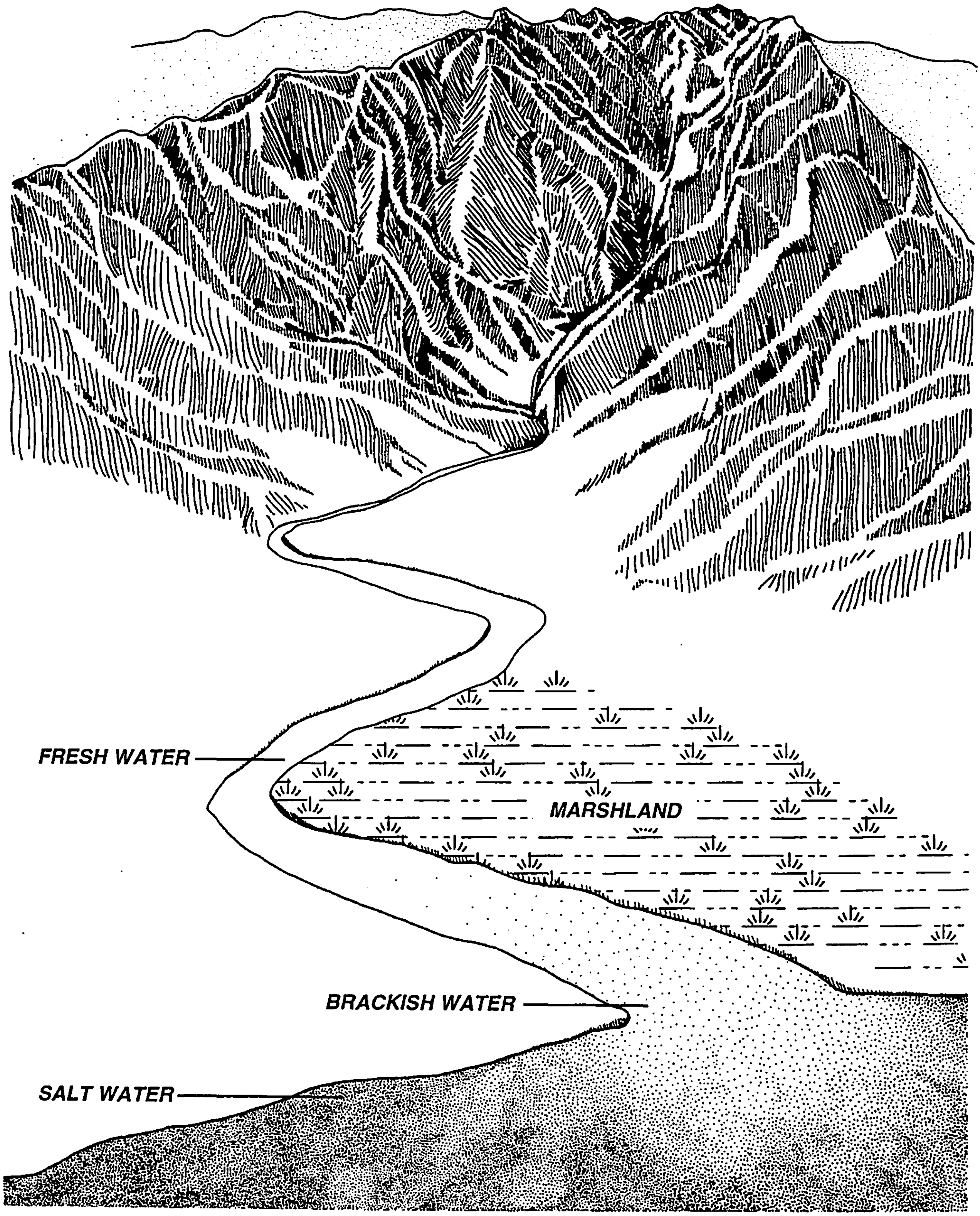
THEREFORE, WE URGE YOU TO SUPPORT/DEFEAT (CIRCLE ONE)

____
(CONTROVERSY)

THANK YOU FOR YOUR KIND ATTENTION.

Adapted from "Preparing a Position Statement", Claudia Suyat, Dept. of Education, OIS, State of Hawaii

Waikahe Ahupua'a



TURTLE HURDLES

Ref: *Project WILD Aquatic* Page 164

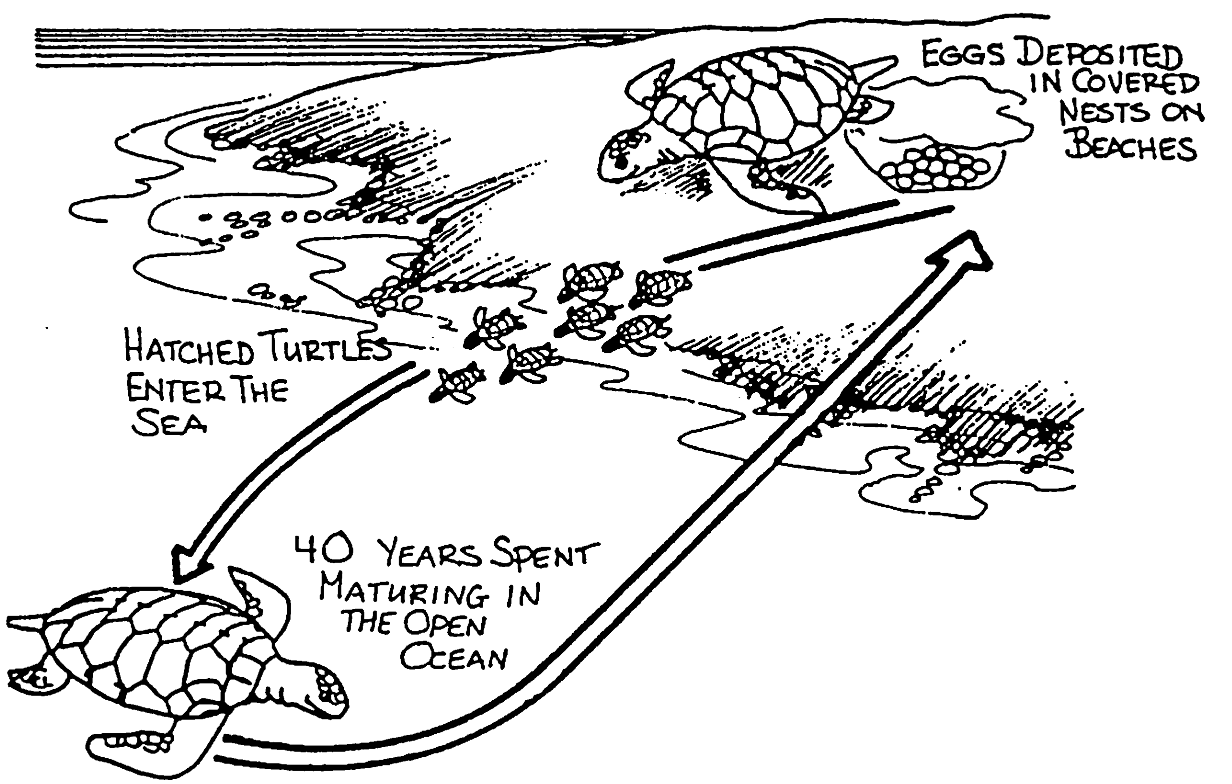
No change to:
OBJECTIVES
METHOD

BACKGROUND
Make the following minor changes.
Second paragraph: Substitute "If the eggs survive predation by crabs, and the encroachment of man—the sea turtles hatch..."
Third paragraph: Substitute "The hatchlings' journey across the beach is typically accompanied by predatory crabs, birds and man. Once hatched..."
Fifth paragraph: Delete second sentence ("Dune buggies...").

Background about Hawaiian Sea Turtles:
There are three sea turtles native to Hawaii: the Green, Hawksbill and Leatherback. Of these, the one most commonly found in Hawaiian waters is the Green sea turtle (honu), *Chelonia mydas*. The honu can grow up to 400 pounds, and is primarily vegetarian, eating limu growing underwater on coral reefs. In its gut are bacteria, necessary to digest the limu it eats. Its fat is greenish in color (reason for its name).

The honu may take up to 40-50 years to reach sexual maturity. At present its breeding population may only be 1200 turtles. Each female may lay 100 two-inch leathery eggs in her hole (breeding takes place primarily near French Frigate Shoals in the Northwestern Hawaiian Islands). This is not the only time that she will come ashore. The honu has been known to bask in the sun to raise its body temperature. This also helps keep it away from its main predator, the tiger shark.

The Hawksbill ('ea) is found around the islands of Molokai, Maui and Hawaii, where a few females have nested in recent years. This small-to-medium sized sea turtle inhabits coral reefs



and uses its long, narrow beak to probe for sponges and other bottom-dwelling invertebrates.

The Leatherback does not nest on or come close to Hawaii's shores. It can, however, be seen feeding in the open ocean on jellyfish near the Hawaiian Islands. The leatherback can weigh up to 1500 pounds and is the only sea turtle without a hard shell.

PROCEDURE

Make these changes:

1. Set up the activity area as shown in the diagram below.
2. Group 2—Limiting Factors

On-land: predators (e.g., crabs, dogs, birds) and limiting factors from human activities (e.g., human egg collectors, shoreline development, heat of the sun or disorientation).

In-sea: predators (e.g., sharks, ulua, killer whales) and limiting factors (e.g., entanglement in fishing gear, eating plastic litter, illegal killing by humans).

3. A. Turtles must spend forty years in the open sea. Each poker chip represents eight years of successful ocean survival.

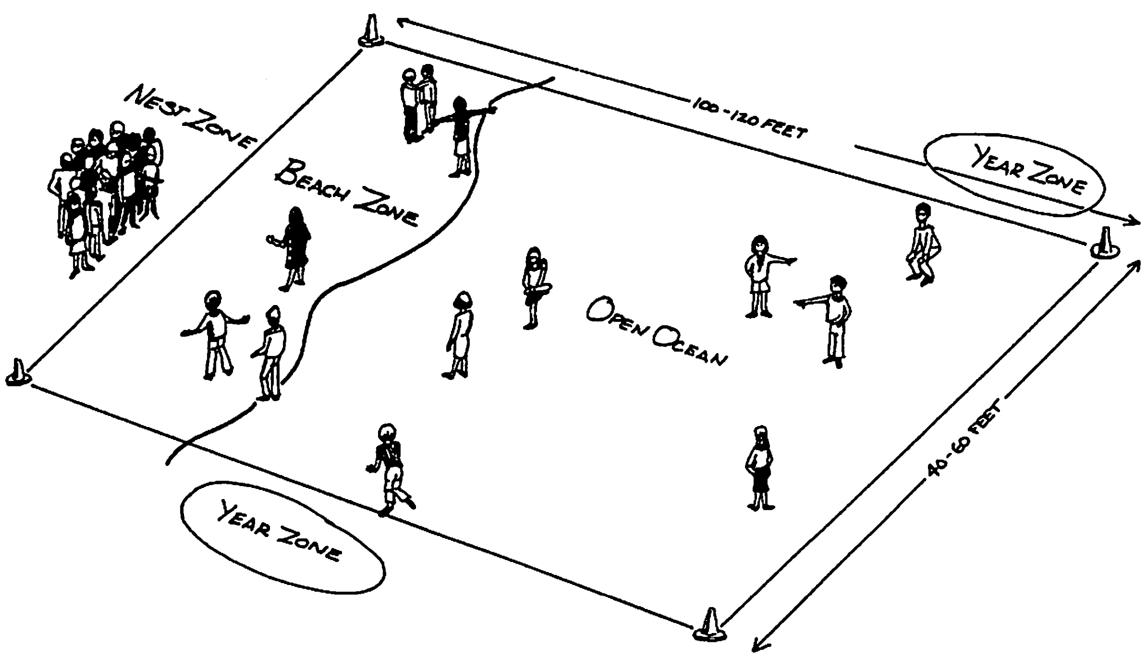
C. Delete this paragraph—no sea grass areas in Hawaii.

EXTENSIONS

Add:

5. Information can be obtained from the Waikiki Aquarium, National Marine Fisheries Service, University of Hawaii, or any local library.
6. You may want to visit Sea Life Park (Oahu) or the Mauna Lani Hotel (Hawaii) to see young sea turtles being raised in captivity.

Age: Grades 4-12



PLASTIC JELLYFISH

Ref: *Project WILD Aquatic* Page 170

No change to:
OBJECTIVES
METHOD
BACKGROUND

MATERIALS
Plastic waste from home (for home version), chart paper, rubber bands, plastic six-pack rings

PROCEDURE
Replace with following:
This lesson has a component that includes the use of resources outside the classroom if the teacher wishes. Prior arrangement for these excellent resources (slides, speakers and literature) should be considered when planning this lesson. Allow for time to obtain the material or arrange for speakers.

1. Ask the students to collect and save every piece of plastic waste produced in their homes for a two-day period. Have them bring these materials to school. Or, have them bring a sample if the quantity is too great. Caution the students to clean the plastics before bringing them to school so that they are free of food or drink remains. Also caution them about toxins such as ammonia, chlorine bleach, etc. which may be in the containers. These should be emptied and rinsed completely.
2. If possible, arrange to have the students go on a beach walk, or plan this lesson to coincide with a tide pool excursion. (Consider the community cleanup program "Get the Drift and Bag It".) Be sure to take an adequate supply of trash bags for this activity. Students would probably feel safer and more comfortable with gloves. Have the students comb an area of the beach for marine debris. Caution students against picking up jagged glass or metal, and unknown or possible toxic materials. This can be done only for plastic debris or all debris found on the beach, although the following steps refer specifically to plastic debris. Appropriate variations can be made, depending on what is found and collected. Bring back as much as possible and have a clean-up session outside the classroom. Much sand will have to be sifted out, and other materials cleaned. A big box or two would be needed to hold all the debris in the classroom as the students continue with the lesson the following day.
3. Divide the students into groups of four or five. Consider the quantity of plastics among the groups of students when making grouping decisions; there should be an ample number of plastics to provide for more stimulating classification options. Have them separate their plastic materials into categories. Allow them to categorize the materials in any way their group chooses. There should be time for discussion and group consensus. Provide each group with a large piece of paper (chart paper, poster paper) upon which they can place their plastic material. The students should be physically grouping the plastics on the paper according to their criteria, and in so doing creating a real graph or chart. Glue, tape and staples should be readily available. The following categories are possible ones and might be used only if students have no ideas of their own (see also sample graph):
   - types of plastics
   - likelihood of plastics being perceived and consumed as food by aquatic wildlife (very likely, somewhat likely, unlikely)
   - likelihood of aquatic wildlife being entangled in the plastic
   - physical characteristics of the plastics
   - uses of the plastics
4. When the groups have completed their charts, have them share their work with the rest of the class. Discuss and explore the various classifications that resulted. Students should be allowed to question as well as justify categories. Students will hopefully see that each group may have chosen to classify similar items in different ways.
5. Ask the students to hypothesize about how these materials might affect aquatic animals.

Write their ideas on a class chart so they will have a record to check their hypotheses against after studying the literature and/or conducting the simulation exercises.

6. Have students check their hypotheses against current findings reported in the literature. Excellent resources are available. Consider the slides available through Sea Grant and/or the presentation on marine debris that Sea Life Park provides. Please note: this part of the lesson will require pre-arrangement with Sea Life Park or Sea Grant.

7. Simulation activities. These activities will be another way for the students to check their hypotheses, and extend their understanding of the hazards caused by marine debris.

A. **"All Bound Up"** Have students work in pairs; each pair needs one rubber band. One student will be the marine animal. The other student will use a rubber band to bind the fingers on one hand of the "marine animal". The rubber band should go across the back of the hand, looping around the thumb and small finger. The "marine animal" will then attempt to remove the rubber band using only that hand. To make it more challenging, have the "marine animals" hold their breaths until they can free themselves. After a reasonable time, have the students switch roles.

B. **"No Way Out"** Now provide each pair with a plastic six-pack ring. Again, one student will be the "marine animal" who will have one hand put through the ring (it may be necessary to cut through part of the ring so larger hands can fit). The "marine animal" attempts to extricate him/herself again without use of the free hand.

8. Ask students which part of an animal might become entangled, and by what types of debris? How could the animal free itself? Discuss the effects entanglement might have on the animal, from limiting its mobility, or its ability to feed or escape danger or mate, or even lose a limb or die of strangulation. Have students summarize what they have learned about the potential hazards to aquatic wildlife from plastic waste materials.

9. Invite the students to survey their schoolgrounds or community for plastic litter. Look to see if and where it exists. Investigate its potential negative impact on animals in the community. If there is damaging plastic litter in the community, ask the students to create an action plan that will increase awareness of the problem and help take care of it. Help the students put the plan into effect.

EXTENSIONS

Add:

8. Have the students create a bulletin board or mural depicting the problem of marine debris and some solutions.

9. Younger students can make an egg-carton turtle puppet (see Appendix 11), and dramatize what happens to the turtle using real debris. Students may also write a class story about marine debris and sea turtles.

10. Have a poster contest. Each student will create his/her own slogan and poster concerning marine debris, and ways to help reduce the problems it causes. Display posters around school or the community.

Age: Grades 1-12

WATERSHED

Ref: *Project WILD Aquatic* Page 172

No change to:
MATERIALS
PROCEDURE

OBJECTIVES
Students will be able to: 1) describe the characteristics of watersheds; 2) discuss the role of watersheds in providing wildlife habitat as well as human habitats; 3) describe the path of water through a Hawaiian watershed; and 4) give examples of how watersheds can be preserved and protected.

METHOD
Students measure the area of a small watershed and calculate the amount of water it receives each year; then measure the area of an actual Hawaiian watershed, calculate the amount of water it receives and the amount used by human activities; and discuss the varied roles the watershed plays in human and wildlife habitat.

BACKGROUND
A **watershed** is all the land area that contributes runoff to a particular watercourse (stream, river, etc.) or body of water (lake or ocean). It is a catch basin in which all the precipitation and runoff is funneled down toward a stream or bay, and eventually ends up in the ocean.

On the mainland, mountain winter snows form reservoirs of frozen water which which become snowmelt in the spring, gradually increasing stream and river flows. Low water occurs in the hot days of Summer and early Fall.

Hawaii has a similar cycle, but streams and rivers here are more variable, with occasional sudden floods, called **freshets**, caused by intense tropical rainfall, sometimes exceeding an inch per hour.

Hawaiian watersheds are short and steep, since no point in the islands is more than 29 miles inland and some mountains rise several thousand feet above the ocean.

Water is necessary to life itself, and each watershed is a system which supports plant and animal life within it. Prior to human contact, watersheds in Hawaii were in a kind of balance, with much vegetation to hold rains and reduce erosion. Vegetation allows more water to seep into the land, contributing to groundwater, which we use directly today by drilling wells.

Weathering and runoff shaped a number of watersheds on each island. The softer shapes of older islands like Kauai and Oahu contrast with the jagged landscapes of new lava flows on younger Hawaii island.

Natural weathering occurs in watersheds due to wind, rain and the resulting downslope movement of materials. Before the time of humans in Hawaii the weathering of watersheds was very gradual.

Watersheds conform roughly with some **moku** (land divisions) and smaller **ahupua'a**, or mauka-makai land subdivisions named by the early humans in Hawaii. Early Polynesian settlers used valleys, ridges, and rivers to define political and social boundaries.

Beginning about 500 years ago, people modified the land to support Hawaiian agriculture and aquaculture. The first water diversions were used to irrigate crops and to supply fishponds.

Hawaiian watersheds were further altered to supply water for modern agriculture operations such as sugar and pineapple. Industry requires large volumes of water for manufacturing and processing, but Hawaii does not have the kind of heavy industry found on the mainland. However, population growth, private and public building, and

Save for Camp Waiane

greater demands for water in today's modern Hawaii home also create pressure on local watershed resources.

Today about eight percent of the water consumed throughout the United States is for domestic use, 33% for agriculture, and 59% for industrial use (U.S. Geological Survey Circular 1001). In Hawaii, the percentages are 45% for domestic/municipal use, 37% for agriculture, and 18% for government/industrial/military use (FY 1992 Honolulu Board of Water Supply).

While the patterns of consumption vary from watershed to watershed, the outcome is discouragingly clear. The quality of water in most watersheds has deteriorated in the past 200 years. Many experts believe that there is no uncontaminated drinking water in the United States. Fortunately, the situation is improving somewhat due to measures such as the Clean Water Act.

What are the sources of these contaminants? What are the impacts on our watersheds? Contaminants may be the result of natural processes that have been accelerated, like soil erosion. Poor land management practices contribute to excessive soil loss through erosion. Contaminants may come from wild animals, which can introduce disease (like leptospirosis) to the water.

The majority of contaminants are caused by human activity. For example, urban runoff carries oil, pet waste, soil, garden chemicals, and other toxins. A range of materials (including nutrients as well as toxins) found anywhere in a watershed will eventually show up in the waterways, ocean, and water cycle.

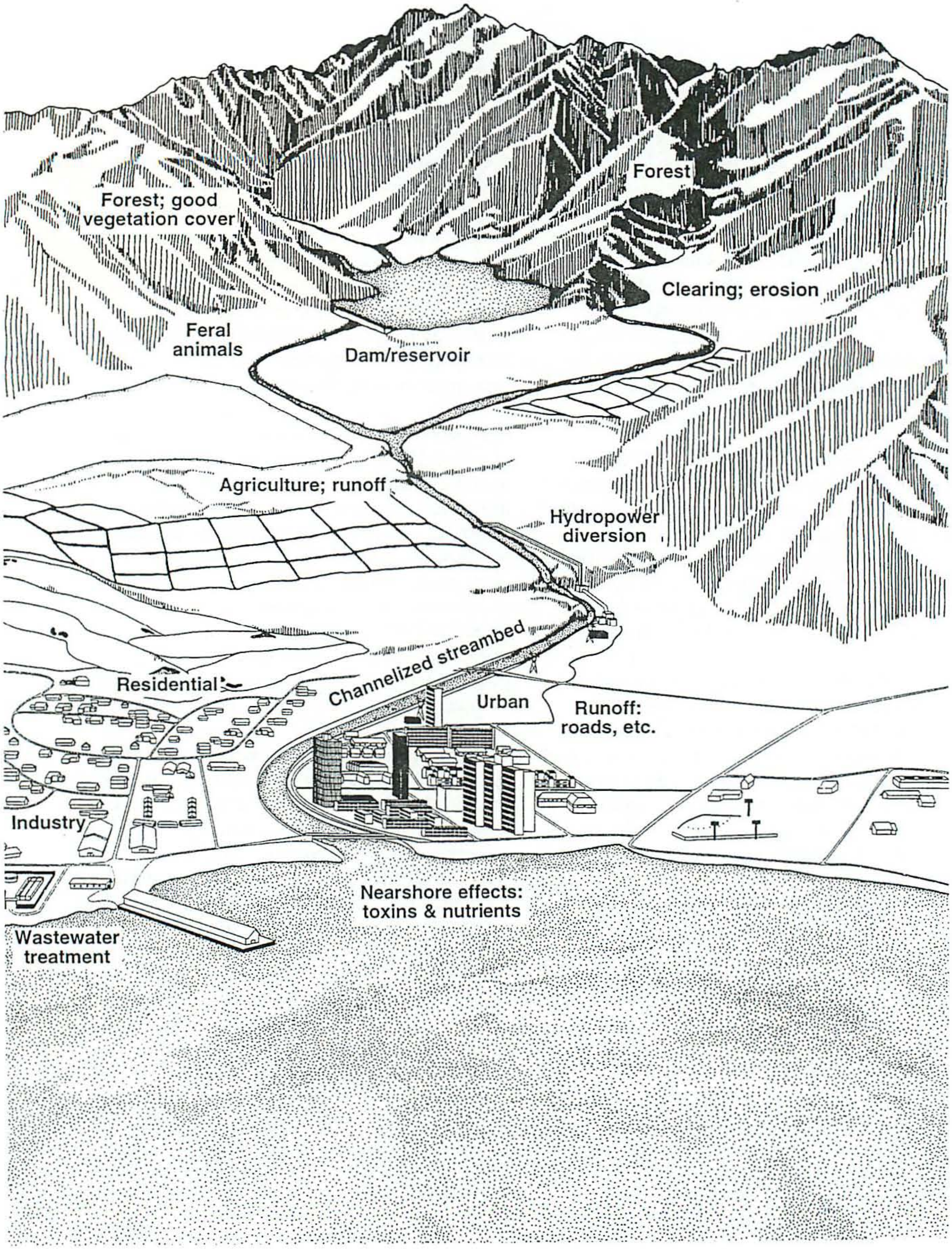
Nutrients can be viewed as beneficial to life unless they are excessive. **Nutrient loading**, a situation where nutrients are excessive, can cause problems. An example would be the overload of nutrients from a watershed resulting in algal blooms in nearshore waters.

Human use of wat [illegible] the form of diversi [illegible] flow of streams an [illegible] groundwater, lake [illegible] human population [illegible] may result in great [illegible] example, the need [illegible] power often result [illegible] Dams may radically alter stream habitat, yet they do provide predictable water supplies for agriculture, domestic uses, and industry.

Both agriculture and industry use large amounts of water. These activities release water back into the watershed that has been altered during its use. Fertilizers and pesticides are the major sources of agricultural contamination. Industrial wastewater can contain a myriad of contaminants, from oil and PCBs to mercury and radioactive wastes. There are approximately 270,000 sources in the United States where hazardous wastes are produced; all of these are real or potential threats to the watersheds in which they are found.

Contamination of watersheds is a serious problem for humans, but it is also a major problem for wildlife. Most often it is the wildlife, and particularly the aquatic wildlife, that suffers the most directly and immediately from contaminated water. Slight changes in pH (acidity) can destroy the natural balance in a body of water. Natural food chains can be damaged for decades by a single contamination.

Perhaps the most important thing to remember about watersheds is that they are systems within which any action may affect water volume or quality. Damage often accumulates as water proceeds downstream. Most scientists feel that it is far more economical to prevent contaminants from entering water systems than to clean up pollution after it takes place. There are obviously tradeoffs to consider in decisions affecting watersheds.



Forest; good vegetation cover
Forest
Clearing; erosion
Feral animals
Dam/reservoir
Agriculture; runoff
Hydropower diversion
Channelized streambed
Residential
Urban
Runoff: roads, etc.
Industry
Nearshore effects: toxins & nutrients
Wastewater treatment

The major purpose of this activity is to introduce students to some of the basic characteristics of watersheds, encouraging them to explore ways in which responsible human action can protect, conserve, and restore the environmental quality of watersheds for people and wildlife.

In the extensions, students will perform calculations that will give them a feel for the amount of water that enters an actual Hawaiian watershed (the example is the Kaiaka-Waialua Bay watershed on Oahu), and how much water is used up by various activities.

Before getting into Part 2, it would be a good idea to review the water cycle in the Hawaiian Islands (refer to pages 2 and 3). Rainfall can be divided into three components: a) **runoff** as surface water, b) return to the atmosphere as **evaporation** and **transpiration**, and c) residual water, also known as **recharge**.

Recharge percolates through the soil to the water table and replenishes the **aquifer**. It's important to recognize that only part of the recharge water is available for human consumption.

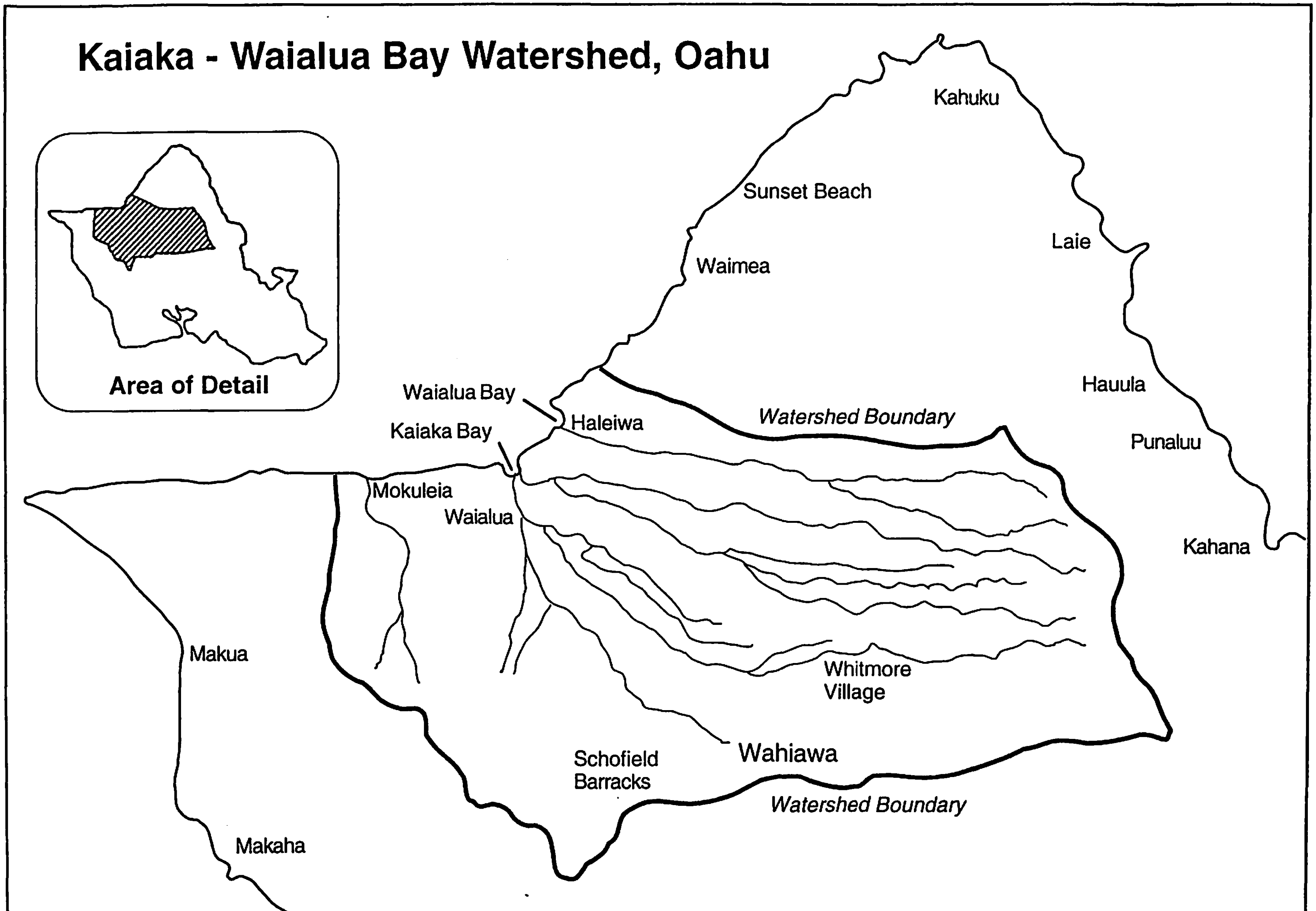
The groundwater body, or lens (which includes the zones of fresh water, mixture and salt water shown on page 3), is dynamic. Some fresh water discharges into the sea, causing a counterflow of sea water inland. The zone of mixture also consumes fresh water by mixing it with salt water.

The amount of water available for human use without damaging the aquifer equals the total recharge less the amount necessary to sustain the groundwater lens, which varies with location. An aquifer may require from 10% to 80% of recharge to keep itself healthy.

EXTENSIONS

1. Provide older students with the map of Kaiaka-Waialua Bay watershed and accompanying data. Have them perform the calculations required to answer the questions at the bottom of the page.
2. Explore actual conditions in the watershed in which your school is located. Identify locations of water diversion from natural pathways, determine the use of the diverted water and describe the condition of the water when it is returned to the natural drainage. Sources of information on watershed boundaries, rainfall and water usage include the U.S. Dept. of Agriculture and your county water supply agency.
3. Contact the state Department of Health and find out the locations of contaminated wells in your school's watershed.
4. Research methods used to calculate soil loss in a watershed. What factors contribute to increased erosion (and therefore decreased recharge).
5. Research and compare the effects of various land uses on the resulting amount of recharge.
6. Simulate a watershed on your schoolground by having students stand in a circle with quart containers of water which they all empty on cue toward the center of the circle. Have them trace the "natural" paths taken by the water and see if they can trace out the watersheds indicated by the diverse flow pattern.
7. Calculate the amount in gallons of rain that falls on your schoolground each year.
8. Trace out the watersheds of the major Hawaiian rivers on your island. Use tracing paper or acetate overlays on maps.
9. A noted scientist once remarked that, "Human activities speed up the flow of water while nature slows it down". Is this true for the watershed in which you live?

Age: Grades 6-12


Kaiaka - Waialua Bay Watershed, Oahu
Area of Detail
Kahuku
Sunset Beach
Waimea
Laie
Hauula
Punaluu
Kahana
Waialua Bay
Kaiaka Bay
Haleiwa
Watershed Boundary
Mokuleia
Waialua
Makua
Makaha
Whitmore
Village
Schofield
Barracks
Wahiawa
Watershed Boundary

Name ____________________________

Kaiaka-Waialua Bay Watershed, Oahu

Average annual rainfall	35-300 inches per year, depending on location
Population	65,000
Total area of watershed	70,700 acres
Cropland:	
Sugar cane	12,000 acres
Pineapple	6,500 acres
Other crops	1,500 acres (includes truck crops, taro, lotus root, macadamia nuts)
Pasture land	7,000 acres
Urban and military	12,000 acres
Golf courses	2 (1 18-hole, 1 9-hole, approximately 600 total acres included in above)
Forest reserve	31,700 acres

Water use by activity:

Domestic/commercial use	est. 65 gallons/person/day
Military use	3,700,000 gallons/day
Sugar processing (mill)	5,000,000 gallons/day
Cropland:	
Sugar cane	4,660 gallons/acre/day
Pineapple	3,400 gallons/acre/day
Other crops	5,000 gallons/acre/day
Golf courses	380,000 gallons/day (ave. for 18 hole course, w/clubhouse; included in Military use above)

---

1. Determine the total amount of water used up in the watershed **per year** by each of the following by each of the following. It might help to express the values in scientific notation.
a) domestic/commercial;
b) military
c) sugar processing;
d) sugar cane
e) pineapple;
f) other crops
g) total of all these
2. Assume the amount of water entering the watershed is 115 billion gallons per year. What percentage of the water entering this watershed each year is used by humans?
3. Assume 60% of the water entering the watershed evaporates from freewater surfaces (streams, etc.) and from plants, thus returning to the atmosphere. How many gallons of water is that?

Total water used per year by:

domestic/commercial = ________________ gallons

military = ________________ gallons

sugar processing = ________________ gallons

sugar cane = ________________ gallons

pineapple = ________________ gallons

other crops = ________________ gallons

TOTAL water used = ________________ gallons

Percentage of water entering watershed used by humans = ______________ %

Amount of water returned to atmosphere by evaporation = __________ gallons

SOMETHING'S FISHY HERE!

Ref: *Project WILD Aquatic* Page 176

No change to
OBJECTIVES
METHOD
MATERIALS

BACKGROUND
Replace with:
Protection or conservation of aquatic habitats depends largely on people (young and old alike) understanding the consequences of various actions and making informed choices. Human impacts on aquatic environments can have far-reaching consequences. The most well meaning educator or outdoor enthusiast can irreparably harm the delicate balance of our reefs and tidepools. Exploring the reefs and leaving rocks turned with the undersides up, pulling seaweeds from the rocks, collecting organisms and allowing them to die in insufficient environments (buckets, tanks or even tidepool waters that may be different from the specific zone from which they were taken), all constitute actions that adversely affect the tidepools.

Introducing non-native fish into streams can alter and affect the habitat of aquatic animals as much as sewage, siltation, chemicals, etc. Just as pollution can severely alter streams because of its various effects on food sources and dissolved oxygen, so can the accidental introduction of non-native fish. These exotic species may displace native animals or actively prey on them.

Every organism, from the smallest, most seemingly insignificant, to the most elaborate and attractive, plays a vital part in the ecosystem of the reef. Careful stewardship of these aquatic environments is required to preserve a healthy population of reef life.

PROCEDURE
Substitute the stories on the following pages.
Omit step 5.
Replace:
6. Next have the students generate a list of possible aquatic wildlife problems related to exotic introductions (younger students) or habitat disturbances (older students) that they believe exist in places with which they are familiar. Have them form groups that have a common interest in the problem and develop a plan to find out more about it. Once they have targeted a problem and location, have each group report back to the class. Or, decide on one problem and work on it as a class.

EXTENSIONS
Replace:
1. Follow through on the plan to initiate environmental action to reduce the negative consequences of exotic introductions or habitat disturbance.

EVALUATION
Replace:
1. (For younger students): Name three examples of non-native fish or other animals that are found in streams. How might they have gotten into streams? What effects might they have on native stream animals?
(For older students): Give three examples of human activities that can result in loss of habitat for nearshore reef animals. How might these effects be mitigated or reversed?

Age: Grades 2-8

(for younger students)

SOMETHING'S FISHY

The cool tradewinds made the spring morning quite pleasant as Kim and Russ wound their way through the path that led to their favorite stream. The two cousins were intent on spending the morning swimming and fishing for swordtails, malaysian prawns and crayfish to add to their growing collection at home.

Russ was developing a growing interest in fish and other aquatic life ever since he brought home a comet from the class aquarium in school. He had spent much of his third grade year observing all sorts of animals in his science class and was now trying to keep up a decent aquarium of comets and tetras.

Kim was the couch potato who was willing to leave her TV programs in order to spend a day with her cousin. Kim was just a year behind Russ in school and looked forward to the activities she saw Russ involved in during the school year.

"I wonder if Mrs. B. (that was Mrs. Bright, his science teacher) ever got some fish from streams instead of pet stores," Russ thought aloud to Kim. "I bet if she knew where Maka Falls was, she would come and get some," said Kim.

Maka Falls had always had a ready supply of swordtails, guppies and crayfish. Russ and Kim were accustomed to seeing them darting in and out of the water. This time they planned to take some home and perhaps add them to the aquarium or start another fish bowl. Russ wasn't sure how the fish would do in another environment. The children finally made it down to the water's edge and decided to go for a quick dip before looking for some fish. "Last one in is a rotten egg!" shouted Russ as he took a flying head start off his favorite rock, into the cool mountain water. "Eh, you cheat," Kim said, but in a moment she was next to Russ, and the two began their imitations of bomber pilots zooming through the sky. Their territory was endless patches of clear water.

They were lost in play when Kim noticed someone walking carefully toward the stream a short distance away. It was a man carrying a plastic bag filled with water and fish. Kim got Russ's attention and signaled him to watch. What was the man planning to do?

They didn't have to wait long as the man quickly opened up the bag and released several fish into the stream. He then turned and made his way back towards the highway which ran above the stream, never noticing the curious pair of eyes following his every move.

Russ scrambled out of the water. "Boy, what kine fish you think he put in the stream? You figure we can catch them?" he asked Kim. Kim was right behind him feeling quite uncertain about the whole thing. She remembered a TV spot she had seen that showed a stream full of huge fish that weren't supposed to be there.

"Eh Russ, you know what? I think that man did something wrong. I remember something on TV..." "Aaaah, you and your TV," Russ interrupted, "you gotta stop watching that tube so much." "Come on, let's at least start looking for some fish to catch even if we can't find what the man dumped."

Kim persisted. "No Russ, you gotta listen. I mean it...there was something on TV and I saw all these fish that got real big and stuff like that, and it wasn't good for the other fish. And then they said something about how you're not supposed to throw aquarium fish into the water...you listening to me?"

Russ had half an ear on Kim and the rest of his attention was on the stream bed. "Hey, Kim, look at this...what happened to all the swordtails we used to see? There's hardly any...hey, what's this?

Kim and Russ looked into the bright red scoop net and saw something really strange. It was long and fat with a flat bottom and a huge sucker-shaped mouth. The fin on its back was enormous, and this fish had some of the biggest scales Russ ever saw.

"I don't know, Russ," Kim started. "No, wait! I've seen this fish before, on TV. It's one of those they said not to throw into streams. See? I told you that man was doing something bad."

Russ looked around and said, "I don't see any more swordtails, but sure get plenty of this ugly fish. Let's take it back to Mrs. B. and see if she knows what it is." The children put the strange looking fish into a bucket, and kept it to take to school on Monday.

Early Monday morning Kim and Russ showed up in Mrs. B.'s room. Mrs. B. was puzzled. "I'm not sure what kind of fish this is, but I have an idea." She called her friend at the Department of Agriculture and described the fish to him over the phone.

When she hung up the phone, she looked at the two cousins and said, "It's an armored catfish. Aquarium owners like to have small ones in their tanks to eat the algae that grows on the glass. But the fish keep growing, and finally these people decide they're too big for their tanks, so they toss them into the nearest stream."

"There were lots of them in the stream," Russ said, "and hardly any swordtails. Did these fish eat up the swordtails?" Mrs. B. shook her head. "These fish only eat algae off the rocks, but the swordtails might have moved someplace else because of them. That's one of the reasons you shouldn't put things in the stream that aren't supposed to be there—they make life tough for the native fish."

"Like the swordtails?" Russ asked. "No," Mrs. B. said, "the swordtails aren't native either. They were put there to eat mosquitoes and provide food for other fish. But they don't cause as many problems as a lot of other fish that people release into streams. People think they're doing their fish a favor, but they're really messing things up."

Kim just sat there thinking, "So that's why the commercial said not to throw aquarium fish into the streams. I knew there must have been some good reason. I hope people stop doing that—I liked the stream at Maka Falls a lot better the way it was."

(for older students)

SAD TIDINGS AT THE REEF

Monday dawned bright and promising after a steady downpour of rain all weekend. Mike and Brad were plodding through the hallways of their intermediate school grumbling about the weather. "Just our luck. As soon as we take one step inside the school, the sun decides to come out," Mike held his hands out in disgust as he commented on the fine weather that had been so elusive just a day ago.

"Well," countered Brad, "at least we get to have Mr. Lee for first period." Mr. Lee was by far their favorite teacher. He taught seventh-grade science, and had a way of bringing the outside world into the classroom, helping them to see the world around them as a place where learning constantly occurs. "Yeah, that's the only good thing about this rotten Monday," Mike said to Brad as they turned into the classroom and headed for their seats.

Mr. Lee was busy setting up the slide projector at the back of the room. "All right! Movies!" yelled Brad as he caught a glimpse of the action at the back of the room. "Not quite, Brad, but you'll enjoy these slides I have just as much as movies," said Mr. Lee as he made his way to the front.

"Good news, folks. We got the OK to go on that reef walk we've been talking about." Amid the whoops of the excited students, Mr. Lee went over the details of the trip to the reef flats near the airport. The students listened intently to the instructions concerning proper attire, and look boxes that could be constructed at home.

Preparations for the excursion included a request for parents who would be willing to help out on that day. Mike and Brad exchanged looks, neither wanting their parents along on an outing to the beach.

Mr. Lee soon turned their attention to the slides he had set up earlier. The students were quickly absorbed in pictures of the various animals that inhabited the reef flats. The usual fare of brittle stars and sea cucumbers, sea urchins and crabs were quite familiar to may students including Mike and Brad, who still remembered the reef walk they had taken five years ago in the second grade. However, there were many more interesting and beautiful organisms that captured their attention and before they knew it, the class was over.

The rest of the week was spent studying in greater depth the different organisms, the predator/prey relationships among the various animals, and the delicate balance of life on the reef and in tidepools. The students learned how even the seemingly insignificant sea cucumber makes a big difference in the natural recycling of wastes and nutrients in the water.

A lot of time was spent discussing responsible reef walking, and the procedures everyone would follow as they observed and explored the flats.

Three parents offered to join the group, and to Mike's dismay, his dad was one of the first to sign up. Not only did his dad agree to accompany them on the excursion, but he came to school along with the other two parents on the day that Mr. Lee explained the procedures for the reef walk.

To Mike's surprise, he found that there was so much to talk about at home that night. His dad was extremely interested in the reef, and shared his recollections of his boyhood days spent out there. His dad told Mike about one adventure after another and of the beautiful marine life that inhabited the reef. Mike's enthusiasm grew. "Maybe it won't be so bad having Dad along after all," Mike thought to himself.

The day of the excursion was as clear and sunny as that Monday several weeks earlier when the two boys first found out about the reef walk. Mike and Brad were grouped with several other students and Mike's dad. Each group knew that only one specimen of any organism was to be picked up and brought to buckets on the beach, carefully equipped with air pumps. They had to listen carefully to what was being placed in the buckets, because any duplicates were to be observed and left in place on the flats.

Mike was eager to get something into the bucket and turned rocks over in anticipation of finding brittle stars or shrimp or even a sea cucumber. He remembered to turn the rock back the way it was in order to restore the natural habitat of any living organism that was on the rock.

Mike was surprised to find his search slow and rather non-productive. After a while, someone called out that they had found a sea cucumber. Another person found a hermit crab.

Mike looked over at Brad and asked his longtime buddy, "Hey, do you remember when we were in second grade, weren't there tons of brittle stars and stuff like that?" Brad nodded and recalled how they had picked one after another out of the water. It sure wasn't the same.

The morning wore on and soon the class was reassembled on the beach, ready to discuss their findings. "Mr. Lee," Mike started, "how come it took so long to find even one little sea urchin?" A chorus of voices joined in claiming a slow and frustrating search.

Mr. Lee restored order and said, "We were able to find at least one specimen from most of the groups we had discussed in class. That's great, but there seems to be an alarmingly small number of each one on this reef. Why do you think that is so? What are some reasons this reef flat is not brimming with life?"

Mike and Brad thought seriously along with the others, including the somber faced parents. It was quite unsettling to think that the reefs were not as they remembered several years ago.

Brad looked around and took closer notice of many exposed rocks with some sponges and feather duster worms that appeared half-dried. In fact, there seemed to be fewer rocks on this beach than in years past. He also recalled seeing many brittle stars, hermit crabs and sea urchins for sale at pet stores. He raised his hand and shared his observations and recollections of the pet store supply.

Another student raised her hand and told of her experiences as a summer fun junior leader. She said that hundreds of summer fun children visited the reef flat each summer and they didn't have the same kind of instruction that Mr. Lee had given them. She said that the children did not turn the rocks back to the original positions and many children took sea creatures home even if they weren't supposed to.

Mr. Lee and the group listened thoughtfully to what was being said. This tidepool excursion was proving to be more than a lesson on specific animals and their habitats. Mr. Lee looked at his students and challenged them, "It certainly appears that our reef is not receiving the proper respect and care that is needed. The public has the right to enjoy our reefs, but should they be allowed to abuse it? What can we do to help get the word out about the problems we see and possible solutions?"

APPENDICES

Background:

In marine environments in Hawaii, there are a number of factors which contribute to or limit limu **habitats,** that is, places which provide what these plants need in order to live. Some of the basic life supporting factors are the same for limu as for land plants: **light, oxygen** and **carbon dioxide,** and **nutrients.** Because of the marine environments in which limu grow, these basic needs are in turn influenced by other factors, including **water depth, temperature, transparency** or **turbidity,** degree of **salinity** (salt concentration), degree of **water movement,** and exposure to air by **tidal fluctuation.** Also important are **shoreline topography** and type of **substratum** (bottom surface) to which the limu attach. The size of fleshy limu is often impacted by **grazing fishes,** and **overpicking** or **incorrect picking** by humans can severely reduce limu populations.

Light

Like other plants, limu make their own food through **photosynthesis,** converting light energy into energy-rich chemicals. Therefore, limu need sunlight. The amount of sunlight that can reach limu is affected by **water depth,** and **transparency** or **turbidity**—that is, whether the water is clear, or muddied and stirred up with particles. Different limu seem to have differing light requirements, as some are found growing in dark cracks and crevices, or under other limu.

Water temperature, oxygen and carbon dioxide

Limu use **carbon dioxide** and produce **oxygen** during the day, through the process of photosynthesis. At night, limu use oxygen and produce carbon dioxide through **respiration.** In tide pools, the oxygen produced by the seaweed saturates the water during the day, but is lost as the water heats up. When photosynthesis stops at night, respiration by limu and marine animals in the tidepools uses up the remaining dissolved oxygen, reducing its concentration to very low levels. This limits growth, particularly of marine animals.

Nutrients

Nitrogen and phosphorus are two of the most important **nutrients** (food substances) for limu. These are available in varying amounts in the water surrounding the limu. The presence of nutrients is impacted by **water movement**—waves and currents carrying away waste materials and bringing fresh supplies of nutrients into the area. **Fresh water runoff** and streams carry nutrients (including fertilizers) from the land into the sea. The discharge of sewage (including human waste) is another source of nutrients for marine life.

Note: Land development or deforestation can affect limu habitat. Streams and runoff can bring to the shore areas loads of **silt** (fine grained soil carried and laid down by moving water). **Siltation** of shoreline areas can block sunlight from reaching limu, or cover the bottom with a soft and shifting surface unsuitable for limu attachment.

Substratum

Most limu are attached by their holdfasts to hard surfaces rather than soft and shifting surfaces such as sand, mud or gravel. Rocky shorelines, reef flats and tidepools provide excellent **substrata** (plural of substratum) for limu attachment. Concrete pilings, lava boulders and other hard objects also provide limu attachment sites.

Salinity

Different species of limu vary in their ability to tolerate degrees and changes in salinity. Some species, such as limu 'ele'ele, thrive in **brackish** (mixed fresh and salt) water, such as that found at the mouths of streams or near springs at the edge of the sea. These areas also receive the benefit of nutrients carried by streams from upland areas.

Changes in salinity are common in tide pools. Here the water may be subject to evaporation, resulting in an increase in the concentration of salt. On the other hand, the salt concentration in a tidepool may be diluted by heavy rains and runoff, which will have little effect on the nearby open ocean environment. Pools which are further from the sea are more subject to fluctuations in salinity and temperature than those which are isolated from the open ocean for shorter periods of time during **tidal fluctuation** or changing tides.

Zonation and Tidal Fluctuation

Different shoreline and nearshore **zones** are identified according to how much they are covered by sea water or exposed to air by the changing tides. The zones we will be studying here include:

Splash zone: the portion of the shore above the reach of normal waves and high tide that is still regularly wetted by wave spray.

Intertidal zone: seaward of the splash zone, the region alternately covered and exposed by waves and the tide.

The **high intertidal zone** is only covered by water at high tide, but is always kept wet by waves.

The **low intertidal zone** is covered most of the time and exposed only during low tide, between waves.

Subtidal zone: the area continually covered by water, even at low tide.

These zones are summarized and illustrated on the handout entitled **Limu Habitat Notes** (see following page).

Shoreline topography and wave exposure

The above zones can be found on sandy as well as rocky shorelines, but are less obvious on sandy beaches. The distribution in bands, or **vertical zonation,** of limu can be observed readily on many rocky shorelines.

Zonation of limu and other marine organisms is also impacted by degree of **wave exposure,** influenced by **shoreline topography,** or the shape, size and position of physical elements of the shore. The size of waves and currents differs greatly from wave-sheltered bays and coves to open stretches of beach. The forms of limu vary with the environments, with those facing surf action tending to be stony, tough and/or flexible, and those in quieter water more delicate.

Large fleshy seaweeds (edible limu are all fleshy) are more abundant on flat areas, such as reef flats and limestone benches, than in wave surge environments at the **reef crest** and the steep, sloping seaward edge of reefs. These areas are dominated by stony **coralline algae,** seaweeds which deposit calcium carbonate and actually produce most of the reef through their growth.

Limu Habitat Notes

Near Shore Zonation:

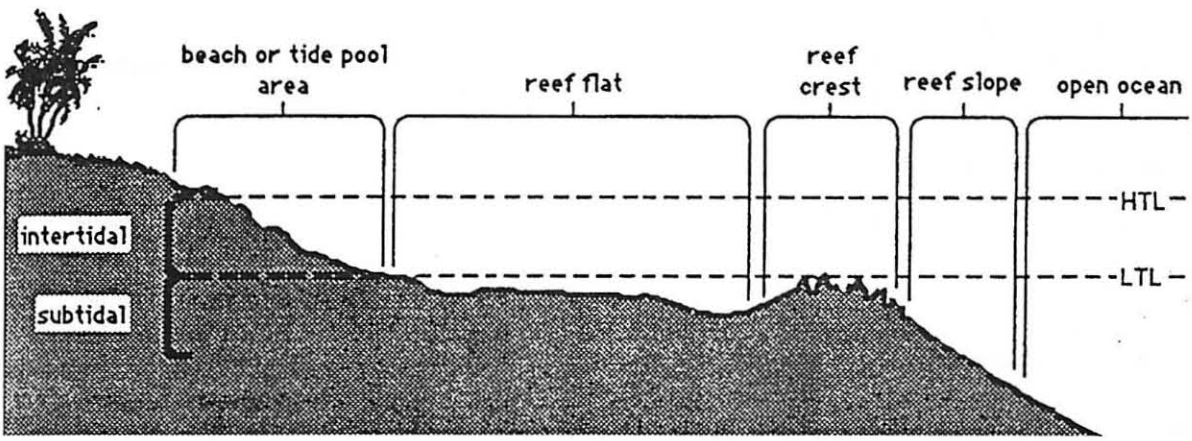
The **splash zone** is the portion of the shore above the reach of normal waves and high tide, but regularly wetted by wave spray.

The **intertidal zone** is that part of the shore which is covered, then exposed, as the tide changes.

The **high intertidal zone** is only covered with water at high tide.
The **low intertidal zone** is covered most of the time and only exposed at low tide.

The **subtidal zone** is always covered with water, but includes tidepools as well as deeper water.

Habitats of Hawaiian Seaweeds



HTL: high tide level **LTL:** low tide level
Adapted from Magruder, William H. and Jeffrey W. Hunt, *Seaweeds of Hawai'i*, p. 9.

Habitat Notes for Selected Hawaiian Limu

Limu 'ele'ele *(Enteromorpha prolifera)*
Common in brackish (mixed fresh and salty) water, such as at the mouth of a stream, in an oceanside pond or near a spring at the edge of the sea. Usually grows on small rocks buried in fine sand.

Limu palahalaha, papahapaha, pakaiea *(Ulva fasciata)*
Common and abundant in areas with freshwater influence. Found in a range of intertidal and subtidal habitats, from calm shallow tidepools and slightly brackish water, to a depth of more than five feet on reefs. Especially common on lava rock and old coral.

Limu wawae'iole, 'a'ala, 'a'ala'ula *(Codium edule, C. reediae)*
Common and locally abundant over reef flats. C. edule found in low intertidal and especially subtidal habitats, six to ten feet deep. C. *reediae* found subtidally, in calm, deep tidepools and reef flats.

Limu lipoa *(Dictyopteris plagiogramma, D. australis)*
Abundant where found, generally in deep water (3-40 feet) outside reef crests or occasionally on reef flats. D. plagiogramma is also found on rocky shores at zero tide level (average lower low tide). Both species are found as shore drift, year round.

Limu kala *(Sargassum echinocarpum)*
Common in intertidal zone, in rocky and sandy places, on wave-swept lava benches, from warm, calm tide pools to depths of more than ten feet over reef flats.

Limu pahe'e *(Porphyra* species*)*
Uncommon and highly seasonal, found occasionally in winter and early spring, following periods of high surf. Grows on exposed lava boulders, high in the wave-splashed intertidal zone, usually in areas with fresh water influence.

Limu kohu, koko, lipehe, lipa'akai *(Asparagopsis taxiformis)*
Common seasonally in shallow subtidal zone where there is constant water motion, such as on reef crests. Also grows well on intertidal lava benches.

Limu huluhuluwaena, pakeleawa'a *(Grateloupia filicina)*
Found occasionally, on shallow reef flats or rocks covered with sand in intertidal zone. Usually found in areas with fresh water influence, such as near springs or stream mouths.

Limu lepe 'ula'ula, lepe-o-Hina *(Halymenia formosa)*
Uncommon, grows subtidally to depths of twenty feet, often in slightly turbid conditions (muddy or stirred up). Frequently washes up on shore.

Limu manauea *(Gracilaria coronopifolia)*
Formerly common, now less so. Grows on shallow reef flats, occasionally in tide pools, and is often washed up on shore. Another species, Gracilaria parvispora (long ogo) grows on calm reef flats.

Limu 'aki'aki *(Ahnfeltia concinna)*
Abundant where present. Grows at very high intertidal level on rugged lava coastlines, sometimes as a distinct, dense band covering the exposed lava rock, or only in small crevices and cracks.

Limu lipe'epe'e *(Laurencia succisa)*
Common intertidally in areas with moderate to heavy surf, especially in small pools of a'a basalt or limestone. Grows downward into crevices or sea urchin holes, and may be found under larger seaweed.

Limu mane'ene'o, maneoneo *(Laurencia nidifica)*
Common in lower intertidal zone, sometimes deeper. Grows on sandy and eroded reef rock.

Sources:

Abbott, Isabella Aiona. *Limu: An Ethnobotanical Study of Some Hawaiian Seaweeds.*
Lawa'i, Kaua'i: Pacific Tropical Botanical Garden, 1984.

Fortner, Heather. *The Limu Eater.*
Honolulu: University of Hawai'i Sea Grant College Program, 1979.

Magruder, William H. and Jeffrey W. Hunt. *Seaweeds of Hawai'i.*
Honolulu: The Oriental Publishing Company, 1979.

Notes on Limu Distribution

Excerpted from: Abbott, Isabella Aiona. *Limu: An Ethnobotanical Study of Some Hawaiian Seaweeds.* Lawa'i, Kaua'i: Pacific Tropical Botanical Garden, 1984.

Limu 'ele'ele *(Enteromorpha prolifera)*
Near freshwater streams entering ocean or underwater springs such as are found at Ho'okena and Punalu'u on Hawai'i; Puko'o, Moloka'i; Kahala and Hau'ula, O'ahu; Hanapepe and Hanalei, Kaua'i.

Limu palahalaha, papahapaha, pakaiea *(Ulva fasciata)*
Common throughout islands.

Limu wawae'iole, 'a'ala, 'a'ala'ula *(Codium edule, C. reediae)*
C. edule common throughout islands. On O'ahu, especially at Waikiki, Kawela Bay and Nanakuli; on Maui at Kihei. C. reediae found from 'Ewa Beach to Sand Island on O'ahu and on the southwestern shore of Maui.

Limu lipoa *(Dictyopteris plagiogramma, D. australis)*
Found at Nomilu, Kaua'i; Kane'ohe to the Blowhole and Waikiki, O'ahu; Olowalu and Lahaina, Waihe'e to Sprecklesville, Maui; Kohala, Hawai'i.

Limu kala *(Sargassum echinocarpum)*
Common throughout islands.

Limu pahe'e *(Porphyra species)*
Seasonal. On all large islands in areas with heavy surf and fresh water: Moloa'a and Kalihiwai, Kaua'i;
Waimea and Ma'ili, O'ahu; Honolua, Pa'ia, and Hana, Maui; Kohala, Kona, Waikapuna, and Ka Lae, Hawai'i.

Limu kohu, koko, lipehe lipa'akai *(Asparagopsis taxiformis)*
Occasional on all major islands. Especially Anahola district of Kaua'i; also Wai'anae, Hau'ula and Kahuku, O'ahu; Moloka'i; Hana and Pa'ia, Maui; and Kohala, Hawai'i.

Limu huluhuluwaena, pakeleawa'a *(Grateloupia filicina)*
Occasional on all major islands: Honokowai, Ma'alaea, and Mala, Maui; Kupeke, Moloka'i; Waikiki and Hanauma Bay, O'ahu; Hilo, Hawai'i.

Limu lepe 'ula'ula, lepe-o-Hina *(Halymenia formosa)*
Off Kahala, Kailua, Hau'ula, and 'Ewa Beach, O'ahu; Kama'ole, Kihei, and Kahului, Maui; Laupahoehoe and Kona, Hawai'i.

Limu manauea *(Gracilaria coronopifolia)*
Formerly common on O'ahu. Grown commercially on the North Shore.

Limu 'aki'aki *(Ahnfeltia concinna)*
Rare on O'ahu. Common on Maui, on Hawai'i, and at Hanama'ulu, Kaua'i.

Limu lipe'epe'e *(Laurencia succisa)*
Common except on Hawai'i. Poipu, Kaua'i; Halona and Mauna Lahilahi, O'ahu; Hana, Maui.

Limu mane'ene'o, maneoneo *(Laurencia nidifica)*
Common on all islands except Hawai'i. Kapa'a, Kaua'i; Kualoa to La'ie, O'ahu; Ma'alaea and Pa'ia, Maui.

LIMU 'ELE'ELE

Limu 'ele'ele means black seaweed and is descriptive of the dark color of the prepared seaweed. This limu is actually grass green in color. Long strands of limu 'ele'ele may be found growing at the mouth of many island streams. Its presence shows that fresh or brackish water is nearby.

The cleaned seaweed is rinsed and drained and salted. This prepared limu adds a nutty flavor to stews, saimin, and raw fish and its green color makes it a good garnish. It also can be eaten as a spice or dried in Japanese fashion to make a seasoning salt or thin sheets of sushi nori.

LIMU HULUHULUWAENA

In ancient Hawai'i, this limu was reserved for the ali'i. It was called the queen limu because of its dark hair-like branches. It was also considered the best edible limu.

This limu grows in different ways. Some have branches that are fine and hair-like, while others may be 1/2" wide. There are also flat, curled, and twisted varieties.

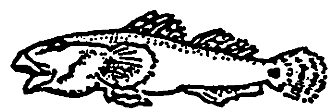
Traditionally, it is cleaned, rinsed in salt water, chopped and added to 'opihi, raw liver and other limu. It has a delicate but distinctive flavor when fresh and combines well with fish, poultry and dairy products.

Identification and Biology of Native Stream Animals

Fishes

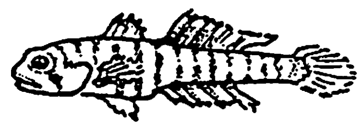
'O'opu nakea *(Awaous guamensis)*

This is the largest of the stream gobies, reaching 14 inches (35 cm) in length. It is indigenous to Hawai'i, and found in other Pacific Island groups. Nakea is 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 for food on Kaua'i during the late summer spawning migrations.



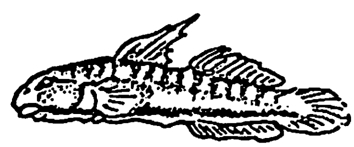
'O'opu naniha *(Stenogobius hawaiiensis)*

This endemic species 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 9 to 11 dark vertical bands. Large specimens reach 6 inches (15 cm) in length.



'O'opu nopili *(Sicyopterus 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.



Limu Recipes

Adapted from: *Coral: A Hawaiian Resource. An Instructional Guidebook for Teachers* by Ann Fielding and Barbara Moniz. State of Hawai'i Department of Education RS 81-O652. March 1981

Limu should be washed thoroughly with tap water before using. "Wilting" is optional.

To "wilt" limu:

Place the clean limu in hot (but not boiling) water, to cover. Let it sit in the hot water for a short time, from a few seconds up to a minute. Then pour off the hot water and rinse the limu immediately in cold water, to stop the "wilting" process. If it "wilts" too long, the limu will become like a soft gel.

1. Kim Chee ogo (Korean Style)

1 lb. ogo (limu manauea, Gracilaria species)
1/2 cup shoyu
1/4 cup vinegar
1 Tbsp. mirin
Ginger, grated (to taste)
Chili pepper, grated (add to taste)
Garlic, chopped fine (add to taste)

After cleaning the limu, and wilting it if desired, mix the seasonings and add to the limu. This kim chee may be bottled and kept in the refrigerator.

2. Kailua ogo

1/2 cup red wine-vinegar
1 lb. ogo
1 tsp. sugar
1 tsp. chives (diced green onions)
1/4 diced tomato
Hot sauce to taste

After cleaning the limu, and wilting it if desired, mix the seasonings and to the limu. This may also be bottled and kept in the refrigerator.

3. Pickled Codium

1/2 lb. codium (limu wawae'iole or 'a'ala'ula)
1/2 cup wine-vinegar
1/2 tsp. sugar
1/4 diced tomato

Clean the codium using only cold water. Mix ingredients to make sauce. Codium toughens rapidly in the sauce. Another way to serve this is to use the sauce as a "dip."

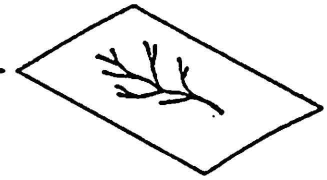
4. Limu Tsukudani (serve with hot rice)

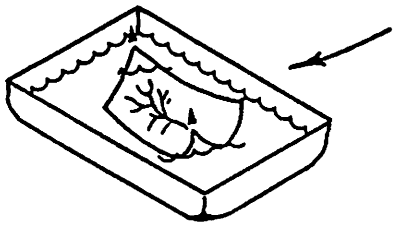
I lb. ogo
1-1/4 cup brown sugar
1/2 cup mirin
1-1/4 cup shoyu
1/4 tsp. monosodium glutamate (MSG) (optional)

Clean limu. Mix sugar, mirin and shoyu together in a heavy saucepan. Bring to a full boil. Add limu and stir frequently to prevent burning. Cover and cook to a "mush" (about 45 minutes) Goma (sesame seeds) and chili pepper may be added to taste.

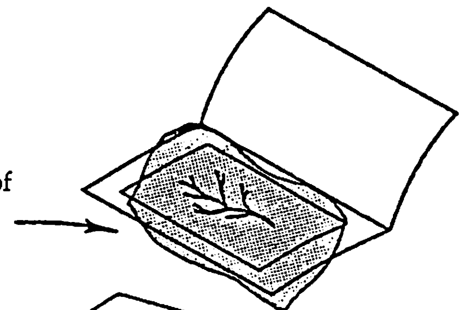
Limu Pressing Handout

1. Arrange and spread each specimen on a piece of heavy weight paper such as botany or biological paper, charcoal paper, index cards, etc.

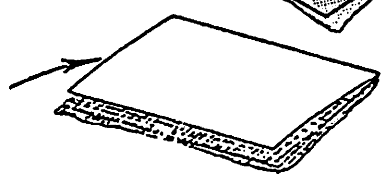




For algae that have very fine hairs or branches, place the paper in a tray of water and then spread the algae on top of the paper in the tray. The water will spread the fine branches very nicely. When it is arranged as desired, carefully lift the paper out of the water by its opposite corners. Slowly lift the edges letting the water drain off the paper. Be careful not to disturb the position of the specimen.

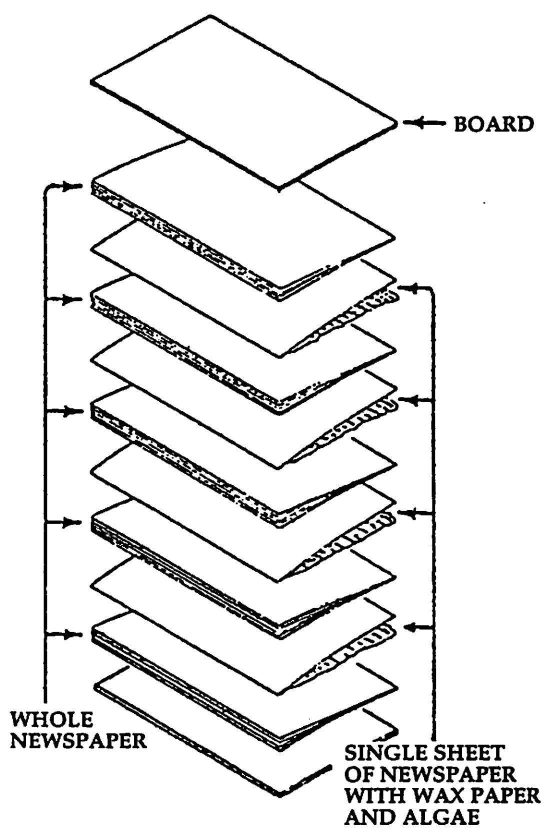


2. Place each paper with the arranged algae on one half of a single (not manifold) thickness of newspaper. Place a piece of wax paper over it.



3. Fold the other half of the newspaper on top.

4. Alternate the folded newspaper preparations between whole dry newspapers. Build up a pile in this way, capping the pile with a board. Place rocks or other heavy material on the pile of newspapers. Change the wet manifold newspapers for dry ones at the end of 12 hours and once a day thereafter until the specimens are dry to the back of one's hand. The wet newspapers should be dried in the sun or otherwise reused.



The pile of newspapers and drying algae can be pressed together by placing them between two boards and roping the lot together.

The algae should stick to the paper naturally when dried. If not, glue the algae on the paper when dried.

<u>Hawai'i</u>

Harry K. Brown Park	Except for beach drift of miscellaneous algae and sponges, very few marine algae or animals can be found on the black sand beach.
Richardson Ocean Center Beach	Limu 'ele'ele can be found in the anchialine ponds; in the splash zone can be found limu 'aki'aki.
Leleiwi Beach Park	Beach drift includes limu wawae'iole, 'ele'ele, 'aki'aki, kala, and pala halaha.
Laupahoehoe Beach Park	Ahnfeltia (limu 'aki'aki) can be found in the tidepools.
'Anaeho'omalu Bay	Coralline algae encrusts the anchialine ponds and the tide pools inter spersed on the north and south sides of the bay.
Keahole Point (Natural Energy Laboratory of Hawaii [NELH], OTEC Beach)	Ulva (limu palahalaha), Padina, and Sargassum (limu kala) are present in tidepools.
Old Kona Airport State Park, Kuka'ilimoku	Limu is sparse in tidepools on the northern portion, but tidepools on the south side have an abundance of seaweed. Note that the area is designated as a Marine Life Conservation District; limu may be studied in habit, **but not collected or removed.**
Kahalu'u Beach Park	Limu is sparse, but some limu 'aki'aki and palahalaha are present.
Pu'uhonua o Honaunau National Historical Park, Honaunau Bay	There is a significant amount of limu palahalaha growing on the reef. [NOTE: Limu collecting not allowed.]

<u>Moloka'i</u>

Mo'omomi Beach	The long stretch of shoreline from Mo'omomi to Keonelele Beach con tains a wide variety of marine life including seaweeds.
Kiowea Park	The shallow mudflats contain a number of diverse marine life including seaweeds.
Oneali'i Beach Park	The shallow mudflats harbor many different types of marine life, including various seaweeds.
Murphy Beach Park	Tidepools and shallow fringing reef. Marine life here includes sea weeds.

<u>Lana'i</u>

Hulopo'e Beach Park	The tidepools offer excellent opportunities for field trip explorations and contain seaweeds. Note that the area is designated as a Marine Life Conservation District; limu may be studied in habit, **but not collected or removed.**

O'ahu, continued

Diamond Head Beach Park*	The off-shore area is an uneven coral reef flat containing pockets of sand. There are a number of [species of] algae.

***NOTE:** The area is part of the Waikiki-Diamond Head Shoreline Fisheries Management Area (FMA). The FMA extends from the Diamond Head Lighthouse to the ewa wall of the Waikiki War Memorial Natatorium, outward 500 yards or to the seaward edge of the reef (whichever is greater). The FMA is "open to fishing" from January 1 to December 31 of even-numbered years (1994, 1996, etc.). It is closed to all forms of fishing, **including limu picking,** from January 1 to December 31 of odd-numbered years (1995, 1997, etc.). Contact the Hawai'i State Department of Land and Natural Resources, Division of Aquatic Resources (587-0100) for updated information.

<u>**Maui**</u>

Pu'unoa Beach Park	Sandy and cobble-stone beach, tidepools/intertidal area. Marine algae are present in the cobblestone beach area.
Launiupoko State Wayside Park	Tidepools, intertidal area, reef flat with algae.
Ma'alaea Small Boat Harbor	Tidepools, intertidal area, reef flat. The offshore area contains marine algae.
Waipu'ilani Reef Flat	Tidepools, fish pond, reef flat. On the shallow submerged portion of the reef flat one can find various types of marine algae.
Hamakua Poko Papa or H-Poko Papa Beach Park	Zonation of marine algae and animals is exhibited over an exposed and unprotected reef platform.
Ho'okipa County Beach Park	Intertidal areas, reef flat. The tidepool biota includes marine algae.
Hamoa Tidepools	Tidepools, intertidal area, reef flat are rich with algae.

<u>**Kaua'i**</u>

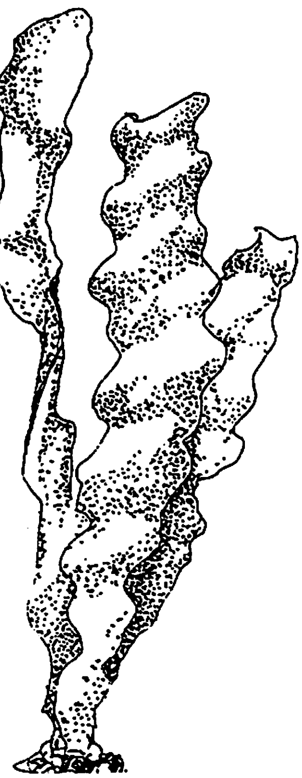
Maha'ulepu Beach	Tidepools. Many types of marine life are found in this area, including seaweed.
Kapa'a Beach Park	The reef flat and tidepools support a wide variety of marine life that includes seaweeds.
Anahola Beach Park	The reef flat fronting the beach park contains a wide variety of marine life that includes seaweed.
'Anini Beach Park	The 'Anini Reef exhibits a wide diversity of marine life including sea weeds—attracting many seaweed harvesters.
Ha'ena State Park (Ke'e Beach)	The reef flat offers a good diversity of marine life including seaweeds.

Coastal Field Sites Suitable for Limu Study

Excerpted from *A Compendium: Coastal Field Sites in the State of Hawai'i.* State of Hawai'i Department of Education. RS 85-8O5O. (Rev. of RS 83-4146) June 1985. Sites are included in this list only if the entry in the *Coastal Field Sites* guide mentioned the presence of seaweed. Other sites may be appropriate as well. Check *Coastal Field Sites* for complete site and field trip planning information. See especially section A, Field Trip Safety and Preparation.

<u>O'ahu</u>

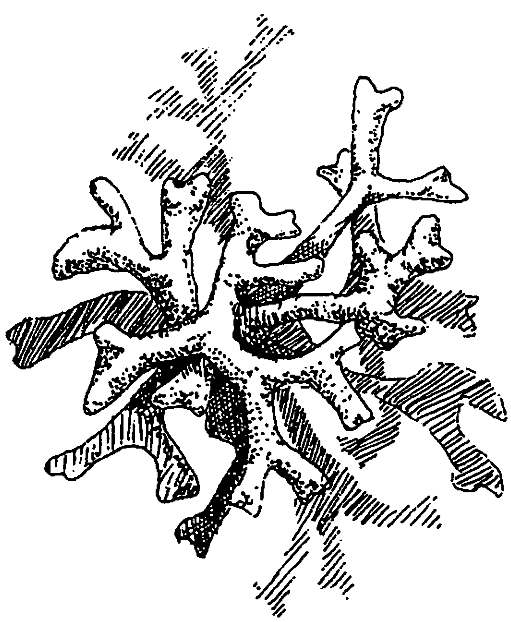
Kewalo Basin	Tidepools, intertidal areas and reef flats. At different times of year, abundant seaweed materials are present, primarily Acanthophora, Ulva, and Padina.
Reef flat on Hickam Air Force Base	A limited variety of algae is present.
'Ewa Beach Park	Beach, reef flat. Many species of limu are abundant but can disappear in a single tide change. This is one of the most popular limu picking areas on O'ahu.
Ma'ili Beach Park	Different types of seaweed grow on the reef flat.
Ma'ili Point Reef	Seaweed is present in small amounts on the reef flat and intertidal area.
Lualualei Beach Park	Tidepools, reef flat. Algae are dense near the seaward edge of the reef.
Ka'ena Point State Park	Tidepool and reef flat. Tidepool biota includes limu.
Mokule'ia Beach Park	Tidepool, reef flat. The narrow reef flat along the beach displays a sharp intertidal zonation of limu and marine organisms.
Kaiaka State Recreation Park	Tidepools, estuary, reef flat. Reef biota includes algae.
Malaekahana State Park	Beach, reef flat. At different times of year, abundant seaweed drift material is deposited along the beach.
Kualoa Regional Park	Reef flat. Various species of algae are found off-shore
He'eia Fishpond and Mangrove Marsh	The intertidal reef contains a number of algae species.
King Intermediate School Reef Flat	Tidepools, reef flats, intertidal microhabitats on concrete pilings. Limu are found along the coastal area.
Kawaiku'i Beach Park	Beach, reef flats. Ectocarpus algae are found washed up on the beach in large quantities. The off-shore reef area contains a variety of algae species.
Wai'alae Beach Park	There are a number of algae [species] on the off-shore fringing coral reef.



LIMU PALAHALAHA

This limu has long, flat, bright green blades. In the water, it resembles a leafy head of lettuce so it is often called sea lettuce. This limu is one of the most common limu in the islands and is found in abundance along the shore. This limu is edible but is rarely collected for eating. When it is prepared properly, it can be a delicacy.

A legend tells that an early ancestor of the shark was wrapped in the leaves of the limu palahalaha and then put into the sea. To this day this limu is thought to be sacred to the shark god and is kapu to people whose 'aumakua is the shark.



LIMU WAWAE'IOLE

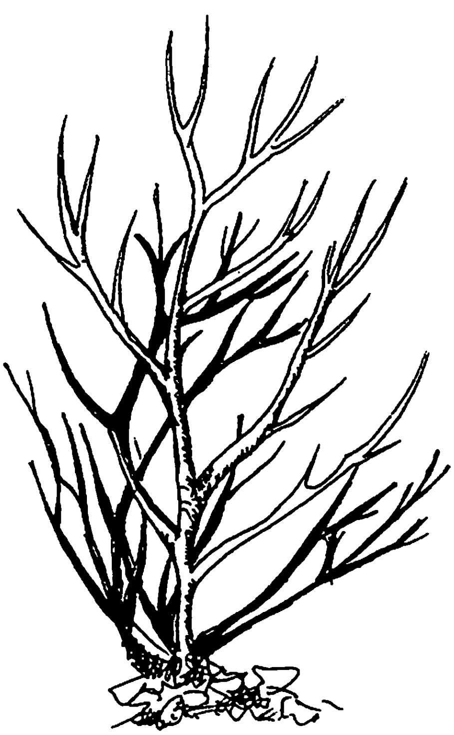
This spongy, green limu has stubby, flattened ends at its cylindrical branches that resemble a rat's foot, hence its name wawae'iole which means rat's foot.

This limu grows in the form of a creeping mat over coral and sand. Frequently, when it is picked up, its bottom will be covered with pieces of shell, sand, or small rocks. It is found in abundance along the shore and is especially prized for eating by the Filipino people. It is called pokpoklo in Filipino and miru in Japanese.

LIMU MANE'ONE'O

This limu is peppery, almost hot to the taste, so it is sometimes called chili pepper or mustard limu. It combines well with raw fish and should only be eaten fresh.

Clumped at the base, this limu grows in bushes to a height of about eight inches. The tips of its branches have pits in them from which many colorless hair grow. This limu ranges in color from bright green to dark green and can be found growing in crevices and holes and along rocky coastlines.



OGO

This seaweed is not native to Hawai'i. It probably arrived here around the turn of the century by hitch-hiking on the hull of a Japanese ship. The branches are cylindrical with pointed tips that are long and narrow. This is one of our larger red seaweeds.

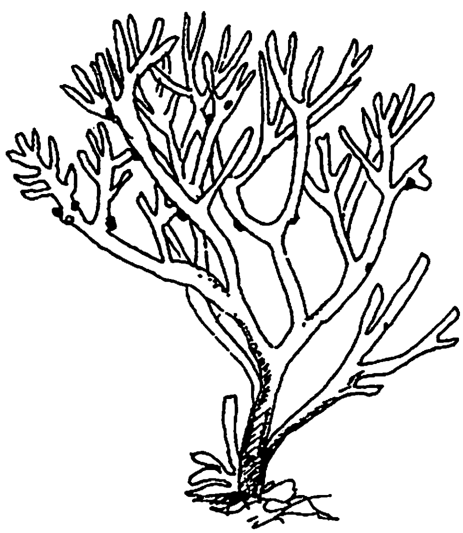
Ogo grows in shallow reefs and is often washed up on the shore. The color varies from red, when it grows on the reef flats, to almost white when it grows in areas of bright sunlight.

This is the most popular limu for eating today. The mild flavor and crunchy texture is recommended for beginning limu eaters.

LIMU LIPOA

Limu lipoa means gathered from the deep because this limu is a deep-water plant. It grows at three to fifteen foot depths, frequently in meadows, beyond the reef. It is not appreciated by the surfer and beach-goer because it clutters the water and the shore.

This limu has flat blades that are two to eight inches in length. It has a prominent dark brown midrib and is golden-colored with dark spots. It has a strong, perfume-like aroma and is highly favored for its unique spicy flavor.



LIMU MANAUEA

Limu manauea is a cousin to the limu ogo and is commonly referred to by that name. The limu manauea has a more reddish color and is shorter and more branched than the limu ogo.

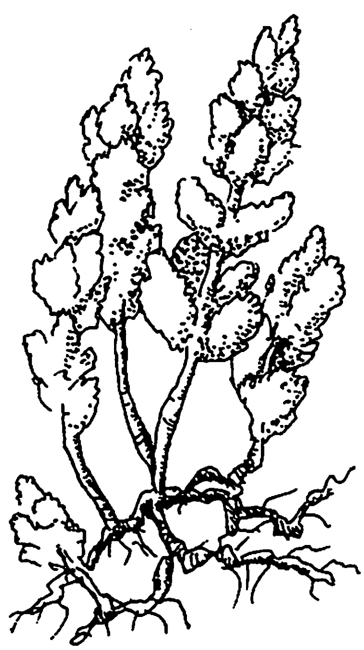
This limu grows in shallow coral and sand reefs and is often washed up on the shore.

Like the Japanese ogo, the limu manauea has a mild flavor and crunchy texture. It is also one of the most popular limu for eating.

LIMU KALA

This limu is of ritual and medicinal importance to the Hawaiian people. The word kala means "to free, loosen" and "to forgive, pardon"; and thus it was used symbolically in many ceremonies.

This holly-like brown limu often has small inflated gas bladders which have flattened stalks. It grows in tide pools and reef flats and is commonly found on our beaches. Because of its leathery texture, it is not used much for food.



LIMU KOHU

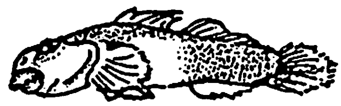
This is a small red limu. In the water, it looks like a forest of tiny pink pine trees with tufts of fuzzy branches at the top.

Limu kohu grows well where there is a constant flow of water.

In ancient times, this limu was forbidden to all except the ali'i because it was desired for its peppery flavor and was considered the best of all seaweeds. It is usually used sparingly as a spice or a condiment. It is also combined with meat or fish in a stew.

Limu kohu appears to be found only in Hawai'i.

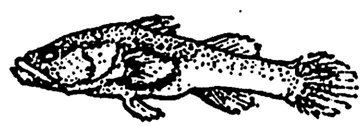
'O'opu hi'ukole or alamo'o *(Lentipes concolor)*



This goby is often found 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 small gobies average about 2 inches in length.

'O'opu okuhe or akupa *(Eleotris sandwicensis)*



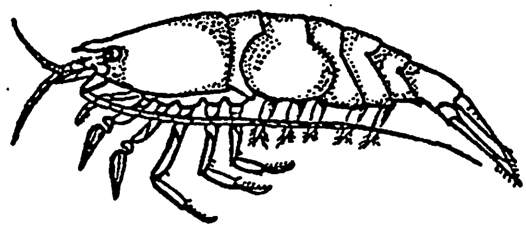
This species is not a true goby, and lacks the fused pelvic fins characteristic of that group. It is endemic and found on all islands. Length may reach 10 inches (25 cm). Coloration may be brownish above and lighter below with the second dorsal fin narrowly edged with white, black and white, or mottled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

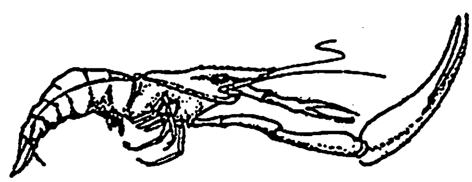
There are two endemic shrimp ('opae) found in Hawaiian streams. Both have marine larval stages.

'Opae kala'ole *(Atyoida 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 appearance 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 (sword-like 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 fewer 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

Mollusks

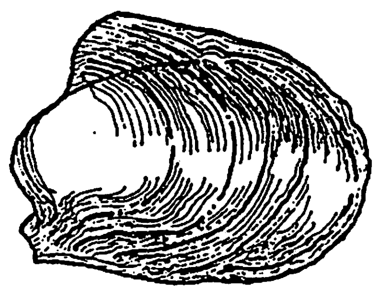
Two mollusks common in streams are the hihiwai and the hapawai. Both have a limpet-like shell and a strong muscular foot which aid in clinging to rocks in swift currents. Both are in the family Neritidae, which includes the black pipipi *(Nerita picea)* common along Hawai'i's rocky shorelines. The hihiwai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

Hihiwai *(Neritina granosa)*

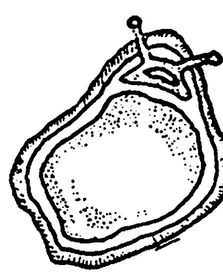
This species lives attached to stones in streams and under waterfalls. The low, rounded tubercles of the black shell are distinctive of animals living near the sea. Hihiwai shells found above waterfalls or on vertical cliffs may have fairly smooth shells which are oval in shape.

(Discuss with the class what might lead to the clear difference in shell shape within the same species.) This species is not as abundant on O'ahu and Kaua'i due to overfishing and habitat degradation. It is herbivorous and grows to 2 inches (5 cm). Its eggs are deposited on submerged rocks and on the shells of other hihiwai in tough white capsules about 2 mm in length. Each capsule may contain as many as 450 developing hihiwai. 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.

Hapawai *(Neritina vespertina)*



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



(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.

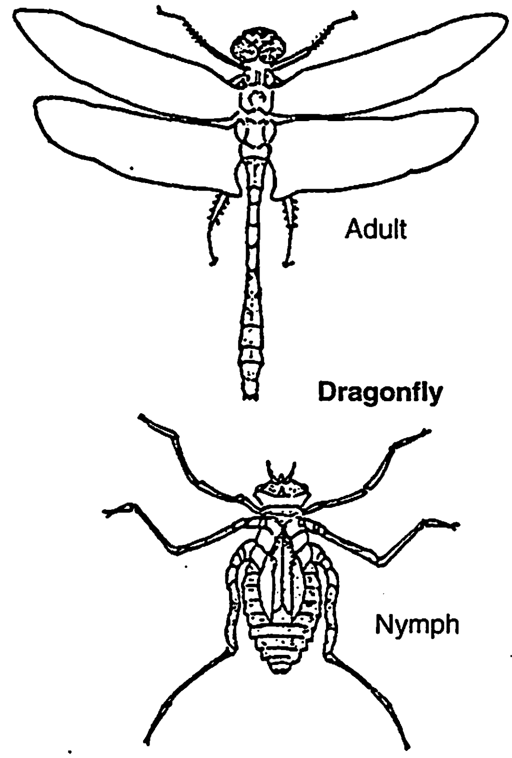
Hawai'i's endemic dragonfly, the "green darner" or pinao *(Anax strenuus)* is the largest of Hawaiian insects, with a body length of 11 cm and a wingspan of 14 cm.

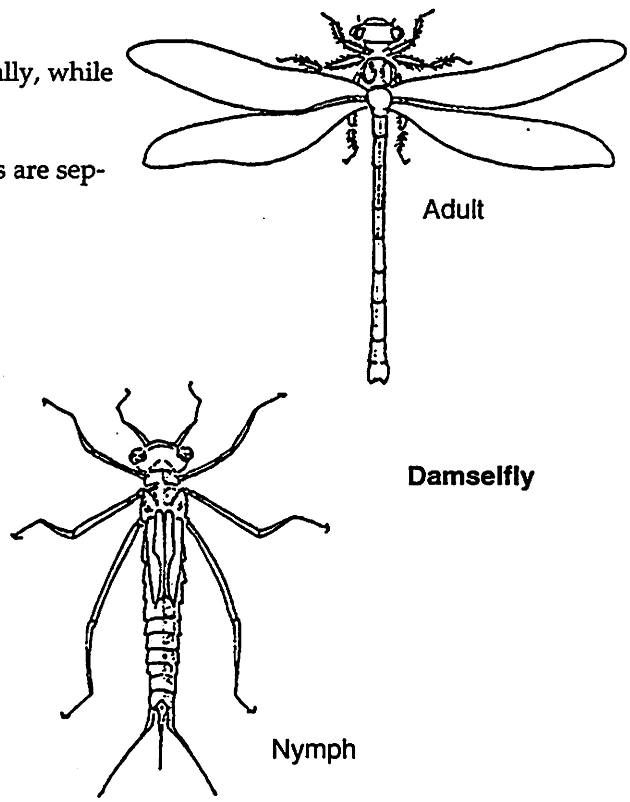
The damselflies include at least 23 different endemic species belonging to the family Megalagrion. (For more information on Hawaiian insects, see Zimmerman, 1948, Maciolek & Howard, 1979 and Cowles, 1977.)

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.

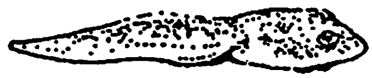
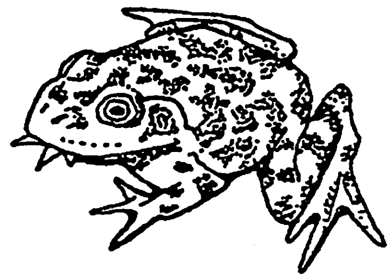
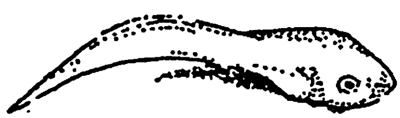
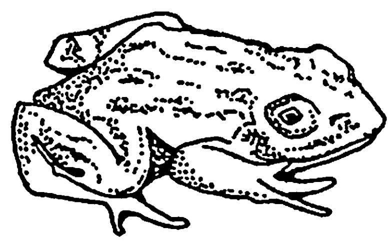
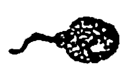
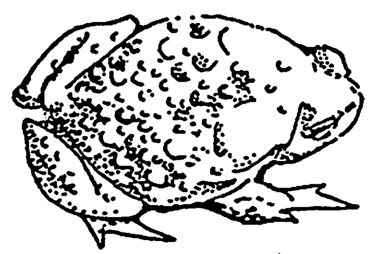




Identification Guide to Exotic Stream Animals

A. Amphibians

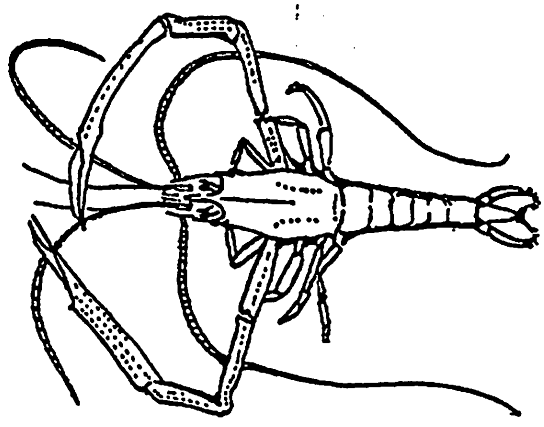
There are 3 species of frogs and toad in Hawaiian streams. The adults and tadpoles can be identified by using the following chart:

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 1-1/2 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.

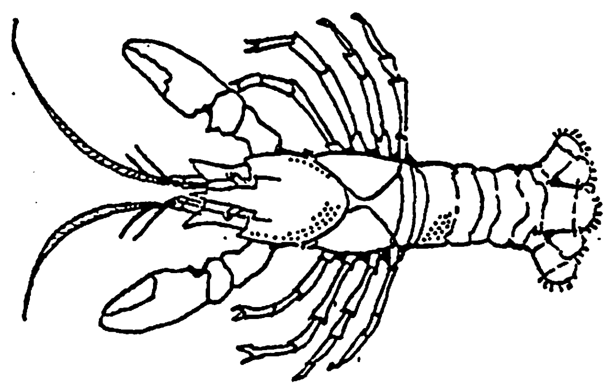
B. Crustaceans

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.

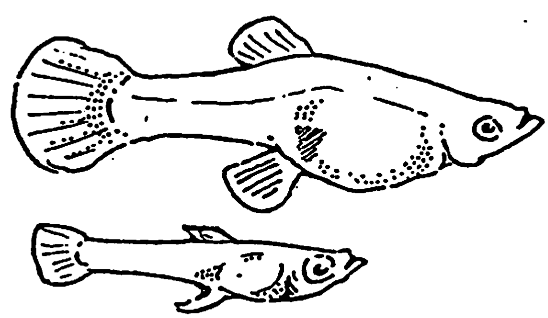
Crayfish *(Procambarus clarkii)*



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.

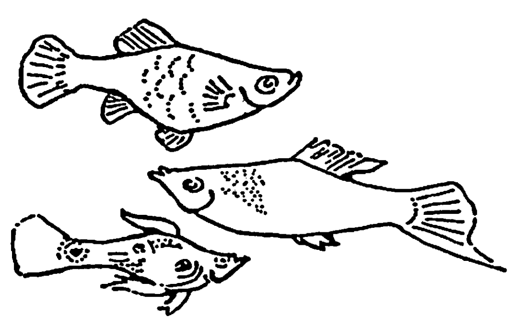
C. Fish

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).

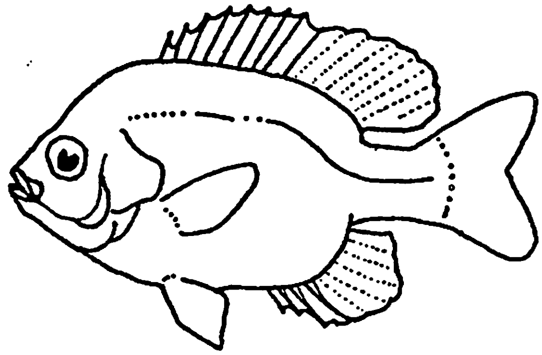
Mollies, guppies, top minnows, swordtails
(Family Poeciliidae)



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.

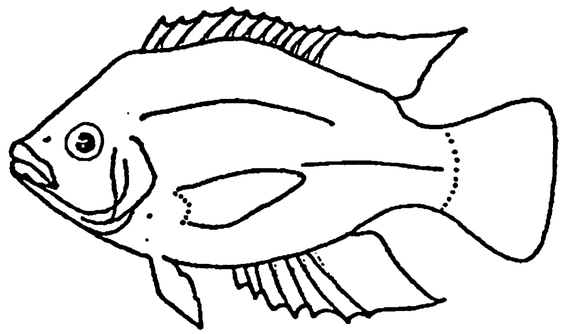
Bluegill *(Lepomis macrochirus)*

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.



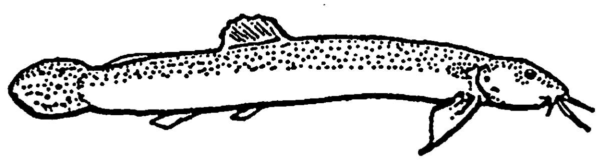
Tilapia (four introduced species)

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.



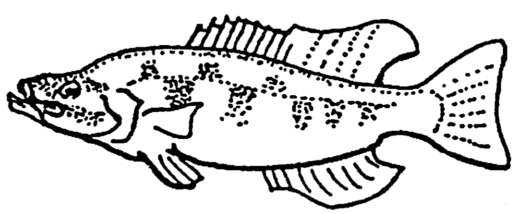
Dojo *(Misgurnus anguillicaudatus)*

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



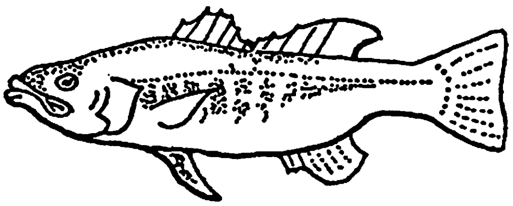
Smallmouth Bass *(Micropterus dolomieu)*

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.



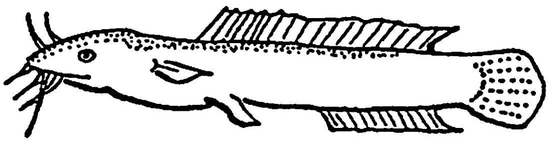
Largemouth Bass *(Micropterus salmoides)*

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)*

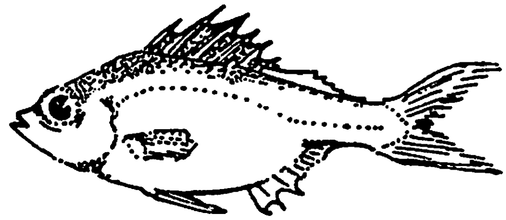
Introduced around 1900. Inhabits muddy bottoms of taro patches, streams and ditches. Color ranges from black to flesh-colored.



Identification Guide to Life in Hawaiian Estuaries

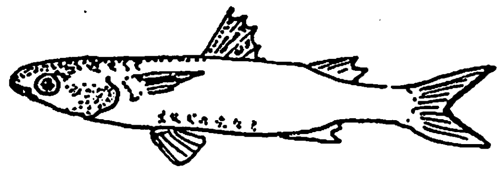
Juvenile Aholehole *(Kuhlia sandwicensis)*

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.



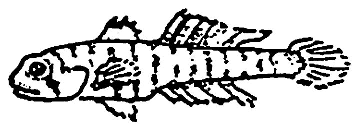
Juvenile Mullet *(Mugil cephalus)*

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



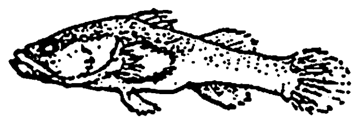
'O'opu naniha *(Stenogobius hawaiiensis)*

A small native goby; grows up to 6 inches in length. Recognized by 9 to 11 dark vertical bars on the body. Herbivorous.



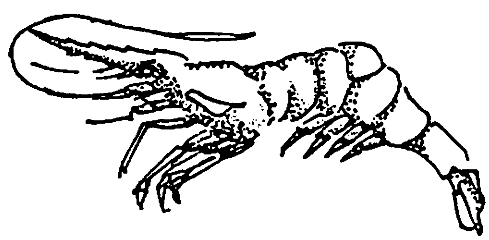
'O'opu okuhe or akupa *(Eleotris sandwicensis)*

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)*

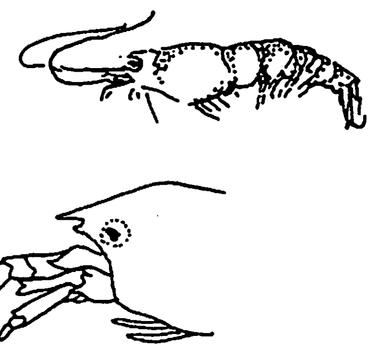
A transparent shrimp with small patches of black and white over the body. Probably feeds on detritus. To 1 inch in length.



'Opae 'ula *(Halocaridina rubra)*

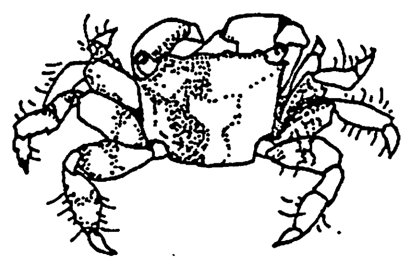
A small red shrimp endemic to Hawai'i and found only in this habitat. Feeds on benthic algae, detritus and phytoplankton. Has brush-like pincers. About 1/4 inch in length.

Red Shrimp *(Metabetaeus lohena)*



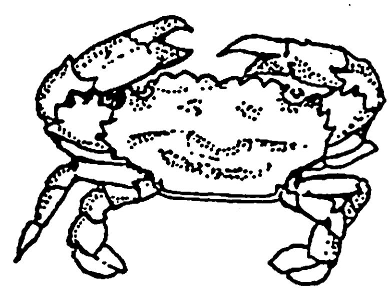
Like the previously mentioned 'opae-ula, this shrimp is also red, endemic and found only in this habitat. However, this species is twice as large (1/2 inch), and is carnivorous, preying upon the 'opae-ula. Other differences that help to identify this shrimp are the abdomen is red and pink striped, their 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 *(Metapograpsus thunkuhar)*



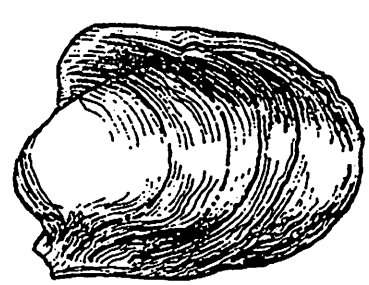
This small crab is about 3/4 inch across the body. Usually dark, may be speckled. Found along the shores of the ponds or in holes in the mud. Semi-terrestrial (able to live out of water part of the time). Herbivorous.

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.

Hapawai *(Neritina vespertina)*

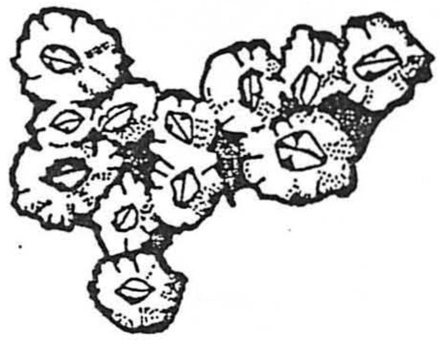


A limpet-like snail about 1/2 inch in length. Olive to brown in color. These herbivores graze algae off rocks. Endemic to Hawai'i.

Hihiwai *(Neritina granosa)*

Similar to N. vespertina, but often wider than long. Black in color. About inch long. Endemic. Herbivorous.

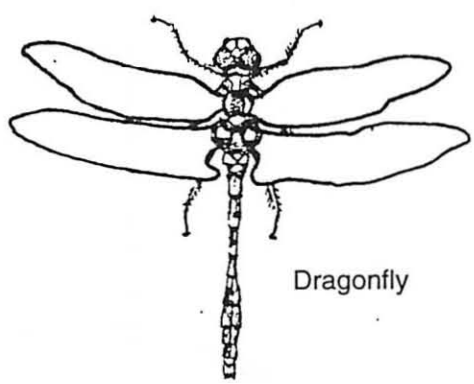
'Okohekohe, barnacles *(Chthamalus intertextus)*



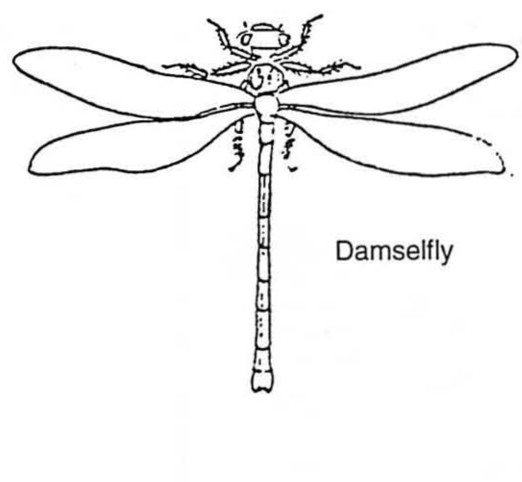
These barnacles encrust rocks and concrete piers between the tide marks. Color is light purple. Base of the shell is ribbed and wrinkled. About 1/4 inch across the base. Jointed fan-like appendages filter phytoplankton from the water.

Dragonflies and damselflies (Odonata)

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



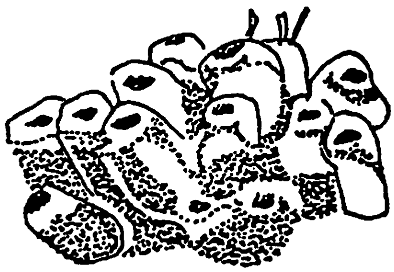
Dragonfly



Damselfly

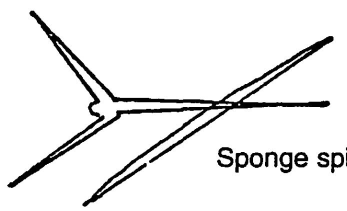
Guide to Marine Invertebrates

PHYLUM PORIFERA
SPONGES



Upright sponge

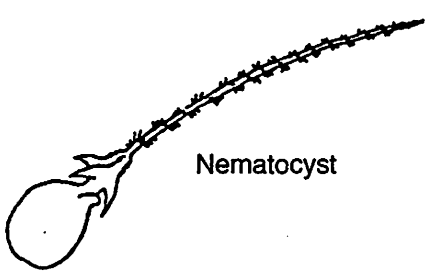
Sponges are the simplest of the animals made from more than one cell. They don't move and are always attached to something. They may be upright (like a simple bush) or **encrusting** (flattened). They are often brightly colored. They have many small holes by which food and water enter the body, and several large ones by which the water and wastes exit.



Sponge spicules

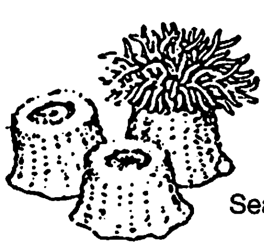
Sponges have skeleton elements called **spicules.** These tiny glass rods can be irritating to human skin. You can examine the spicules by putting a little Clorox on a small piece of sponge. This dissolves the tissue so you can look at the spicules with a microscope.

PHYLUM COELENTERATA (=CNIDARIA)
SEA ANEMONES, CORAL, JELLYFISH, HYDROIDS



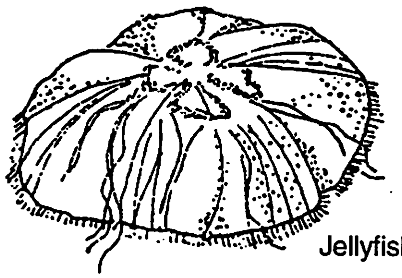
Nematocyst

Coelenterates are soft bodied. The individual animals are **radially symmetrical** (round, like a pie) with a ring of tentacles around a central mouth. The tentacles have stinging cells (**nematocysts**) for food gathering and protection. This group has two basic body forms: the **polyp** and the **medusa.**

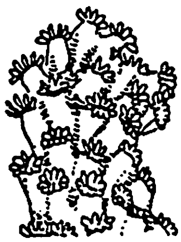


Sea anemones

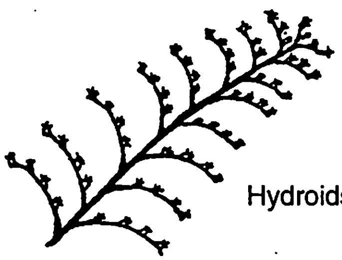
Sea anemones illustrate the polyp form of this group. A polyp has an upright stalk with the mouth and tentacles directed upwards. Zoanthids are colonies of anemone-like animals which share tissue. They form soft mats of living animals.



Jellyfish illustrate the medusa form. There is no stalk, only a bell-like structure with the mouth and the tentacles on the undersurface of the bell. Jellyfish swim by muscular contractions of the bell. Some can give a painful sting.

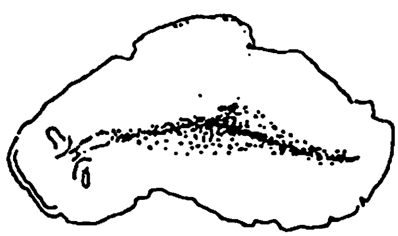


Corals are colonies of anemone-like animals which secrete a hard, calcium carbonate ($CaCO_3$) skeleton. Reef-building corals have tiny, one-celled algae living in their tissue. These algae aid in the formation of the hard skeleton.



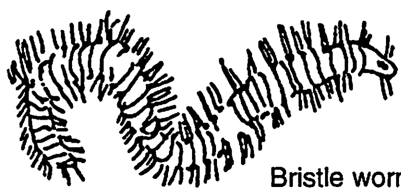
Hydroids are colonies of polyps which form a plant-like structure. The stems and branches of the colony are hollow and food and water are passed through them. Hydroids can sting and should not be handled.

PHYLUM PLATYHELMINTHES
FLATWORMS



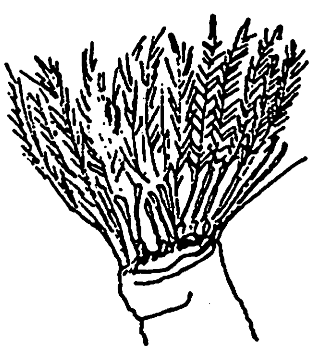
Flatworms are **bilaterally symmetrical** (having a right and left side) and very **flat.** They glide along by secreting a sheet of mucous and beating small hairs on their undersurface on this mucous sheet. Some can swim also. They are very thin so that wastes can pass from the body interior through the skin.

PHYLUM ANNELIDA
SEGMENTED WORMS



Bristle worm

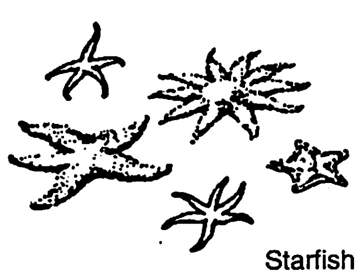
Annelid worms are bilaterally symmetrical and segmented. Some structures, like muscles and kidneys, are repeated in each segment. Marine annelids are called **polychaetes** (=many bristles) because they have spines or bristles along the sides. These may be used for protection or for holding on in a tube. Some annelids, like the **bristle worm** are free-living and are found under rocks.



Featherduster worm

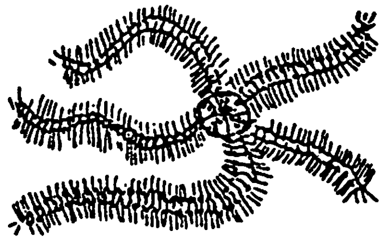
Tube worms, featherduster worms, and **spaghetti worms** are annelids which secrete a protective tube. They stay in this tube and extend tentacles or fans from the head end to catch food. When frightened, they can draw this food catching apparatus in rapidly.

PHYLUM ECHINODERMATA
STARFISH, SEA URCHINS, SEA CUCUMBERS, BRITTLE STARS



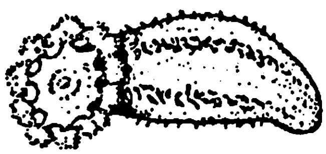
Starfish

Echinoderms are basically built on a 5 ray plan. This plan is evident in starfish and brittle stars, and can be seen on sea urchin tests (=shells). Echinoderms are the only group that has **tube feet** for locomotion and/or attachment. This group exhibits a high degree of ability to regenerate lost body parts. **Starfish** usually have 5 arms or at least 5 sides, but some, like the crown-of-thorns, have many arms. There is a row of tube feet on the undersurface of every arm. The digestive and reproductive systems extend into the arms. Starfish eat by extruding a thin, pouch-like stomach over their prey.



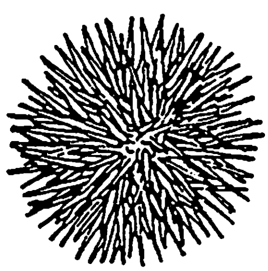
Brittle star

Brittle stars look like skinny, black starfish, but are really quite different. Their body and arms are distinctly separate and they can drop their arms at will. Their digestive and reproductive systems do not extend into the arms, the arms are lined with spines, and the tube feet do not have suction cups on the ends as they do in starfish. Brittle stars are commonly found under rocks.



Sea cucumber

Sea cucumbers have an elongate body with the mouth and anus at opposite ends. The mouth is ringed with food gathering tentacles. Sometimes a small black and white crab may be found in the mouth. Certain kinds of sea cucumbers spit out sticky white threads when disturbed. **Tube feet** are found all over the undersurface of most Hawaiian sea cucumbers, helping them to hang onto rocks. Sea cucumbers breathe by pumping water in and out of the anus. Their respiratory mechanism is inside the body near the anus.

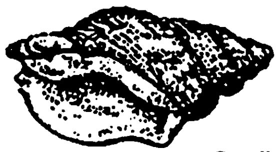


Sea urchin

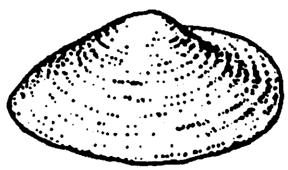
Sea urchins are usually spiny. Most are harmless unless you fall or step on them, but the ones with long, thin spines are venomous. All sea urchins are edible, the gonads being the part that is eaten. Sea urchins eat with 5 hard teeth found in the center of the underside of the body. These are part of a larger internal structure called an Aristotle's lantern. Sea urchins have rows of tube feet among their spines.

Feather star

Crinoids are the most ancient members of this group. They are also called **feather stars.** Unlike their relatives their mouth is on the top rather than underneath. Food particles are caught on the feathery arms and moved to the mouth.



Snail



Clam

Octopus

PHYLUM MOLLUSCA
SNAILS, SLUGS, CLAMS OYSTERS, SQUID, OCTOPUS, ETC.

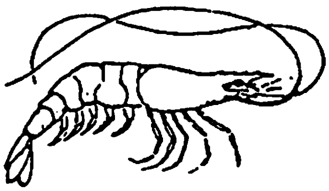
Mollusks have a soft body which is usually protected by a shell. The shell may be single or paired.

Mollusks have a mantle which secretes the shell, and which, in the cowries, can cover the shell. The foot is a muscular structure which is used for crawling or digging (as in clams). Mollusks also have eyes and **rhinophores** (chemically sensitive tentacles on the head). Cones are snails which catch their prey with a venomous dart. **Nudibranchs** and **sea hares** are also termed **sea slugs**, because they are snails with only tiny shells or none at all. They are often very colorful.

Octopus, cuttlefish, chambered nautilus and **squid** are all mollusks that feed with tentacles. The chambered nautilus is the most primitive and ancient member of this group and retains a large shell. The octopus is the most highly evolved member, having a highly developed nervous system and no shell. Both the octopus and cuttlefish are able to change color and texture rapidly.

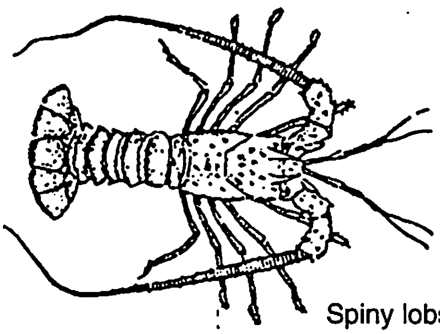
PHYLUM ARTHROPODA
BARNACLES, SHRIMP, LOBSTERS, CRABS

Arthropods have jointed legs and hard body coverings which they must molt periodically in order to grow. During molting the hard body covering is shed, exposing a new, soft one underneath. This hardens in a short time. Most marine arthropods are termed **crustacea** (not barnacles though).



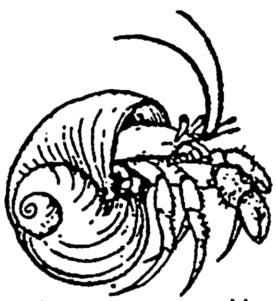
Shrimp

Shrimp have a long abdomen and 5 pairs of legs. They have 2 pair of antennae and a rostrum, or point between the eyes. Usually one, two and sometimes three pairs of legs have pincers. The mouthparts are several pairs of modified legs. Some large, edible shrimp are called **prawns.**



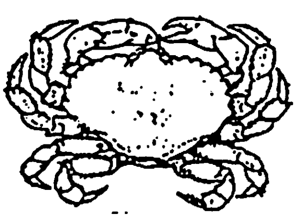
Spiny lobster

Spiny lobsters have 5 pairs of legs and no pincers. One pair of antennae is enlarged greatly, and has a spiny base; this structure is used in encounters with other animals. **Slipper lobsters** are flattened lobsters with no pincers. These are closely related to spiny lobsters. **True** or **Maine lobsters** have pincers on the first pair of legs and are not closely related to spiny lobsters.



Hermit crab

Hermit crabs have a reduced and softened abdomen which they usually cover with a mollusk shell. Some species of hermits have sea anemones that live on the shell. These probably help protect the hermit crab from predators because they have stinging cells.



Crab

Crabs have a totally reduced abdomen. All that is left of it is a flap under the body which covers the reproductive structures. Crabs exhibit many adaptations to different life styles. The last pair of legs on **swimming crabs** are paddle shaped. **Rock crabs** are flattened and have spines on the legs for hanging onto rocks in the surf zone. **Box crabs** and **Kona crabs** are adapted for burrowing in the sand. Some crabs have long eyestalks for peering out of the mud or sand in which they live. Many crabs are **semi-terrestrial** meaning they are adapted to live out of water for extended periods.

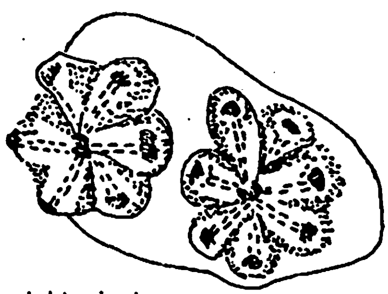
Barnacles

Adult **barnacles** don't look like other members of this group, but when they are in the larval stages, they look like small shrimp. They settle out on a hard surface and form their stony house around themselves. The 2 "doors" at the top open during high tide to allow the feathery feet to catch small animals in the plankton.

PHYLUM CHORDATA
SUBPHYLUM UROCHORDATA
TUNICATES OR SEA SQUIRTS

Sea squirt

Sea squirts and **colonial tunicates** are in the phylum Chordata (and so are you). They have Chordate characteristics during the larval stages. Some of these characteristics are gill slits and a notocord. In the adult stage, however, they look like very simple animals. A **sea squirt** is a single individual with 2 openings into the body, one for the entrance of water and food and one for exit of water and wastes. Sea squirts are **sessile** organisms, which means they are permanently attached. If you squeeze them, water will squirt out.



Colonial tunicates

Colonial tunicates are colonies of tiny, sea squirt-type animals. Often they form themselves into petal-like arrangements. This is done so they can share a common waste exit. Some of these colonies are as big and fat as a softball, others are very thin. They are often colorful.

Examples of Exotic Aquatic Animals

Name	Year Introduced	Principle Habitat	Purpose of Introduction
MOLLUSKS			
Eastern oyster *Crassostrea virginica*	1871	Estuary	
Japanese clam *Cytherea meretrix*	1926	Estuary	
Japanese oyster *Crassostrea gigas*	1926	Estuary	
Asiatic clam *Corbicula fluminea*	1977 (Kauai) 1989 (Oahu)	Freshwater	Food
CRUSTACEA			
Crayfish *Proccambarus clarkii*	1923	Freshwater	Food, bait
Samoan crab *Scylla serrata*	1926	Estuary	Food
Tahitian prawn *Macrobrachium lar*	1956	Estuary	Food, bait
AMPHIBIANS			
Bullfrog *Rana catesbeiana*		Freshwater	
Wrinkled frog *Rana rugosa*		Freshwater	
Neotropical toad *Bufo marinas*		Freshwater	
Poison arrow frog *Dedrobates auratus*	1932	Freshwater	Mosquito control
FISHES			
Mosquito fish *Gambusia affinis*	1905	Freshwater	Mosquito control
Guppy *Lebistes reticulatus*	1922	Freshwater	
Goldfish *Carassius auratus*	prior to 1900	Freshwater	Hobby, trade
Swordtail *Xiphophorus helleri*	1922	Freshwater	Hobby, trade
Tilapia (Four *Tilapia* app.)	1951-1957	Freshwater	Algae control, food
Bluegill *Lepomis macrochirus*	1946	Freshwater	Sportfishing, bait
Dojo *Misgurnus anguillicaudatus*	prior to 1900	Freshwater	Bait
Largemouth bass *Micropterus salmoides*	1896	Freshwater	Sportfishing
Smallmouth bass *Micropterus dolomieui*	1953	Freshwater	Sportfishing

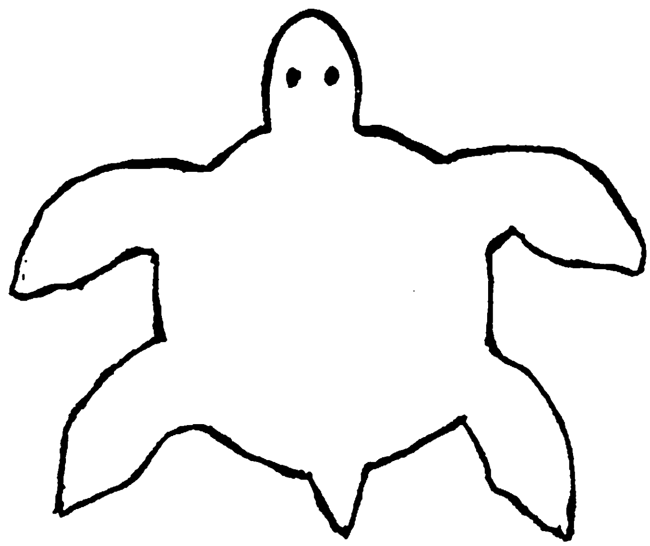
Examples of Exotic Aquatic Animals (cont.)

Name	Year Introduced	Principle Habitat	Purpose of Introduction
FISHES (cont.)			
Rainbow trout *Onchorhynchus mykiss*	1920	Freshwater	Sportfishing
Chinese catfish *Clarias fuscus*	prior to 1900	Freshwater	Food
Channel catfish *Ictalurus punctatus*	1953	Freshwater	Sportfishing
Armored catfish *Hypostomus spp.*		Freshwater	Hobby, trade
Convict cichlid *Cichlasoma nigrofasciatum*		Freshwater	Hobby, trade
Silver-sided needlefish *Xenentodon cancila*		Freshwater	Hobby, trade
Grouper (roi) *Cephalopholis argus*	1956	Marine	Sportfishing, food
Blacktailed snapper (toau) *Lutjanus fulvus*	1956	Marine	Sportfishing, food
Bluelined snapper (taape) *Lutjanus kasmira*	1955	Marine	Sportfishing, food
Marquesan sardine *Sardinella marquesensis*	1955	Estuary-marine	Bait

Examples of Exotic Aquatic Plants

Name	Habitat	Effects
Cattail *Typha augustata*	Marshy, shallow brackish water	Overcrowding
Pondweed *Potamogeton nodosus*	Pools, taro ponds, streams	Overcrowding
Sea wrack *Halophila hawaiiana*	Reefs, salt water, aquaria	Used to oxygenate aquaria
Water weed (ditch moss) *Elodea densa*	Ponds, streams	Pest; chokes ecosystem
Papyrus, kaluha *Cyperus papyrus*	Banks, shores of quietly flowing water	Cultivated as ornament in flower gardens, floral arrangements
Taro (kalo) *Colocasia esculenta*	Streams, marshy land, artificial terraces (loi)	Cultivated for consumption (poi)
Water lettuce *Pistia stratiotes*	Freshwater pools, aquaria	Ornamental; escaped and covers streams and ponds on Oahu
Lesser duckweed *Lemna minor*	Floating on pools and ditches	Cuts off light to bottom
Greater duckweed *Lemna polyrrhiza*	Floating on pools and ditches	Cuts off light to bottom
Water hyacinth *Eichhornia crassipes*	Ditches, slow moving streams, ponds, reservoirs	Ornamental; overruns ponds and chokes streams if not controlled
Lotus *Nelumbo nucifera*	Cultivated in pools	Ornamental
American or red mangrove *Rhizophora mangle*	Near mouths of streams	Stabilizes banks; provides habitat for fish
Oriental mangrove *Bruguiera conjugata*	Near mouths of streams	Stabilizes banks; provides habitat for fish; may overcrowd
Ogo *Gracilaria parvispora*	Reef flats	Food source
Acanthophora spicifera (no common name)	Reef flats	Not utilized; displaces other algal species

Making an Egg Carton Turtle



1. **The Base**

   Consists of head, flippers and tail.

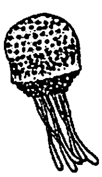
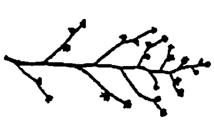
   a) Use the pattern above to make the base, using construction paper, felt, cardboard or other firm material.
   b) Put eyes on the head.
   c) Color is optional (green or brown is most realistic). Colors may be used alone or in combination.
   d) To color, may use water based colors, felt pens, crayons, ink, etc.

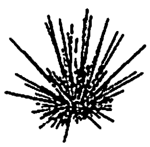
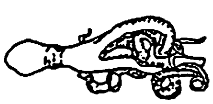
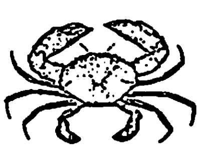
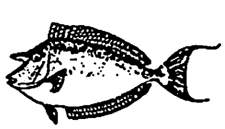
2. **The Shell**

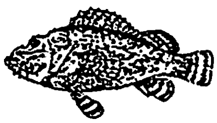
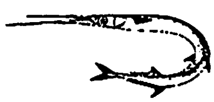
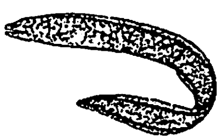
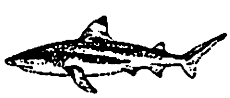
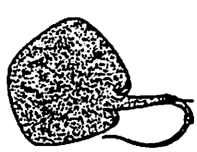
   Made from the bottom of an individual egg cup from a cardboard egg carton.
   a) Cut the cup off at desired height.
   b) Color the "shell" if desired.

3. **Construction**

   a) Put glue around cut edge of egg cup.
   b) Place on base.
   c) Fasten a chopstick under the base at the tail of the turtle to allow child to use as puppet.

ORGANISM	CAUSE OF INJURY	SYMPTOMS/ INJURY	TREATMENT	PREVENTION
Coral 	Sharp edges, stinging cells	Abrasions, irritation, torn skin, bleeding; possible infection (coral will <u>not</u> grow inside a cut)	Soak irritated areas in dilute vinegar solution; clean cuts with rubbing alcohol, hydrogen peroxide, or soap and water, apply antiseptic; if cut is deep see a physician	Wear tabis or sneakers when reef walking; wear gloves when handling coral; avoid shallow rough waters
Portuguese Man-O-War 	Stinging cells in tentacles	Stinging, burning sensations; severe reactions include irregular breathing and heartbeat	Remove tentacles from skin; apply full strength vinegar, or paste of vinegar and meat tenderizer (don't use meat tenderizer if victim is allergic to papaya); if reaction is severe get emergency help immediately	Avoid water where sighted (usually blown in from open ocean); avoid walking near washed up Man-O-War on beach
Jellyfish 	Stinging cells in tentacles	Same as Portuguese Man-O-War	Same as Portuguese Man-O-War	Avoid areas where sighted; avoid handling jellyfish
Sea anemone 	Stinging cells in tentacles	Itching and burning, prickly sensation to severe pain; severe reactions may include shortness of breath; not all species will produce a noticeable reaction	Same as Portuguese Man-O-War	Wear tabis and gloves; avoid contact with skin; don't put hands or fingers into holes or crevices
Hydroids 	Stinging cells	Itching, burning, rash that may last up to several days; severe allergic reaction in some people	Same as Portuguese Man-O-War	Avoid brushing against or grabbing underside of floats, pilings, boat bottoms, submerged lines and other areas to which hydroids may be attached
Sponges 	Spicules - supporting structures within sponge which can lodge under skin if handled; fire sponge produces irritating chemical	Burning or itching; fire sponge may cause small blisters	Same as coral	Wear gloves; avoid handling sponges

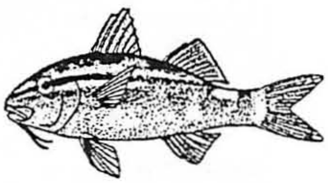
ORGANISM	CAUSE OF INJURY	SYMPTOMS/ INJURY	TREATMENT	PREVENTION
Fireworm 	Sharp bristles which contain toxin	Burning, itching, stinging, swelling, inflammation	Vinegar, or treatment for coral; bristles may sometimes be removed with adhesive tape	Wear gloves; use care turning over rocks
Sea urchin 	Long brittle spines, some of which are venomous on certain species	Throbbing pain, puncture wounds; possible infection	Soak in hot water until pain goes away, apply undiluted vinegar; see a physician for removal of long embedded spines	Wear tabis with thick soles; don't put hands into crevices; avoid handling sea urchins
Cone shell 	Venomous dart-like structure at narrow end of shell, used to paralyze prey	Mild to severe pain, burning, numbness, vomiting; stings by the most toxic species may cause paralysis, respiratory failure, cardiac arrest	Soak in hot water, see a physician; bring shell along for identification if it can be done safely	Avoid handling cone shells; if collecting live shells hold only at broad end
Octopus ("squid") 	Beak in mouth at base of tentacles; salivary glands contain toxin	Skin wound, bleeding, stinging pain	Same as coral; see a physician	Use care when handling octopus
Crabs 	Pinchers	Shallow to deep wounds, depending on size of crab; possible infection; large crabs can amputate fingers	Wash with soap and water, apply antibiotic; if wound is serious apply pressure to stop bleeding and see a physician	Use care when handling crabs
Surgeonfish 	Spines at base of tail	Bleeding, stinging or throbbing pain; possible infection	Soak in hot water, wash with soap and water, apply antibiotic; see physician if spines are embedded in skin	Use care when handling surgeonfish

ORGANISM	CAUSE OF INJURY	SYMPTOMS/ INJURY	TREATMENT	PREVENTION
Scorpionfish 	Venomous spines in dorsal fin	Extreme throbbing pain which may last for hours; in rare severe cases convulsions or cardiac arrest may result	Soak in hot water, get medical attention immediately	Wear protective footwear on reef; be careful where you put hands and feet; avoid handling live scorpionfish; use care handling dead scorpionfish
Barracuda 	Sharp teeth	Torn skin, bleeding; severe bleeding may lead to shock	Apply pressure and elevate wound to control bleeding; lay victim down if in shock, keep warm, elevate legs if possible; see a physician	Use caution when swimming and barracuda is seen, avoid splashing, don't wear reflective jewelry; avoid handling caught barracuda near mouth
Needlefish 	Long pointed jaw	Deep puncture wounds, bleeding; part of jaw may break off; possible infection	Clean wound with antiseptic solution; do not attempt to remove embedded parts of jaw; get medical attention immediately	Use caution when night diving or torch fishing since needlefish are attracted to lights
Moray eel 	Sharp teeth	Torn skin, bleeding, injury to muscle, tendon, ligament, nerve tissue; possible infection	Clean wound with soap and water and apply antiseptic; if wound is serious apply pressure and elevate wound to control bleeding; see a physician	Don't put hands or fingers into crevices on reef; don't provoke moray eels
Shark 	Sharp teeth and scales	Scales can cause abrasions; bites cause severe bleeding and may result in shock; injuries from bites may be mutilating, with amputation or death in the most severe cases	Control bleeding by applying direct pressure and elevating wound; treat for shock by laying victim down and keeping warm; obtain emergency medical help immediately	Avoid swimming in murky water; return to shore if shark is sighted; divers should avoid towing speared fish for long distances
Stingray 	Venomous barb on tail	Puncture wound or deep laceration, severe pain; injuries in abdomen, chest, head or neck especially serious	Soak in hot water; if barb is embedded in skin do not touch or attempt to remove; get medical attention	Shuffle feet when walking in shallow sandy areas

Information based on University of Hawaii Sea Grant Advisory Report UNIHI-SEAGRANT-AR-78-01, July 1978, University of Hawaii Sea Grant College Program; the author and publisher specifically disclaim any liability, loss, or risk incurred as a result of the use and application, either directly or indirectly, of any advice and information presented here. Illustrations: National Oceanic and Atmospheric Administration, Division of Aquatic Resources, Waikiki Aquarium, University of Hawaii Sea Grant College Program.

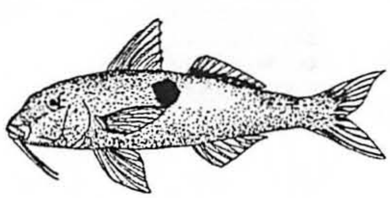
GOATFISH

Goatfish are bottom-feeding carnivores, easily recognized by the pair of barbels under their jaws which are used to locate food. Tucked under the sides of the jaw when not in use, the barbels may not be immediately apparent. Goatfish are common in inshore waters, and are among the most popular food fish in Hawaii.



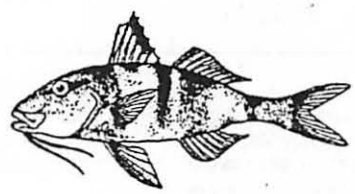
Kumu
Parupeneus porphyreus
Whitesaddle goatfish

Description: Juveniles greenish with red fins, body coloration becomes brick red with age; white saddle behind soft dorsal fin; dark stripe running through eye from near snout to below first dorsal fin, darker spot between eye and upper edge of gill cover.
Size: Length up to 20 inches; weight generally up to 5 pounds
Habitat: Various depths throughout reef areas, especially under coral heads
Feeding: Nocturnal; mostly crustaceans
Schooling: Small groups by day, solitary at night
Fishing methods: Spear, trap, net, handline, pole and line
Seasonality: Young kumu common on inshore reefs throughout spring and summer; adults common year round
Kumu are extremely prized fish in Hawaii; the flesh is considered a delicacy.



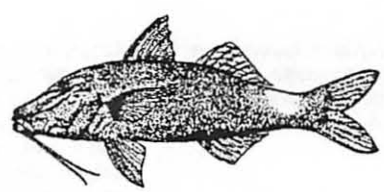
Malu
Parupeneus pleurostigma
Spotted goatfish

Description: Body light, whitish to pink; black spot on side below rear of first dorsal fin, followed by large oval white area.
Size: Length up to 16 inches; weight generally up to 2 pounds
Habitat: Sandy patches adjacent to coral, from nearshore to depths of about 120 feet
Feeding: Diurnal; small worms, crustaceans
Schooling: Adults solitary; juveniles small groups
Fishing methods: Handline, spear, trap, net



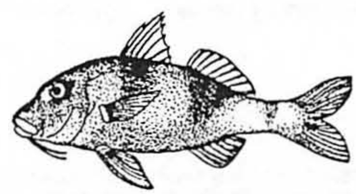
Moano
Parupeneus multifasciatus
Moana, manybar goatfish

Description: Reddish with shades of yellow and white; black marks behind eye, at base of pectoral fin, and black saddle areas in front of first dorsal fin, between dorsal fins, below soft dorsal fin, and in front of tail; deepness of color varies with light intensity, becoming lighter in bright light.
Size: Length up to 14 inches; weight generally up to 1 pound
Habitat: Rocky areas, sandy bottoms near coral heads
Feeding: Diurnal; crustaceans, small fish
Schooling: Solitary or small groups
Fishing methods: Handline, trap, spear, pole and line
Endemic to Hawaii



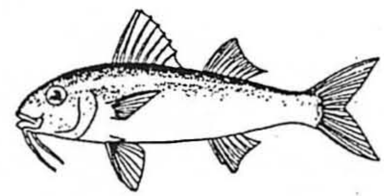
Moano kea
Parupeneus cyclostomus
Moana kali, blue kumu, blue goatfish

Description: Bluish-purple, with prominent yellow saddle at base of tail; slender body, long snout and long barbels.
Size: Length up to 2 feet; weight generally up to 5 pounds
Habitat: Rocky or reef areas, from nearshore to depth of about 200 feet
Feeding: Diurnal; small fish, crustaceans
Schooling: Adults small groups; juveniles solitary
Fishing methods: Handline, spear, trap, net, pole and line



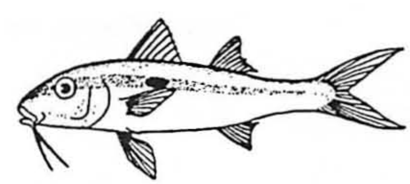
Munu
Parupeneus bifasciatus
Joe Louis, doublebar goatfish

Description: Reddish to yellowish-gray; black triangular saddle under each dorsal fin and near tail.
Size: Length up to 16 inches; weight generally up to 3 pounds
Habitat: Rocky areas, especially lava rocks, from nearshore to about 150 feet
Feeding: Diurnal and nocturnal; small fish, crustaceans
Schooling: Solitary or small groups
Fishing methods: Handline, spear, trap, net, pole and line



Red weke, 'Oama
Mulloides vanicolensis
Weke 'ula, yellowfin goatfish

Description: Light pink with yellow hues; long yellow band extending from eye to base of tail; fish becomes reddish when dead; inner lining of abdomen is black.
Size: Length up to 16 inches; weight generally up to 2 pounds
Habitat: Reef areas, generally in depths from 20-200 feet
Feeding: Nocturnal; small worms and crustaceans
Schooling: Large schools during the day; solitary or small groups at night when feeding
Fishing methods: Mostly net and trap
Seasonality: Juveniles, known as 'oama, common offshore in late summer; adults common year round



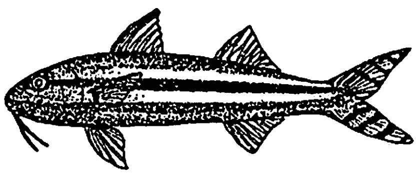
White weke, 'Oama
Mulloides flavolineatus
Weke a'a, sand weke, yellowstripe goatfish

Description: Silvery white; yellow band extends from eye to tail when schooling; band becomes less distinct when feeding, and a black spot appears below first dorsal fin; very slender body compared with most other goatfish.
Size: Length up to 18 inches; weight generally up to 2 pounds
Habitat: Sandy bottom areas near patches of coral; shallow water (to about 100 feet)
Feeding: Nocturnal and diurnal; crustaceans, worms
Schooling: Schools by day

Fishing methods: 'Oama (juveniles) taken by pole and line; adults by net, trap, pole and line, spear

Seasonality: 'Oama commonly found in shallow sandy areas during late summer; adult weke common year round

'Oama make excellent bait for papio and other predators, and are highly sought after by shoreline fishermen.



Weke pueo

Upeneus spp.

Nightmare weke, obake weke, bandtail goatfish

Description: Light greenish above, fading to white below; black and white horizontal stripes on tail.

Size: Length up to 12 inches

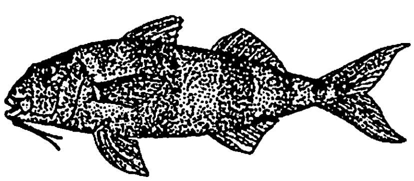
Habitat: Shallow sandy or muddy bottoms

Feeding: Diurnal; crustaceans and small fish

Schooling: Small groups

Fishing methods: Pole and line, net, spear

Weke pueo should be prepared and eaten with care, since the head may cause hallucinations and other symptoms of poisoning if consumed.



Weke 'ula

Mulloides pflugeri

Moelua, red weke, aka weke, Pfluger's goatfish

Description: Red with vertical orange-yellow bands when alive; color changes to uniform red when dead; inner lining of abdominal cavity white; fairly robust compared with most other goatfish.

Size: Length up to 24 inches; weight generally up to 8 pounds

Habitat: Sand patches and limestone bottoms, usually 60-300 feet

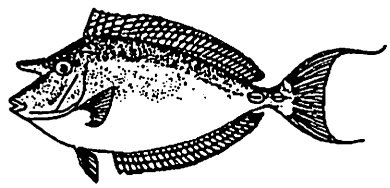
Feeding: Diurnal; small fish and crustaceans

Schooling: Small groups or large schools

Fishing methods: Handline, trap, spear

SURGEONFISH

Surgeonfish (tangs) have blade-like spines on either side of the base of the tail, which are sometimes used defensively by the fish. (Fishermen have suffered cuts on their account, so surgeonfish should always be handled with care.) Surgeonfish are very common in inshore waters, feeding primarily by day, and at night resting on the bottom in a sleep-like state. Because they are mostly plant eaters, having small mouths and specialized teeth, most surgeonfish are difficult to catch with hook and line.



Kala

Naso unicornis

Unicornfish

Description: Dusky olive, with light blue on the fins and around the caudal spines; horn protruding from front of head about eye level (lengthens with age). A similar species, *Naso brevirostris*, is grayish green with numerous small spots or dark lines on the sides, and a body that is less deep. Kala have two fixed caudal spines on each side.

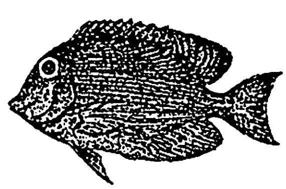
Size: Length up to 2 feet; weight generally up to 8 pounds

Habitat: Inshore reef areas and along rocky shores

Feeding: Diurnal; algae, especially more leafy varieties

Schooling: Schools; large adults sometimes found singly at edge of reef

Fishing methods: Net, spear, pole and line



Kole

Ctenochaetus strigosus

Yelloweyed surgeonfish

Description: Dark brown with about 35 light blue horizontal lines extending into the fins, small blue spots on the head, bright yellow ring around the eye; single retractable caudal spine on each side.

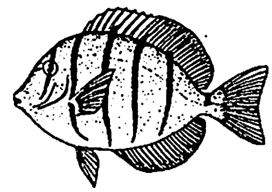
Size: Length up to 7 inches; weight generally up to ½ pound

Habitat: Inshore reef areas, and depths of 150 feet or more

Feeding: Diurnal, small bits of algae and decaying plant material

Schooling: Solitary

Fishing methods: Spear



Manini

Acanthurus triostegus

Convict tang

Description: Silvery, may have yellowish tinge; six black vertical bars, the first passing through the eye and the last near the base of the tail; single small retractable caudal spine on each side.

Size: Length up to 12 inches; weight generally up to ¾ pound

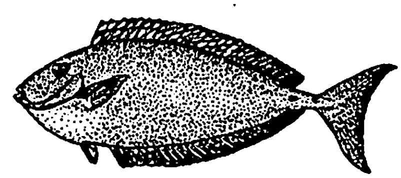
Habitat: Most reef areas, from shore to depths of about 90 feet

Feeding: Diurnal; mostly fine algae

Schooling: Large schools, but also seen singly or in small schools

Fishing methods: Net, spear

Manini are the most abundant surgeonfish in Hawaii.



'Opelu kala

Naso hexacanthus

Sleek unicornfish

Description: Color varies from dark brown to pale blue, with a dark blue tail fin; two fixed caudal spines on each side.

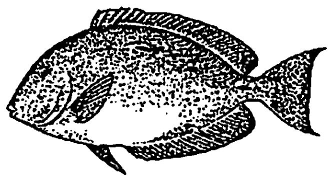
Size: Length up to 2 feet; weight generally up to 3 pounds

Habitat: Deeper waters outside reef; not common in waters less than 30 to 50 feet

Feeding: Diurnal; plankton, including crab larvae and small worms

Schooling: Large schools

Fishing methods: Spear, net, pole and line



Palani
Acanthurus dussumieri
Eyestripe surgeonfish

Description: Yellowish brown with black spots, bright blue tail fin, fine blue lines on body fading towards belly, yellow dorsal and anal fins, yellow band between and behind the eyes; single white retractable caudal spine on each side, surrounded by a patch of black.

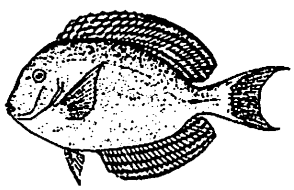
Size: Length up to 18 inches or more; weight generally up to 3 pounds

Habitat: Mostly bays and outer reef areas over sandy patches, usually at depths of at least 10 feet

Feeding: Diurnal; algae and decaying plant material

Schooling: Schools

Fishing methods: Spear, trap



Pualu
Acanthurus spp.
Ringtailed surgeonfish, yellowfinned surgeonfish

Description: Purplish gray, sometimes with irregular dark stripes along the sides, dorsal and anal fins have horizontal blue bands, yellow spot between eye and top of gill cover; single black retractable caudal spine on each side.

Size: Length up to 20 inches or more; weight generally up to 5 pounds

Habitat: Bays and harbors; also deep outer reefs with sandy patches, usually at depths of 30 feet or more

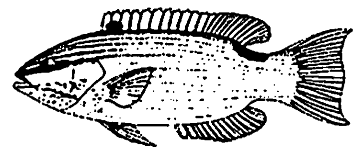
Feeding: Diurnal; mostly algae, but often hooked with animal material as bait

Schooling: Schools

Fishing methods: Spear, net, handline

WRASSES

Wrasses make up the largest family of fishes in Hawaii. Nearly 50 species are known to exist here, but only a few are popular with fishermen. Males and females of the same species frequently have different colorations, and wrasses are known to undergo sex conversions from female to male. Coloration changes as the fish gets older.



'A'awa
Bodianus bilunulatus
Table boss, blackspot wrasse

Description: Juveniles (up to 4 inches) whitish with reddish brown horizontal lines and large black spot between soft dorsal and anal fins; as fish grows older spot disappears and black saddle forms at rear of dorsal fin; females white with brown horizontal lines in front, shading to yellow near tail; males wine-colored or purplish brown, and black saddle is faint or absent.

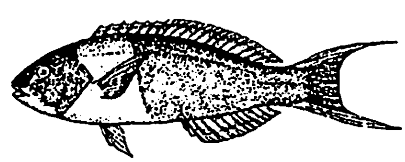
Size: Length up to 2 feet; weight generally up to 4 pounds

Habitat: Common throughout reef area, taken on bottom in shallow water out to depths of about 100 feet or more

Feeding: Diurnal; small fish, crustaceans, molluscs, sea urchins

Schooling: Solitary

Fishing methods: Handline, spear, pole and line



Hinalea
Thalassoma duperrey
Hinalea lauwili, saddle wrasse

Description: Green with vertical purple-red bars, purplish blue head and wide orange saddle surrounding body just behind head; saddle not apparent on juveniles.

Size: Length up to 1 foot; weight generally up to ½ pound

Habitat: Very abundant along shallow rocky shorelines and reef areas

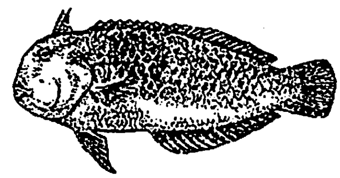
Feeding: Diurnal; seaweed, crustaceans

Schooling: Solitary or small aggregate

Fishing methods: Pole and line, handline

Generally an incidental catch; food value considered poor, often used as bait.

Endemic to Hawaii



Laenihi
Xyrichtys pavo
Nabeta, razor wrasse

Description: Blue-green or grayish body with faint vertical crossbands, one dark scale on either side below front of dorsal fin, yellow stripe on anal fin.

Size: Length up to 15 inches; weight generally up to 2 pounds

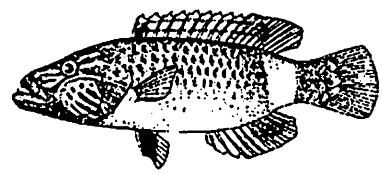
Habitat: Sandy areas at depths of 60 to 300 feet, generally within a few hundred yards of the shoreline

Feeding: Diurnal; crustaceans

Schooling: Solitary

Fishing methods: Handline

Considered an excellent food fish.



Po'ou
Cheilinus unifasciatus
Rosecolored wrasse

Description: Color varies with age; at 10 inches the fish is plain olive green with white saddle near tail; fish 20 inches and over have no white saddle, but show black spots at base of dorsal and anal fins, and have dark pelvic fins.

Size: Length up to 2 feet; weight generally up to 2 pounds

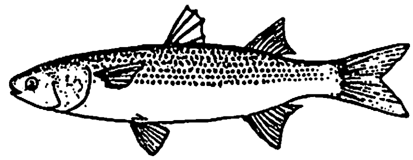
Habitat: Reef and rocky areas at depths of up to 40 or 50 feet

Feeding: Diurnal; fish and crustaceans

Schooling: Solitary

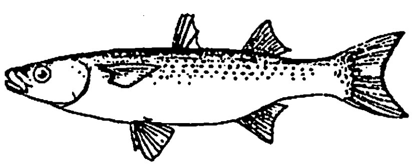
Fishing methods: Handline, spear

MULLET



'Ama'ama, Pua
Mugil cephalus
Striped mullet

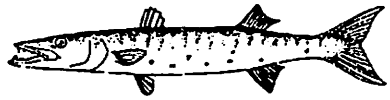
Description: Body silver with grayish-green above changing to white below, reddish tinge around mouth and gills. A similar species, *Chelon engeli* (summer or Australian mullet), is smaller than the amaama, growing to a length of about 8 inches, and has slightly larger scales.
Size: Length up to 2 feet; weight generally up to 5 pounds
Habitat: Calm waters close to shore, around mouths of streams and inlets, and brackish bays and harbors
Feeding: Diurnal; algae and small plants, especially along bottom.
Schooling: Schools
Fishing methods: Generally taken with nets; difficult to catch with pole and line, but will take a hook baited with thin seaweed or bread
Seasonality: Spawns December through February



Uouoa
Chaenomugil leuciscus
False mullet

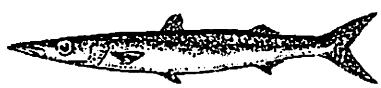
Description: Grayish back, changing to silver on the sides, white belly; yellow spot present at base of pectoral fins; snout more pointed than amaama.
Size: Length up to 16 inches; weight generally up to 1½ pounds
Habitat: Sandy shores, tide pools, rocky surge areas
Feeding: Diurnal; seaweed, some crustaceans
Schooling: Schools
Fishing methods: Net
Seasonality: More common November through March

BARRACUDA



Kaku
Sphyraena barracuda
Great barracuda

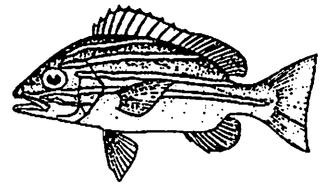
Description: Greyish back turning silvery on sides and belly, with irregular black flecks on sides.
Size: Length up to 6 feet; weight generally up to 70 pounds
Habitat: Various, inshore and offshore; juveniles prefer brackish water areas, bays and stream mouths
Feeding: Diurnal and nocturnal; fish and squid
Schooling: Generally solitary
Fishing methods: Generally caught casting from shore, trolling lures and baits, and handlining from boats. Prominent sharp teeth make a wire leader essential, and the fish should be regarded with caution.



Kawalea
Sphyraena helleri
Heller's barracuda

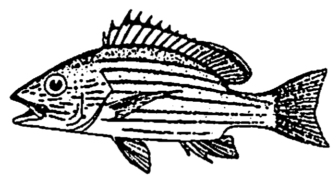
Description: Silvery olive above, becoming silvery on sides and belly; sides marked with two horizontal yellowish stripes which disappear after death. Smaller than kaku, with more slender head and larger eyes.
Size: Length up to 2 feet; weight generally up to 4 pounds
Habitat: Inshore to depths of 50 to 200 feet
Feeding: Nocturnal; small fish
Schooling: Large schools
Fishing methods: Mostly handline

NEARSHORE SNAPPERS



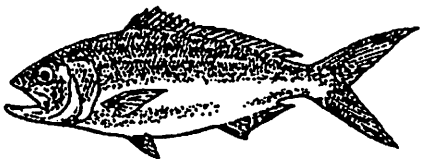
Ta'ape
Lutjanus kasmira
Bluelined snapper

Description: Bright lemon yellow with four pale-blue horizontal stripes edged with lavender or deep purple.
Size: Length up to 15 inches; weight generally up to 1½ pounds
Habitat: Hard bottom areas, generally in waters 40 to over 300 feet deep
Feeding: Primarily nocturnal; shrimp and other crustaceans, squid, and small fish
Schooling: Schools
Fishing methods: Generally taken at night with handlines; some taken in traps or nets; occasionally by pole and line near shore and by spear
Introduced 1958 and 1961 from Marquesas Islands and Society Islands



To'au
Lutjanus fulvus
Blacktailed snapper

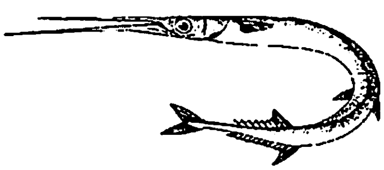
Description: Dusky yellow above fading to pale yellow or white below, six or more thin horizontal yellow stripes along side; dorsal fin reddish, tail fin blackish with reddish tinge and white margin; other fins yellow.
Size: Length up to 13 inches; weight generally up to 3 pounds
Habitat: Inshore, brackish water and around stream mouths out to waters about 40 or 50 feet in depth
Feeding: Nocturnal; crustaceans, especially crabs, and small fish
Schooling: Solitary or small school
Fishing methods: Handline, pole and line, trap, spear
Introduced 1956 and 1958 from Society Islands



Wahanui
Aphareus furca
Gurutsu, forktailed snapper

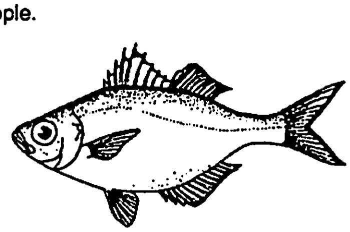
Description: Uniform steel blue or purplish, with yellow border on anal fin.
Size: Length up to 2 feet; weight generally up to 2 pounds
Habitat: Open water, generally just outside or above reef
Feeding: Diurnal; small fish and crustaceans
Schooling: Solitary or small school
Fishing methods: Pole and line, handline, spear

OTHER REEF FISHES



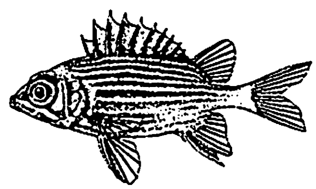
'Aha
Belonidae
Needlefish

Description: Blue green on back, fading to silvery below; jaws long and pointed, with sharp teeth.
Size: Length depends on species, 15 inches to more than 4 feet; weight generally up to 5 pounds
Habitat: Near surface in waters of various depths from nearshore to open ocean
Feeding: Diurnal and nocturnal; small fish near the surface, floating crabs
Schooling: Schools
Fishing methods: Pole and line
Aha can be dangerous at night, especially when torch fishing; the fish are attracted to lights, and have been known to spear people.



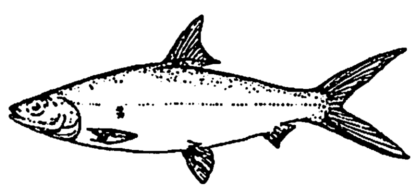
Aholehole
Kuhlia sandvicensis
Hawaiian flagtail

Description: Silvery, with blue tones on back, fins often dusky tipped.
Size: Length up to 12 inches; weight generally up to 1 pound
Habitat: Inshore areas, including streams, bays and along shoreline; generally found at depths less than 20 feet; juveniles live in tide pools or schools close to shore
Feeding: Mostly nocturnal; primarily crustaceans
Schooling: Schools
Fishing methods: Pole and line, cast nets, spear
Seasonality: More taken during fall and winter
Endemic to Hawaii



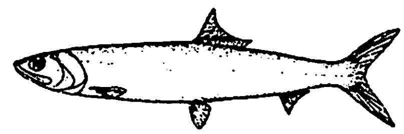
'Ala'ihi
Sargocentron spp.
Squirrelfish

Description: Bright red, fading to lighter below in some species; sides marked with six or more light horizontal lines; most species take on prominent nocturnal coloration, generally white spots or vertical bands.
Size: Length up to 12 inches or more, depending on species; weight up to 5 pounds for largest species
Habitat: Inshore reef areas, congregating in crevices and caves by day and foraging over the reef at night
Feeding: Nocturnal; crustaceans
Schooling: Solitary or grouped, depending on species
Fishing methods: Spear, handline, pole and line, trap



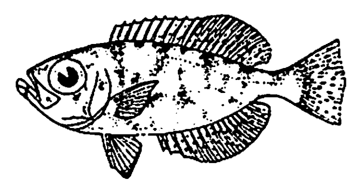
Awa
Chanos chanos
Milkfish

Description: Grayish green above, fading to silvery below.
Size: Length up to 3 feet or more; most caught are around 18 to 24 inches; weight generally up to 40 pounds
Habitat: Near surface in inshore areas, including brackish-water areas, bays and inlets
Feeding: Diurnal; algae
Schooling: Schools
Fishing methods: Pole and line, net
Seasonality: Generally more taken in summer months



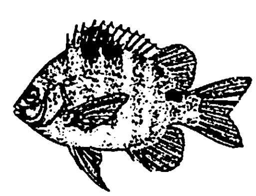
Awa'awa
Elops hawaiensis
Ladyfish

Description: Bright silvery, with blue-green hue on the dorsal area.
Size: Length up to 3 feet or more; weight generally up to 12 pounds
Habitat: Inshore areas, including bays and harbors, and along sandy shorelines
Feeding: Diurnal and nocturnal; small fish and crustaceans
Schooling: Singly or in small schools
Fishing methods: Pole and line, net



'Aweoweo
Priacanthus spp.
Red bigeye, glasseye

Description: Variable coloration, from deep red to silvery, or mottled silvery pink and red; fins often speckled with black; some species plain red by day.
Size: Length depends on species, up to 20 inches; weight generally up to 3 pounds
Habitat: Shallow reefs out to deep boulder areas
Feeding: Nocturnal; small fish and invertebrates
Schooling: Solitary or schools
Fishing methods: Pole and line, handline, spear, net



Kupipi
Abudefduf sordidus
Gray damselfish

Description: Grayish brown above fading to silvery below; sides marked with seven dark vertical bands; dark spot on upper side of caudal peduncle and at base of dorsal fin.

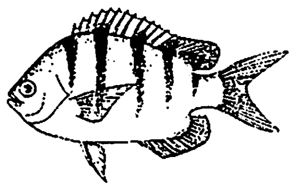
Size: Length up to 9 inches; weight generally up to 1 pound

Habitat: Inshore reef and boulder areas; shallow rock crevices; juveniles common in tide pools

Feeding: Diurnal; algae, small crustaceans and other invertebrates

Schooling: Solitary or small schools

Fishing methods: Pole and line, spear



Mamo
Abudefduf abdominalis
Sergeant major

Description: Pale brassy or green with four or five black vertical bars; belly white with yellow tinge near anal fin.

Size: Length up to 9 inches; weight generally up to ¾ pound

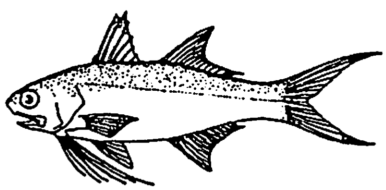
Habitat: Shallow water reefs, harbors and bays, from nearshore to edge of reef

Feeding: Diurnal; small crustaceans, plankton

Schooling: Loose aggregates

Fishing methods: Pole and line, spear

Endemic to Hawaii



Moi
Polydactylus sexfilis
Threadfin

Description: Dusky above, silvery on sides and belly, with numerous narrow wavy horizontal lines along sides; fins black-tipped; characterized by presence of six long filaments extending from base of each pectoral fin, and overhanging snout.

Size: Length up to 24 inches; weight generally up to 6 pounds

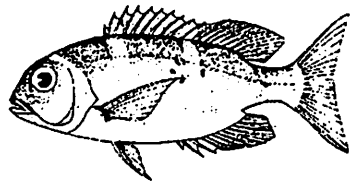
Habitat: Generally found in sandy holes along rocky shorelines, or along sandy beaches in surge areas

Feeding: Diurnal and nocturnal; primarily crustaceans

Schooling: Schools

Fishing methods: Pole and line, net

Seasonality: Spawn during summer months; from about May through August small moi (or "moi-lii") occur in schools along beaches and in sheltered coves



Mu
Monotaxis grandoculis
Grandeyed porgy

Description: Olive gray above fading to silvery below; sides marked with four light vertical bands which fade as fish gets older; inside of mouth red.

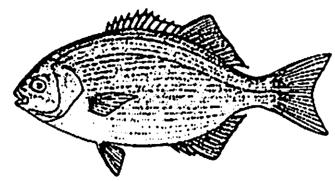
Size: Length up to 30 inches; weight generally up to 5 pounds

Habitat: Various reef areas, generally moving into shallower waters during evening

Feeding: Nocturnal; small mollusks and crustaceans

Schooling: Solitary or loose aggregates

Fishing methods: Pole and line, spear



Nenue
Kyphosus spp.
Enenue, rudderfish, sea chub

Description: Gray brown with blue reflections above, fading to lighter below; narrow dark bands on sides between scale rows; some fish have irregular yellow blotches on sides, and on rare occasions a fish may be entirely yellow.

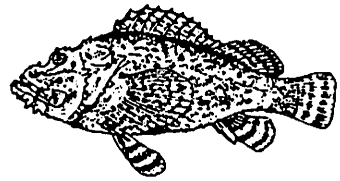
Size: Length up to 24 inches; weight generally up to 6 pounds

Habitat: Rough and turbulent waters along rocky coasts

Feeding: Diurnal; mostly algae

Schooling: Schools

Fishing methods: Spear, net, pole and line



Nohu
Scorpaenopsis cacopsis
Scorpionfish

Description: Mottled camouflage coloration, reddish brown with irregular white and yellow hues, fading to lighter below; spines venomous.

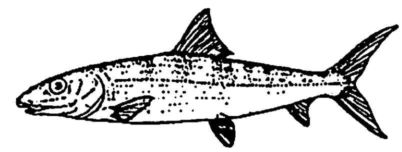
Size: Length up to 20 inches or more; weight generally up to 5 pounds

Habitat: Outer edges of reef in water over 20 feet deep

Feeding: Diurnal; small fish and invertebrates

Schooling: Solitary, sedentary

Fishing methods: Spear, pole and line



'O'io
Albula spp.
Bonefish

Description: Bright iridescent silver, with greenish tinge on dorsal area; elongate upper jaw.

Size: Length generally up to about 18 inches; may reach over 40 inches; weight generally up to 16 pounds

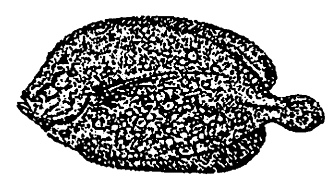
Habitat: Sandy bottoms, usually over sand patches or channels in reef areas

Feeding: Generally nocturnal; crustaceans, small fish

Schooling: Schools

Fishing methods: Pole and line, net, handline

Seasonality: More taken December through April



Paki'i
Bothus spp.
Flounder

Description: Brownish coloration with irregular mottling, lower surface white or tan; coloration changes to match substrate.

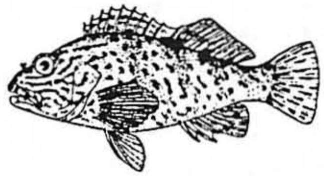
Size: Length up to 16 inches; weight generally up to 4 pounds

Habitat: Sandy patches in shallow water

Feeding: Diurnal; crustaceans and small fish

Schooling: Solitary

Fishing methods: Pole and line, spear



Po'opa'a
Cirrhitus pinnulatus
Spotted hawkfish

Description: Brownish above fading to lighter below, with white mottlings; body and fins have red spots; head bluish white with brownish orange markings.

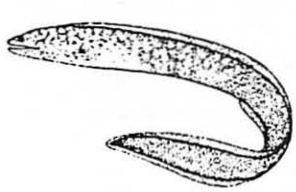
Size: Length up to 10 inches; weight generally up to 1½ pounds

Habitat: Hides in crevices during the day; at night found in turbulent waters of surge zones, often on large rocks or coral heads

Feeding: Diurnal and nocturnal; small fish and crustaceans

Schooling: Solitary

Fishing methods: Pole and line, spear



Puhi
Gymnothorax spp.
Moray eel

Description: Coloration varies with species; generally brown (darker toward posterior) with numerous round or irregular light spots, depending on species; large fanglike teeth.

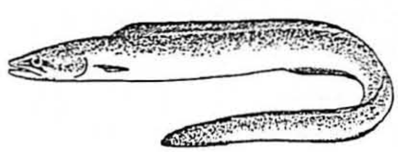
Size: Length up to 5 or 6 feet; most under 2 feet; weight occasionally reaches 70 pounds

Habitat: Crevices and holes in rocky or reef areas; rarely exposed, except for head

Feeding: Diurnal and nocturnal; fish and crustaceans

Schooling: Solitary

Fishing methods: Spear, pole and line, trap



Puhi uha
Conger cinereus
Tohe, white eel, conger eel

Description: Grayish brown on dorsal surface, fading to lighter below, alternating light and dark bars on body when feeding; well-developed pectoral fins are present.

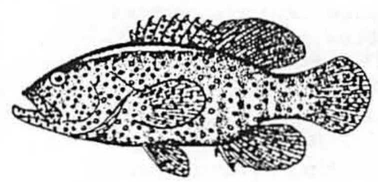
Size: Length up to 5 feet; weight generally up to 25 pounds

Habitat: Crevices and holes in nearshore reef areas by day; moves in open on reef after dark

Feeding: Nocturnal; fish and crustaceans

Schooling: Solitary

Fishing methods: Spear, pole and line, trap



Roi
Cephalopholis argus
Bluespotted grouper

Description: Purple brown with light blue spots; pale vertical bars present towards tail region, fins edged with yellow.

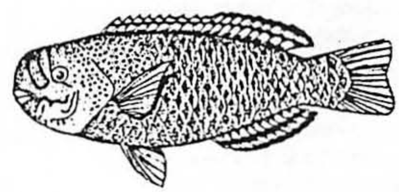
Size: Length up to 20 inches; weight generally up to 5 pounds

Habitat: Reefs and rocky areas at depths of about 10 to 40 fathoms, generally near ledges and crevices

Feeding: Diurnal; fish

Schooling: Solitary

Fishing methods: Spear, trap, handline
Introduced 1956 and 1961 from Society Islands



Uhu
Scaridae
Parrotfish

Description: Coloration varies with species, sex and age; males are generally more gaudy, with colors dominated by blues and greens, females are generally more bland with colors dominated by reddish browns or grays; teeth are fused together and resemble a beak.

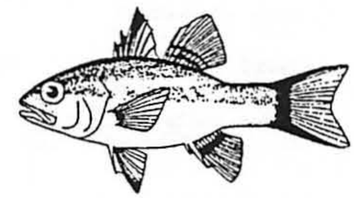
Size: Length up to 2 feet or more; weight generally up to 15 pounds

Habitat: Rocky areas and coral reefs, usually more abundant at outer edge of reef

Feeding: Diurnal; algae, crustaceans

Schooling: Solitary or small groups; juveniles tend to school

Fishing methods: Spear, net



'Upapalu
Apogon spp.
Cardinalfish

Description: Coloration varies with species; generally light red or brown with iridescent hues; dark horizontal bands present in some species.

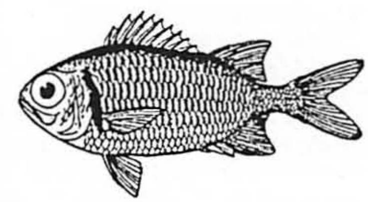
Size: Length up to about 7 inches, depending on species; weight generally up to ¼ pound

Habitat: Nearshore caves and crevices

Feeding: Nocturnal; small crustaceans

Schooling: Solitary when feeding

Fishing methods: Pole and line



'U'u
Myripristis spp.
Menpachi, soldierfish

Description: Bright red by day, lower sides become silvery at night.

Size: Length up to 14 inches; weight generally up to 1 pound

Habitat: Inshore reef areas, congregating in caves and crevices during the day

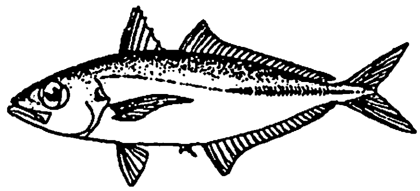
Feeding: Nocturnal; plankton, crustaceans

Schooling: Schools

Fishing methods: Spear, handline, net, trap

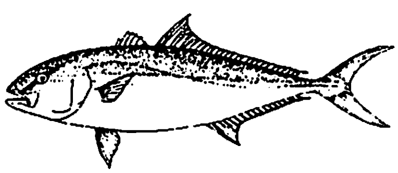
Seasonality: Spawns late spring to mid-summer; generally more taken in late summer and early fall

CARANGIDS
(Jacks and their allies)



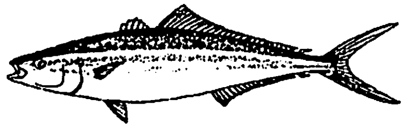
Akule, Halalu
Selar crumenophthalmus
Aji, bigeye scad

Description: Silvery blue above fading to silvery white below, yellow tail fin; very large eyes.
Size: Length up to 15 inches; weight generally up to 2 pounds
Habitat: Mid- or surface waters along coast, or shallow banks near shore
Feeding: Nocturnal; small crustaceans
Schooling: Large schools
Fishing methods: Halalu (juveniles up to about 5 inches) taken with light tackle; akule are generally taken handlining at night, or by day with net or pole and line
Seasonality: Spawn from about March through October, at which time they form large schools in shallow water; halalu common about July to December
An excellent food fish.



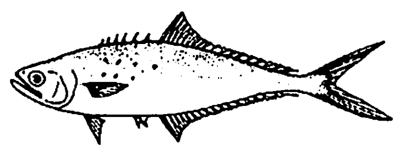
Kahala
Seriola rivoliana
Greater amberjack, yellowtail

Description: Light metallic brown with purplish tinge; light yellow horizontal band extends from head to base of tail, fades after fish is caught; dark diagonal streak through eye.
Size: Length up to 6 feet; weight generally up to 120 pounds
Habitat: Deeper coastal waters, typically 60 to 600 feet or more; lives near bottom; young often found around floating objects at sea
Feeding: Diurnal and nocturnal; fish and squid
Schooling: Solitary or small school
Fishing methods: Caught mostly by fishing over deep-sea ledges or drop offs; usually taken handlining offshore, but often come close enough to shore to be caught with baitcasting gear; occasionally by spear or trap



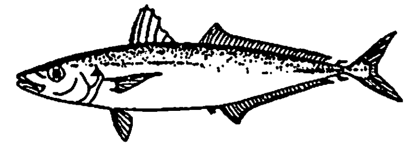
Kamanu
Elagatis bipinnulatus
Rainbow runner, Hawaiian salmon

Description: Dark blue above followed in succession down side by light blue stripe, yellow stripe, another light blue stripe; yellowing silver below, yellow fins.
Size: Length up to 4 feet; weight generally up to 10 pounds
Habitat: Open water, usually near surface; may be found with other fish around floating objects
Feeding: Diurnal; fish and squid
Schooling: Solitary or small school
Fishing methods: Trolling with small lures or baits, by handline, or from shore with baitcasting gear
Considered an excellent food fish.

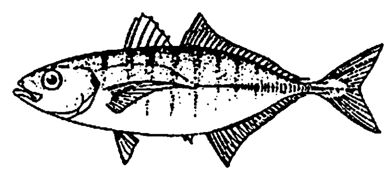


Lai
Scomberoides lysan
Lae, leatherback

Description: Slate blue above, fading to silvery below; fins may have yellowish tinge; leathery skin with small needle-like scales.
Size: Length up to 2 feet; weight generally up to 2 pounds
Habitat: Inshore coastal waters, sheltered bays and harbors, brackish water areas near mouths of streams
Feeding: Diurnal; smaller schooling fishes, especially mullet and nehu, crustaceans
Schooling: Schools near the surface
Fishing methods: Often caught by shore anglers casting bait or lures for young jacks; also by net; should be handled carefully because of sharp anal spines
Not widely sought after for food; skin is valued for making trolling lures.



'Opelu
Decapterus macarellus
Mackerel scad
Description: Bluish or greenish yellow above fading to silvery white below, dark spot on upper part of gill cover.
Size: Length up to 20 inches; weight generally up to 2 pounds
Habitat: Near coast in surface and mid-water; juveniles school far out at sea
Feeding: Diurnal and nocturnal; plankton, especially small crustaceans
Schooling: Schools
Fishing methods: Caught by handline at night, and with special lift nets during the day
Seasonality: Spawns from about March to the middle of August; juveniles enter coastal areas in late fall and winter
Considered an excellent food fish; also popular as bait and live chum for large tuna, marlin, and other predators.

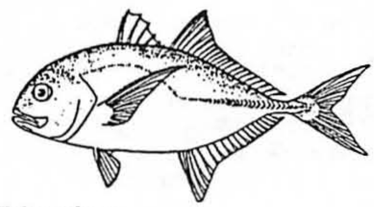


Omaka
Atule mate
Yellowtailed scad

Description: Silvery body with greenish yellow tinge, marked with 9 or 10 darker vertical bars; yellow tail, black spot behind eye on edge of gill cover.
Size: Length up to one foot; weight generally up to ¾ pound
Habitat: Protected bays and estuaries; juveniles very abundant in fall around floating objects, especially jellyfish; not found in open sea
Feeding: Diurnal; plankton, mostly small fish and crustaceans
Schooling: Schools
Fishing methods: Mostly taken with light tackle from shore and piers; occasionally taken with net
Seasonality: More common March to October
Considered an excellent food fish.

ULUA

Like other carangids, ulua are carnivorous fast-swimming predators, feeding on a variety of fish and crustaceans. Juveniles, known collectively as papio, tend to live close to shore for protection, then move toward deeper waters as they get older. Ulua are extremely popular gamefish, and the flesh is very good to eat.

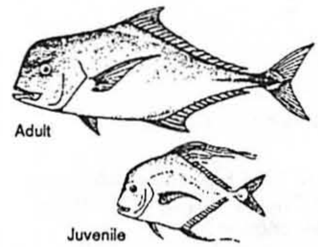


White ulua
Caranx ignobilis
Giant trevally

Description: Pale olive above with greenish tinge around head, white sides, yellow anal fin; color varies to darker shades, depending on fish's temperament and time of day; breast nearly scaleless except for patch of about 10 scales in middle.
Size: Length over 5 feet; weight generally up to 120 pounds
Habitat: Papio caught near shore, adult fish found over nearshore reefs; often hiding in caves during the day
Feeding: Nocturnal, but occasionally caught by day; fish, octopus, crustaceans
Schooling: School; when large (over 30 pounds) generally solitary or in pairs
Fishing methods: Casting from rocky shores and ledges; handline, trap, spear
Seasonality: Young common in summer, adults common year round
An excellent food fish, the white ulua is widely considered to be the ultimate shoreline gamefish.

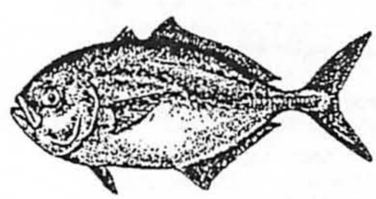
Black ulua
Caranx lugubris
Gunkun, black jack

Description: Dark brown, with almost black head; may tend toward a creamy or dusky shade; breast completely scaled, scutes distinct; definite notch above snout in profile.
Size: Length over 3 feet
Habitat: Outer reef channels
Feeding: Nocturnal; fish and crustaceans
Schooling: Form large schools when feeding
Fishing methods: Casting from rocky shores and ledges
Seasonality: Uncommon year round in main Hawaiian Islands



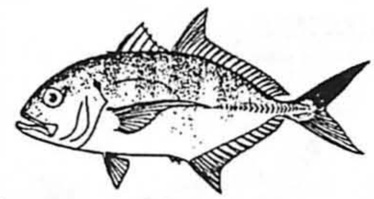
Ulua kihikihi
Alectis spp.
Kagami ulua, threadfin jack

Description: Adults dusky white, often darker along dorsal area, with bluish, greenish, and yellowish hues; juveniles silvery blue above and bright silver below, with a diamond shaped body and long trailing filaments extending from dorsal and anal fins; as fish gets older body becomes more elongate, and filaments begin to disappear.
Size: Length up to 40 inches; weight generally up to 40 pounds
Habitat: Juveniles often found in harbors and other sheltered waters, upon reaching maturity move to deeper and more open water, often taken from depths of 60 to 200 feet
Feeding: Diurnal; mostly crustaceans
Schooling: Solitary or small school
Fishing methods: Handline



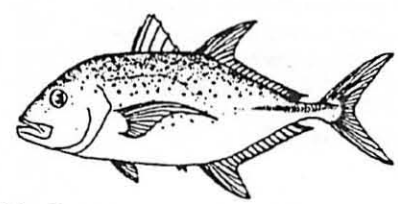
Ulua lauli
Uraspis helvola
Dobe ulua, cottonmouth jack

Description: Dark dusky color, easily identified by looking inside mouth; tongue and roof of mouth are white, back of mouth and throat and gill areas are bluish black.
Size: Length up to 20 inches; weight generally up to 3 pounds
Habitat: Dropoff areas, generally 100 to 200 feet
Feeding: Nocturnal; small fish and crustaceans
Schooling: Schools
Fishing methods: Handline



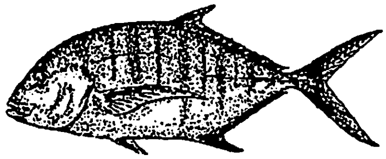
Ulua menpachi
Caranx sexfasciatus
Sasa, bigeye trevally

Description: Dark blue-green to gold above, yellow-green to silver below, upper lobe of tail fin dark with black tip; juveniles have four to seven dark vertical bands.
Size: Length usually under 3 feet; weight generally up to 15 pounds
Habitat: Young fish found in brackish water areas out to deeper coastal waters; adult fish live along rocky shores in turbulent water over reefs
Feeding: Nocturnal; fish and crustaceans
Schooling: Solitary
Fishing methods: Handline; juveniles taken with pole and line
Seasonality: More abundant spring to mid-summer



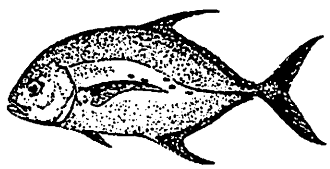
'Omilu
Caranx melampygus
Hoshi ulua, blue ulua, bluefin trevally

Description: Juveniles silvery blue above fading to silver below, with yellow pectoral fins; as fish ages bluish-black spots begin to appear all over, and body changes to neon blue; fins, especially first dorsal, also blue; breast completely scaled.
Size: Length up to 3 feet; weight generally up to 20 pounds
Habitat: Juveniles found in shallow bays and estuaries; medium sized fish (6 to 20 inches) taken over reefs; adults often move in close to shore by following channels in coral reefs, swimming over the reef by day
Feeding: Mostly diurnal; small fish
Schooling: Solitary or small groups
Fishing methods: Usually taken with surfcasting gear; trolling, spear, net, handline, trap; juveniles taken with pole and line



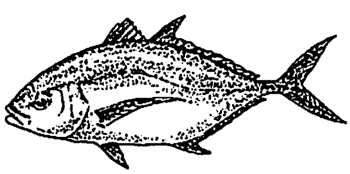
Pa'opa'o
Gnathanodon speciosus
Yellow jack

Description: Creamy yellow with silvery and bluish hues, marked by series of 8 to 12 darker greenish vertical bands; jaws of adults contain no teeth.
Size: Length up to 3 feet; weight generally up to 10 pounds
Habitat: Generally found in sandy channels and bars close to shore
Feeding: Uncertain; fish and crustaceans
Schooling: Small schools
Fishing methods: Pole and line, net
Seasonality: Uncommon year round



Papa
Carangoides orthogrammus
Yellowspot trevally

Description: Silvery blue above fading to silvery white below, bluish and golden hues on fins; sides marked with a few lemon-colored round spots, which tend to fade as fish gets older.
Size: Length up to 2 feet; weight generally up to 5 pounds
Habitat: Near shore
Feeding: Diurnal; small fish and crustaceans
Schooling: Solitary or small groups
Fishing methods: Trolling, spear, pole and line

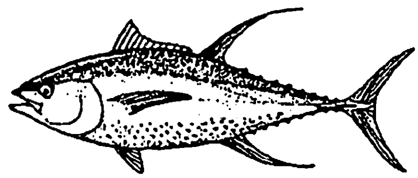


Butaguchi
Pseudocaranx dentex
Pig ulua, buta ulua, thicklipped jack

Description: Dark silver above fading to light silver below, dark spot at upper edge of gill cover; juveniles have yellow horizontal streak extending through eye and along side of body to base of tail; thick fleshy lips, pointed snout, and concave depression in front of eyes.
Size: Length up to 4 feet; weight generally up to 40 pounds
Habitat: Bays and coastal waters
Feeding: Diurnal and nocturnal; fish, crustaceans and octopus
Schooling: Schools
Fishing methods: Handline

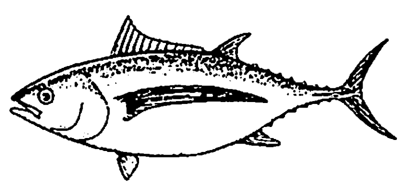
SCOMBRIDS
(Tunas and their allies)

Scombrids are carnivorous fishes that feed on squids, crustaceans and other small fishes. They have well contoured torpedo-shaped bodies, the most perfect body shape for high-speed swimming. The anterior dorsal fin can be completely tucked into a groove on the back. Scombrids often live in large schools, and many species are known to migrate over long distances.



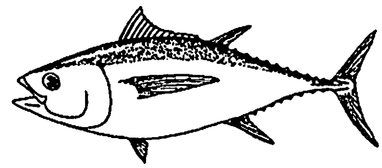
'Ahi
Thunnus albacares
Yellowfin tuna

Description: Blackish blue above fading to white below; faint yellow stripe extends from eye to tail, soft dorsal and anal fins and finlets bright yellow; dorsal and anal fins lengthen with age.
Size: Weight up to 300 pounds
Habitat: Open water, generally found over deepwater banks and submarine ledge areas at depths to 1000 fathoms; young fish often travel near the surface
Feeding: Diurnal and nocturnal; fish, squid and crustaceans
Schooling: Schools
Fishing methods: Longline, pole and line, trolling, handline
Seasonality: Adults more abundant late spring through early fall; juveniles abundant fall and winter



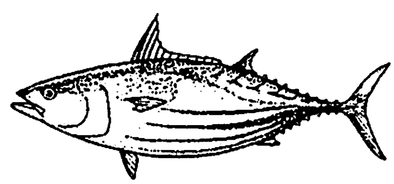
'Ahi palaha
Thunnus alalunga
Tombo, albacore

Description: Blackish blue above fading to silvery below; long pectoral fins which extend beyond the soft dorsal and anal fins.
Size: Weight up to 80 pounds or more, but few exceed 40 pounds
Habitat: Open water, generally staying below 60 fathoms during the day, then moves close to surface by night
Feeding: Diurnal and nocturnal; fish, squid and crustaceans
Schooling: Schools
Fishing methods: Longline, handline
Seasonality: More abundant during summer months



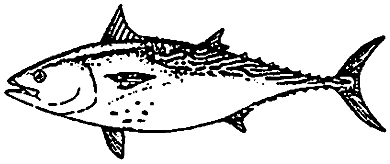
'Ahi po'onui
Thunnus obesus
Bigeye tuna

Description: Blackish blue above fading to silvery below, yellowish finlets; closely resembles ahi, but has larger eyes.
Size: Weight generally up to 150 pounds, but some have been known to reach 300 pounds
Habitat: Open water, generally staying below 60 to 70 fathoms by day, then moving closer to surface by night
Feeding: Diurnal and nocturnal; fish, squid and crustaceans
Schooling: Schools
Fishing methods: Handline, longline
Seasonality: More abundant late fall through late spring



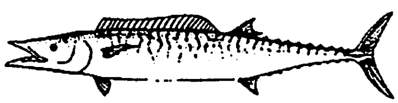
Aku
Katsuwonus pelamis
Skipjack tuna

Description: Dark metallic blue above, light dusky blue below, with four or five dark purplish longitudinal stripes on side of belly.
Size: Weight averages about 18 to 22 pounds during the summer, 5 to 12 pounds during the rest of the year
Habitat: Generally found in waters 100 fathoms and deeper
Feeding: Diurnal; fish, squid and crustaceans
Schooling: Schools
Fishing methods: Pole and line (aku boat type), trolling
Seasonality: Taken year round, but most common during spring and summer.



Kawakawa
Euthynnus affinis
Little tunny

Description: Dark blue or bluegreen above fading to silver below; about 12 dark wavy marks on dorsal area.
Size: Weight up to about 20 pounds, but most are around 4 or 5 pounds
Habitat: Open water, but somewhat close to shoreline, generally in depths less than 100 fathoms; often found over dropoffs, or in association with aku; young may enter bays and harbors
Feeding: Diurnal and nocturnal; small fish, squid and crustaceans
Schooling: Schools
Fishing methods: Trolling, pole and line
Seasonality: Present throughout year, but most abundant during summer when the fish come fairly close to shore in large schools

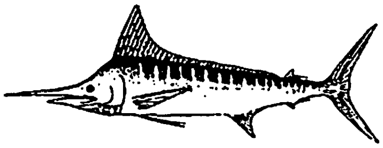


Ono
Acanthocybium solanderi
Wahoo

Description: Dark blue above fading to silver below, with about 30 purplish-gray vertical bars on sides that flash bright blue when the fish is fighting a hook.
Size: Weight up to 100 pounds, average 30 to 40 pounds
Habitat: Roams the surface waters of the open sea, usually over deep-sea ledges; often found near floating logs and other objects
Feeding: Diurnal; fish, squid and crustaceans
Schooling: Solitary or small schools
Fishing methods: Trolling, longline
Seasonality: More abundant late spring through fall

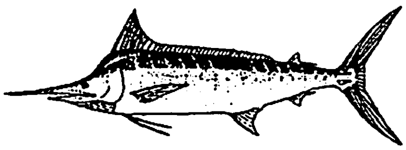
BILLFISH

Billfish are carnivorous fishes of the deep sea, feeding on squid and relatively large fishes. They are characterized by the presence of a spear, or bill, which is actually an extension of the upper jaw. The bill is often used to slash at schools of prey; the billfish then feeds on the wounded fish.



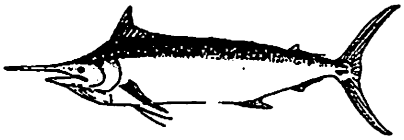
A'u
Tetrapterus audax
Nairagi, striped marlin

Description: Royal blue above fading to silvery below, with lavender or pale blue vertical stripes on sides; dorsal and anal fins cobalt blue; high pointed dorsal fin.
Size: Weight up to 150 pounds or more; most average about 25 to 100 pounds
Habitat: Pelagic
Feeding: Diurnal; fish and squid
Schooling: Solitary or small schools
Fishing methods: Trolling, longline
Seasonality: Taken mostly in spring and fall



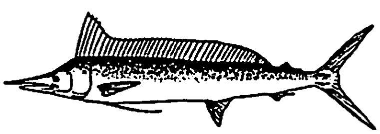
A'u
Makaira nigricans
Kajiki, Pacific blue marlin

Description: Cobalt blue above fading to silvery below, with pale blue vertical stripes on sides and blue patches on dorsal area and tail.
Size: Weight averages about 300 to 400 pounds, but some exceeding 1400 pounds have been taken
Habitat: Generally taken over bank areas where baitfish are abundant, and over offshore ledges where bottom drops off from 100 to 1000 fathoms or more
Feeding: Diurnal; mainly aku and other tunas
Schooling: Solitary
Fishing methods: Trolling, longline
Seasonality: Most abundant during summer



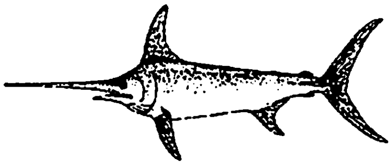
A'u
Makaira indica
Hida, black marlin

Description: Variable coloration; most are dark slate blue above fading to silvery below; may have pale blue stripes or blue patches on sides that fade quickly after death; pectoral fins don't fold against body.
Size: Most average about 200 pounds, but have been known to reach 1800 pounds
Habitat: Pelagic
Feeding: Diurnal; fish and squid
Schooling: Solitary
Fishing methods: Trolling, longline



A'u
Tetrapterus angustirostris
Hebi, shortbill spearfish

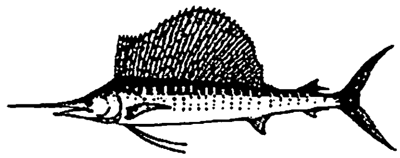
Description: Deep metallic blue above fading to silvery and white below; no significant markings; upper jaw extends on a short distance beyond the lower jaw.
Size: Average weight about 20 to 40 pounds, rarely exceeds 100 pounds
Habitat: Pelagic
Feeding: Diurnal; squid and small fish
Schooling: Solitary or small schools
Fishing methods: Trolling, longline
Seasonality: Most abundant during winter and early spring



A'u ku
Xiphias gladius
Shutome, broadbill swordfish

Description: Coloration varies from metallic purplish to blackish brown, but generally dark brown, with silvery iridescence below; pelvic fins are absent, dorsal fin not retractable.
Size: Average weight about 200 to 300 pounds; large fish may exceed 1000 pounds
Habitat: Pelagic

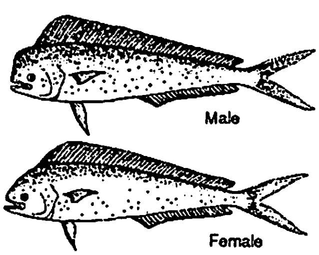
Feeding: Nocturnal; fish and squid
Schooling: Solitary or in pairs
Fishing methods: Longline, handline



A'u lepe
Istiophorus platypterus
Sailfish

Description: Body coloration dark steely blue above fading to silvery white below, with pale purple vertical bars on sides; sail cobalt blue to purple with numerous small blue spots.
Size: Average weight about 30 to 50 pounds
Habitat: Generally near submerged shoals fairly close to shore
Feeding: Diurnal; small fish and squid
Schooling: Usually solitary; may occur in small schools
Fishing methods: Trolling, longline
Seasonality: Uncommon year round

DOLPHINFISH

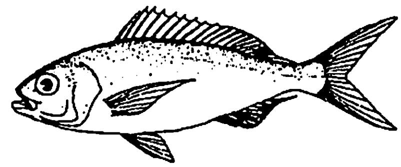


Mahimahi
Coryphaena hippurus
Dorado

Description: Brilliant green and yellow dotted with phosphorescent blue, with purplish blue dorsal fin; colors change rapidly when fighting and just before death. Males have an almost vertical head profile, females are more sloping.
Size: Average weight 20 to 30 pounds; occasionally 70 pounds
Habitat: Open ocean, often seen close to surface near schools of flyingfish, or around floating objects
Feeding: Diurnal and nocturnal; squid and small fish, especially flyingfish
Schooling: School
Fishing methods: Trolling, handline, longline
Seasonality: Small fish (up to 5 pounds) common in summer, large fish (30 to 40 pounds) more plentiful in late winter and early spring

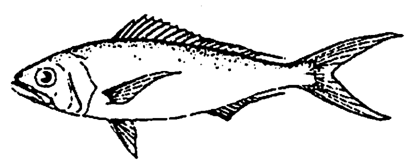
DEEPWATER SNAPPERS

Snappers are voracious carnivores, and the species described here are generally found in the deeper waters of Hawaii, up to 150 fathoms (as opposed to the nearshore species described earlier). Most deepwater snappers are a uniform bright color, usually with red or yellow hues. A few species have color patterns.



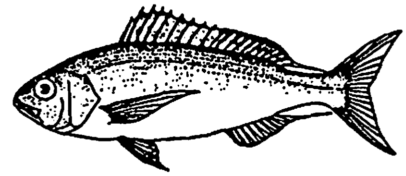
Kalekale
Pristipomoides sieboldii
Kalikali, von Siebold's snapper

Description: Light lavender above fading to lighter below; scales above lateral line have pale-blue spots in center which form lengthwise lines; margin of dorsal fin orange with light lavender; tail fin dark lavender with light margin.
Size: Length up to 2 feet; weight generally up to 4 pounds
Habitat: Deep waters, usually 80 to 120 fathoms
Feeding: Diurnal and nocturnal; fish, squid and crustaceans
Schooling: School
Fishing methods: Handline
Seasonality: Most caught during late fall and winter



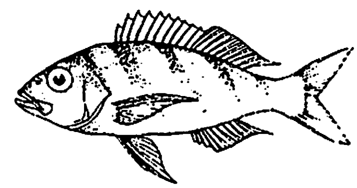
Lehe
Aphareus rutilans
Lehi, ironjaw snapper

Description: Brick red above fading to silvery below; dorsal fin has yellow spot on margins and yellow border; tail has yellowish hues.
Size: Length up to 3 feet or more; weight generally up to 25 pounds
Habitat: Deep waters, usually around 100 fathoms
Feeding: Diurnal and nocturnal; fish, squid and crustaceans
Schooling: School
Fishing methods: Handline
Seasonality: Most caught during late fall and winter



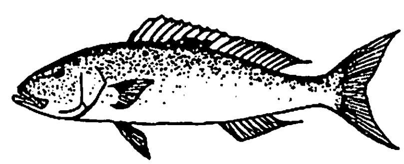
'Opakapaka
Pristipomoides filamentosus
Pink snapper

Description: Light violet brown above fading to dusky white below; pectoral fins yellowish.
Size: Length up to 3 feet; weight generally up to 18 pounds
Habitat: Deep waters, usually 40 to 100 fathoms; most abundant over rocky bottom dropoffs
Feeding: Diurnal and noctunal; fish, squid and sea cucumbers
Schooling: School
Fishing methods: Handline
Seasonality: Most caught during winter months



Ukikiki
Pristipomoides zonatus
Gindai, Brigham's snapper

Description: Pinkish red with four wide vertical yellow bands; dorsal, pectoral and caudal fins yellow.
Size: Length up to 20 inches or more; weight generally up to 4 pounds
Habitat: Deep water, usually 60 to 100 fathoms
Feeding: Diurnal; fish, squid and crustaceans
Schooling: Solitary or small schools
Fishing methods: Handline



Uku
Aprion virescens
Gray snapper

Description: Uniform grayish blue, with dorsal area more bluish than below; dard blue towards head; three dark spots near base of dorsal fin.
Size: Length up to 3 feet or more; average weight about 4 to 8 pounds

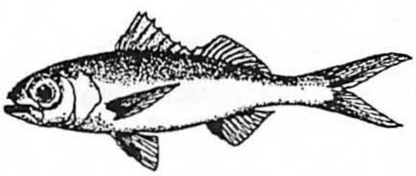
Habitat: Relatively shallow water compared with other snappers, usually less than 60 fathoms; rocky bottom areas outside of reef, deep rocky areas near shore

Feeding: Generally nocturnal; fish, squid and crustaceans

Schooling: Solitary or small groups; large aggregates when spawning

Fishing methods: Handline, spear

Seasonality: Most caught during late spring and early summer when spawning



'Ula'ula

Etelis carbunculus

'Ehu, red snapper

Description: Red above fading to silvery pink below; interior of mouth is pink.

Size: Weight generally up to 9 pounds

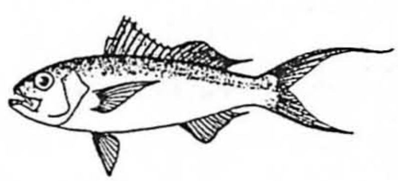
Habitat: Deep waters, usually 100 to 150 fathoms

Feeding: Generally diurnal; fish, squid and crustaceans

Schooling: Aggregates

Fishing methods: Handline

Seasonality: Most caught during winter



'Ula'ula koa'e

Etelis coruscans

Onaga, longtailed red snapper

Description: Red above fading to silvery pink below; dorsal and tail fins red; inside of mouth red; caudal fin lobes are elongate, upper lobe longer than lower.

Size: Weight generally up to 35 pounds

Habitat: Taken over offshore dropoffs, usually in water 100 to 150 fathoms

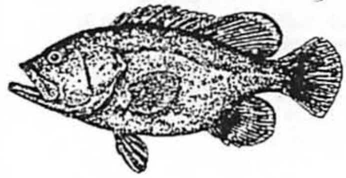
Feeding: Generally diurnal; fish, squid and crustaceans

Schooling: School

Fishing methods: Handline

Seasonality: Most caught during winter

GROUPERS



Hapu'u

Epinephelus quernus

Seale's grouper

Description: Dark purplish brown with small white spots; spots become less distinct as fish grows larger.

Size: Length up to 4 feet; weight generally up to 50 pounds

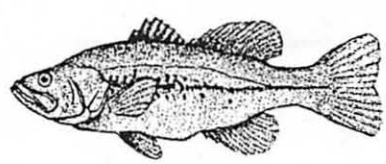
Habitat: Deep water, generally 50 to over 120 fathoms

Feeding: Diurnal; fish and crustaceans

Schooling: Solitary

Fishing methods: Handline

FRESHWATER SPORTFISH (Introduced)



Largemouth Bass

Micropterus salmoides

Description: Coloration varies with location, generally dark green above fading to white below; may have faint horizontal band along sides (more distinct in young fish); jaw extends back beyond posterior margin of eye; dorsal fin deeply notched between spiny and soft portions.

Size: Weight ranges up to 10 pounds in Hawaii; state record 8 pounds (1977); world record 22¼ pounds (Georgia).

Distribution: In Hawaii found on the islands of Kauai, Oahu and Hawaii.

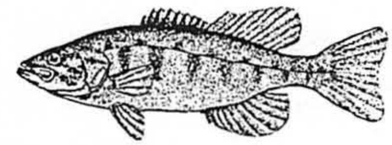
Habitat: Usually found in sluggish waters, occur primarily in reservoirs in Hawaii; prefer submerged logs, weeds or other cover near banks.

Feeding: Young feed on crustaceans, insects and small fishes; adults feed on live fishes, crayfish and frogs.

Life history: In Hawaii spawning season occurs during the winter and spring and is limited to reservoir habitats; male builds a circular nest in 3 to 4 feet of water; male guards the nest and defends eggs and young until they leave.

Fishing methods: Light spinning or baitcasting gear is recommended, with surface or deep running lures, such as plastic worms, crankbaits or spinnerbaits; effective live baits include puntat, tilapia, crayfish and worms.

Introduced to Hawaii in 1896.



Smallmouth Bass

Micropterus dolomieui

Description: Coloration varies with location, generally dark green to olive brown above fading to white below; sides marked with vertical bars and dark mottlings; jaw does not extend back beyond eye; spiny portion of dorsal fin lower than on largemouth bass, and not as deeply notched.

Size: Weight ranges up to 4 pounds in Hawaii; state record 3 pounds 11 ounces; world record 11 pounds 15 ounces (Kentucky).

Distribution: In Hawaii found on the islands of Kauai and Oahu.

Habitat: Found in cool flowing streams and reservoirs fed by such streams.

Feeding: Young feed on crustaceans, insects and small fishes; adults feed primarily on live fishes and crayfish.

Life history: In Hawaii spawning season occurs during the spring and is limited to stream habitats; male builds a hollow nest in sand and guards the young, viciously attacking any intruder.

Fishing methods: Small spinners or poppers are effective lures; live baits include crayfish or worms.

Introduced to Hawaii in 1953.

Channel Catfish

Ictalurus punctatus

Description: Bluish olive to gray above fading to white below, with dark spots scattered along sides; older males become dark in color and lose spots; long barbels surrounding mouth; deeply forked tail.

Size: Generally under 10 pounds, but have unofficially exceeded 50 pounds in Hawaii; state record 43 pounds 13 ounces; world record 58 pounds (South Carolina).

Distribution: In Hawaii found on the islands of Kauai and Oahu.

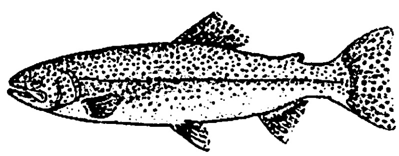
Habitat: Occur primarily in reservoirs in Hawaii.

Feeding: Feeds primarily on small fish, crustaceans, clams and snails.

Life history: Spawning occurs in late spring; eggs are laid in jelly-like masses in holes and crevices, and guarded by the male; hatching occurs after about a week, and the male continues to guard the young.

Fishing methods: Crankbaits or large spinnerbaits are the most effective lures; a catfish weighing 51 pounds (unofficially) was taken from the Wahiawa Reservoir on a spoon; other baits include tilapia, crayfish, aku belly, liver and various stinkbaits.

Introduced to Hawaii in 1958.



Rainbow Trout

Oncorhynchus mykiss

Description: Bluish or olive green above fading to silvery below, with broad pink lateral stripe; back, sides, dorsal and caudal fins marked with small dark spots.

Size: Generally under 3 pounds, but have unofficially reached 8 pounds in Hawaii; state record 5 pounds 10 ounces; world record 42 pounds 3 ounces (Alaska).

Distribution: In Hawaii found on the islands of Kauai and Hawaii.

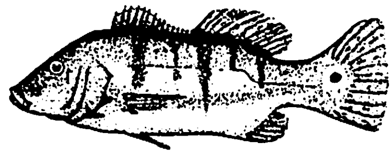
Habitat: Prefers cold water streams with moderate flow.

Feeding: Young feed on small insects and crustaceans; adults feed on fish eggs, minnows and other small fish (including other trout).

Life history: Limited spawning occurs in Hawaii because water temperatures are too high; what spawning does occur takes place from about November to February; annual stockings of the Kokee region on Kauai are accomplished with eggs from California, hatched and raised at Sand Island, Oahu.

Fishing methods: Small spinners or flies are effective lures; salmon eggs are used with good success.

Introduced to Hawaii in 1920.



Tucunare

Cichla ocellaris

Description: Yellow with a green back and white abdomen; vertical bars along sides; during spawning season yellow color intensifies, and males develop a large hump above the head; prominent black spot on caudal fin.

Size: Weight averages about 2 to 3 pounds; state record 8 pounds 13 ounces; species known to reach 12 pounds in South America.

Distribution: In Hawaii found on the islands of Kauai, Oahu, Maui and Hawaii.

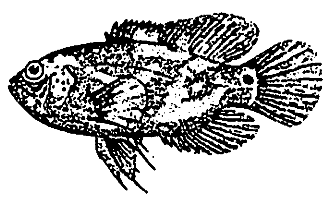
Habitat: Generally found in the larger reservoirs of the state.

Feeding: Feeds exclusively on small fish, especially threadfin shad, mosquito fish, tilapia and bluegill.

Life history: Spawning in Hawaii occurs from about March to September; eggs are laid on rocks or other hard objects and guarded by one or both parents; hatching takes place within four days, and parents guard the young; presence of at least one parent is essential for survival of young, so fishermen are urged not to disturb spawning fish which are often visible near shore.

Fishing methods: Lures include jigs and torpedo-shaped lures that resemble minnows; the only effective live bait is mosquitofish, mollies or tilapia.

Introduced to Hawaii in 1957.



Oscar

Astronotus ocellatus

Description: Brightly colored with irregular red markings on a dark brown body; prominent black spot surrounded by red ring at base of caudal fin.

Size: Weight reaches 3 pounds or more; state record 2 pounds 6 ounces.

Distribution: In Hawaii found on the island of Oahu.

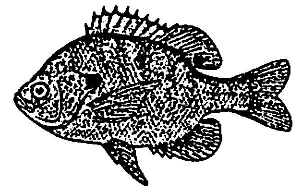
Habitat: Prefers quiet shallow water.

Feeding: Feeds on small fish, crayfish, worms and insect larvae.

Life history: Spawning in Hawaii occurs from about March to September; oscar pairs excavate a circular nest in shallow water, where eggs are deposited; both parents guard the nest.

Fishing methods: Minnow-like lures are effective; live baits include worms, crayfish and mosquitofish.

Introduced to Hawaii in 1951.



Bluegill Sunfish

Lepomis macrochirus

Description: Coloration varies somewhat with sex and age, generally olive green above with blue or purplish sheen along sides; breeding males may have more blue and orange on sides; faint vertical bars along sides; opercular flap is dark blue or black, and prominent dark blotch is present at posterior base of dorsal fin.

Size: Generally 4 to 6 inches in length, may reach 14 inches; state record 8½ ounces; world record 4 pounds 11 ounces (Alabama).

Distribution: In Hawaii found on the islands of Kauai, Oahu, Maui and Hawaii.

Habitat: Usually found in lakes, ponds, reservoirs and sluggish streams, occur primarily in reservoirs in Hawaii; prefer deep weed beds.

Feeding: Young feed on crustaceans, insects and worms; adults feed on snails, small crayfish, insects, worms and small minnows; feed mostly in early morning and late afternoon and evening.

Life history: In Hawaii spawning season occurs in winter and spring; male builds a circular nest in sandy areas 3 to 6 feet deep; after fertilizing eggs male chases female away and guards the nest until fry disperse.

Fishing methods: Worms are the most effective live bait; lures include flies and small spinners.

Introduced to Hawaii in 1946.