

Hō'ike o Haleakalā

*Haleakalā revealed: an opening to view our past and embrace our future
Reveal yourself, summit to sea*

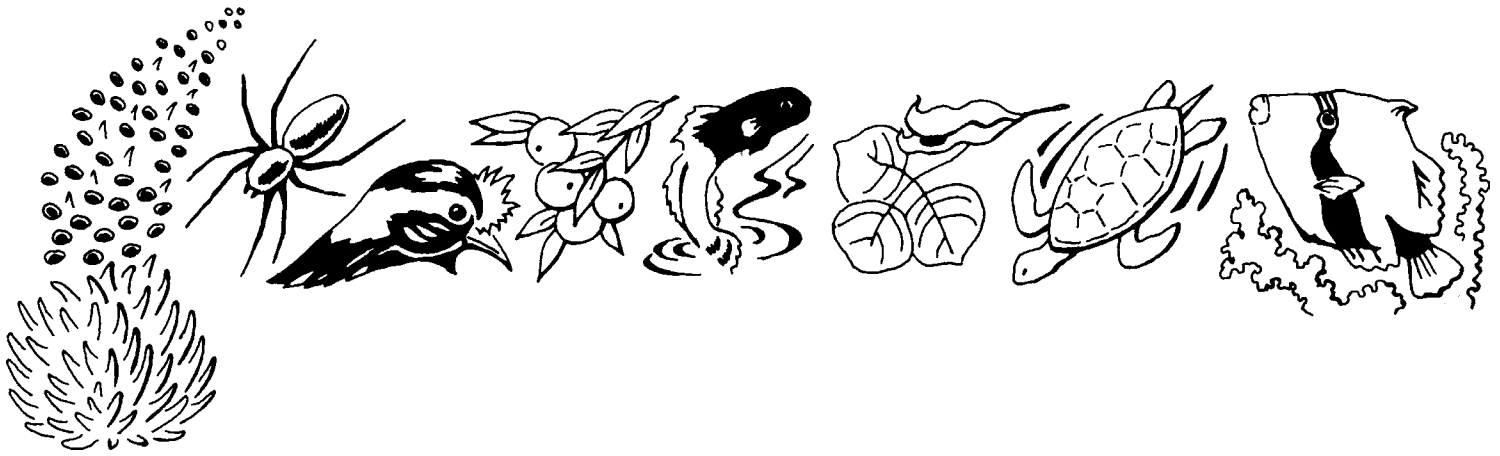


A Multidisciplinary, Science-Based Environmental Education Curriculum for High Schools



Produced by
Hawai'i Natural History Association
Nā Kumu o Haleakalā
Haleakalā National Park
The Nature Conservancy

*Major funding provided by the Strong Foundation
Additional support provided by the Alexander & Baldwin Foundation,
Atherton Family Foundation, Fred Baldwin Memorial Foundation, and Cooke Foundation, Limited*



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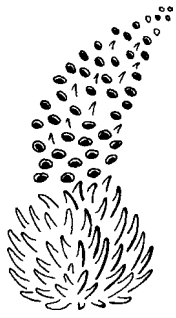
Foreword



Nā Kumu o Haleakalā is a partnership on the island of Maui, Hawai‘i, comprised of teachers from public and private high schools, members of interested community organizations, and staff from the Hawai‘i Natural History Association, Haleakalā National Park, and The Nature Conservancy. The *Nā Kumu* partnership has worked with a highly qualified curriculum writing and development team to produce the beginnings of a comprehensive environmental education curriculum, *Hō‘ike o Haleakalā*, specific to Maui to promote understanding of island ecosystems, a feeling of shared ownership, and a commitment to active stewardship. The target group is primarily high school level, though testing will occur in the local community college and in intermediate schools, as well. The effort was initiated by the National Park Service and local teachers in 1996, and gradually gathered momentum until 1999, by which time sufficient funding had been raised from several private sources to move ahead. The partnership has recently completed ecosystem-based modules for aeolian, rainforest, and the coastal/marine zones of Haleakalā. Future plans call for these to be followed by modules on dryland forest, the subalpine zone, watersheds, and a culminating module on alien species.

Although not entirely conceived as such originally and having much broader educational objectives, *Hō‘ike o Haleakalā* can be thought of as an innovative effort at educating local students to understand the overwhelming effects of invasive alien species (IAS) on biodiversity, agriculture, health, economy, and quality-of-life of an oceanic island ecosystem, and to obtain long-term public support of and participation in such efforts. Each ecosystem-based module has one or more units on the effects and/or future threats of alien species. Haleakalā National Park is the most biologically intact summit-to-the-sea reserve in the Hawaiian Islands and among the most important reserve sites in the United States for conservation of biodiversity. However, the park’s future depends on resource managers’ success in combatting invaders already present and on efforts to prevent additional IAS from establishing on the island of Maui. Since oceanic islands are particularly vulnerable to biological invasions, IAS threats to Hawai‘i and to Haleakalā National Park on Maui are an order of magnitude greater than threats to most other U.S. national parks. The red imported fire ant and Asian longhorn beetle are not yet established in Hawai‘i, but both have been recently intercepted in quarantine. Unless major action is taken – a circumstance which will require solid public support — invasions can be expected to erode the biological integrity of oceanic island ecosystems, eventually even the last strongholds of the endemic island biota.

Lloyd Loope
Research Biologist, U.S. Geological Survey,
Biological Resources Division, Haleakalā National Park



Acknowledgements

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Introduction

Hō'ike o Haleakalā

Haleakalā revealed: an opening to view our past and embrace our future

Reveal yourself, summit to sea

Project Background and Purpose

There are some 6,000 high school students in Maui County. Many of them have never seen a native bird or experienced a native Hawaiian forest. Many of them have no reference point, no experience to know whether the birds they see or the forests they visit are native to the Hawaiian Islands.

This lack of knowledge and experience may not be surprising. Roughly 75 percent of the original Hawaiian forest is gone and the remnants of native forest that remain tend to be difficult to access. Forests, scrublands, and coastal areas dominated by nonnative species are all many Hawaiian residents know. Over 100,000 species of plants alone have been introduced to the Hawaiian Islands since the arrival of the first Polynesians, and many of these now predominate in areas once covered by native vegetation. Furthermore, while the Hawaiian Islands make up well under one percent of the total land mass of the United States, 75 percent of the country's recorded plant and bird extinctions are of Hawaiian species.

Intimately tied to the land, traditional Hawaiian culture, values, and ways of life have declined along with the native plants and animals. Today's residents have little connection to the land—and little connection with the achievements and customs of the ancient Hawaiians. Like many native Hawaiian birds, insects, and plants, Hawaiian cultural values sometimes seemed threatened by extinction—through lack of awareness and understanding.

Hō'ike o Haleakalā aims to help sustain the native Hawaiian landscape and culture by helping students establish and deepen connections to the land and the culture it supports. Project goals are to enable high school students in Maui County—and elsewhere throughout the Hawaiian Islands and beyond—to:

- Gain a greater understanding of island ecosystems;
- Develop an awareness of relationships between people and the environment;
- Build observation, critical-thinking, and decision-making skills;
- Feel a sense of inspiration for and shared ownership of natural areas; and
- ^a Become informed decision-makers active in the stewardship of their island home.

From Vision to Reality

Since 1996, educators from public and private Maui high schools, Haleakalā National Park, Hawai'i Natural History Association, The Nature Conservancy, and members of several community groups have been sharing ideas for improving natural history education in Maui County's secondary schools. Out of these discussions came the idea to, in effect, bring the mountain and its fascinating array of natural systems to the classroom.

Hō'ike o Haleakalā is a fulfillment of that vision. This classroom-based curriculum provides educators with background information, resources, teaching suggestions, and activities for teaching science

and other academic skills in the context of topics and issues relevant to Haleakalā, Maui, and the other Hawaiian Islands.

Hō'ike o Haleakalā is a multi-disciplinary, science-based environmental education curriculum that supports State of Hawai'i high school educational standards, particularly in the science disciplines. Each activity is correlated to state science standards, offering educators a way to fulfill educational requirements using local ecosystems and issues as a context. These materials help you bring science home for your students while fostering a strong science background and critical-thinking skills.

Today's young people have the future of Hawai'i in their hands. They need to know the value of our natural and cultural environment before they can be active stewards. *Hō'ike o Haleakalā* is a celebration of this unique heritage, an exploration of the modern landscape, and an invitation to stewardship.





How to Use This Curriculum

Hō'ike o Haleakalā can be used to structure a semester-long (or longer!) course focusing on native ecosystems and natural resource management issues. Alternatively, the modules, units, and activities in this curriculum may be taught separately. Activities may be infused into standard science classes and some are also suited to use in language arts, mathematics, Hawaiian studies, or social studies classes.

Curriculum Components

The *Hō'ike o Haleakala* curriculum is divided into four modules, each of which covers a discrete ecosystem on Haleakalā. The modules—and the icons used to represent the ecosystems—are:



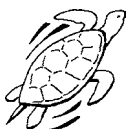
Alpine/Aeolian

The wolf spider (*Lycosa hawaiiensis*) is an endemic species found only near the summit of Haleakalā.



Rain Forest

The 'ākohekohe or crested honeycreeper (*Palmeria dolei*) is an endemic forest bird once found on both Maui and Moloka'i but now found only on East Maui. It is endangered.



Coastal

The honu or green sea turtle (*Chelonia mydas*) is an indigenous reptile that spends much of the year in the coastal waters around the main Hawaiian Islands, migrating up to 800 miles to the Northwestern Hawaiian Islands for summer nesting season. The honu is listed as a threatened species.



Marine

The humuhumunukunukuapua'a or Picasso triggerfish (*Rhinecanthus rectangulus*), a common fish on shallow reef flats, was voted the Hawai'i State Fish in 1984. Its Hawaiian name means “nose like a pig.”

You'll find the icon for each module in the header of each page of that module.



All of the pages associated with the curriculum as a whole (such as this introduction or the glossary) are indicated by an icon depicting 'āhinahina, the Haleakalā silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*). The 'āhinahina is a threatened endemic plant found only on the upper slopes of Haleakalā, and associated around the world with this place.

Each module is divided into five units, each comprised of two to four distinct activities. Each unit and many of the activities may be used separately to supplement your existing lesson plans. Or teach one or more units or an entire module in sequence for a more complete learning experience.



Module Format

Each module consists of five units. Together these units comprise a thorough exploration of the ecosystem. Individual units in each module address key aspects of the ecosystem’s physical characteristics, plant and animal species and relationships, and related management issues.

Module Introduction

- **Ecosystem Connections**—Two pages that give a visual sense of the ecosystem and, through quotations and Hawaiian chant, illustrate its importance to humans
Photocopy these pages for students or make acetates of them to introduce the ecosystem before beginning a module or unit.
- **Ecosystem Summary**—An overview of ecosystem characteristics and status
- **Traditional Hawaiian Significance**—A brief account of the Hawaiian cultural significance of the life zone
- **Journal Ideas**—Suggested topics for journal entries or writing assignments to get students thinking about the ecosystem
- **To Get a Feel for . . .** —A brief activity to introduce students to the life zone
- **Units at a Glance**—An overview of the five units that comprise each module, including the topics covered, the importance of the unit, and constituent activities
- **Optional Field Activities**—A description of field trips, service projects, and other field learning opportunities related to the ecosystem

Five Units

Each unit includes:

- **Introductory Information**—Includes a brief unit overview (read aloud to students before beginning a unit or an activity), length of the unit, and unit focus questions.
- **Unit at a Glance**—Activity-by-activity summary including:
 - Description
 - Length
 - Prerequisite Activity (if any)
 - Objectives
 - DOE Science Standards and Benchmarks met by the activity.
- **Enrichment Ideas**
Use these ideas to build on the activities in each unit. These include suggestions for independent projects, additional research, extending the activities, and putting knowledge into action.
- **Resources for Further Reading and Research**
These resources may be equally useful to both instructors and students.



- **Activity Instructions and Materials**

- **Materials & Setup**—Materials and equipment needed for the activity
- **Instructions**—Step-by-step guidance for conducting the activity
- **Journal Ideas**—Topics for journal entries or stand-alone writing assignments

These written assignments are integral parts of each activity, often helping students explore their personal connections with the subject matter and cement key learning objectives. Selecting from among these—or creating your own topics—also help you focus on the standards and objectives that are most important to you. Some of the journal ideas are appropriate for using before and after a unit to give students an opportunity to reflect on what they learned.

Have students keep a journal if you are teaching the entire curriculum or a substantial piece of it. Collect journals periodically to assess student learning and reflection. If you are teaching a single activity or unit, you may choose to use the journal ideas as writing assignments instead of topics for journal entries.

- **Assessment Tools**—Ideas to help you assess student performance
- **Teacher Background**—Additional information, intricate activity instructions, and other support
- **Masters for Overhead Acetate Transparencies, Game Cards, and Other Instructional Materials**—These masters may be easily identified by looking for the descriptive label in the page header (e.g., “Game Card Master”).
- **Masters for Student Pages**—These activity, data, or reading sheets to duplicate for student use are easily identified by a shaded bar running the length of the page in the right-hand margin containing the label “Student Page.”

Vocabulary Words

Technical terms and those that might be difficult for students to understand are explained or defined in the text of student pages and enclosed in quotation marks the first time they are used. These words are also included in the glossary that accompanies this curriculum at the beginning of each module. This glossary is designed as an easy reference for instructors, but it may be photocopied for student use as well. Most glossary words are followed by a notation indicating the unit(s) in which the terms are used. Those that include no unit number notation are words common to most of the units such as “ecosystem.”

Additional Resources

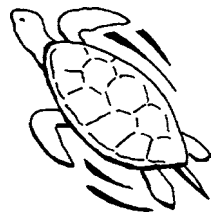
A complement of additional resources such as reports, game boards, reference books, and video tapes accompanies this curriculum. See notations within individual activities that indicate these materials. Where possible, these materials are included in a pocket that accompanies the relevant unit. Resources that are too large to fit in such a pocket are included separately.



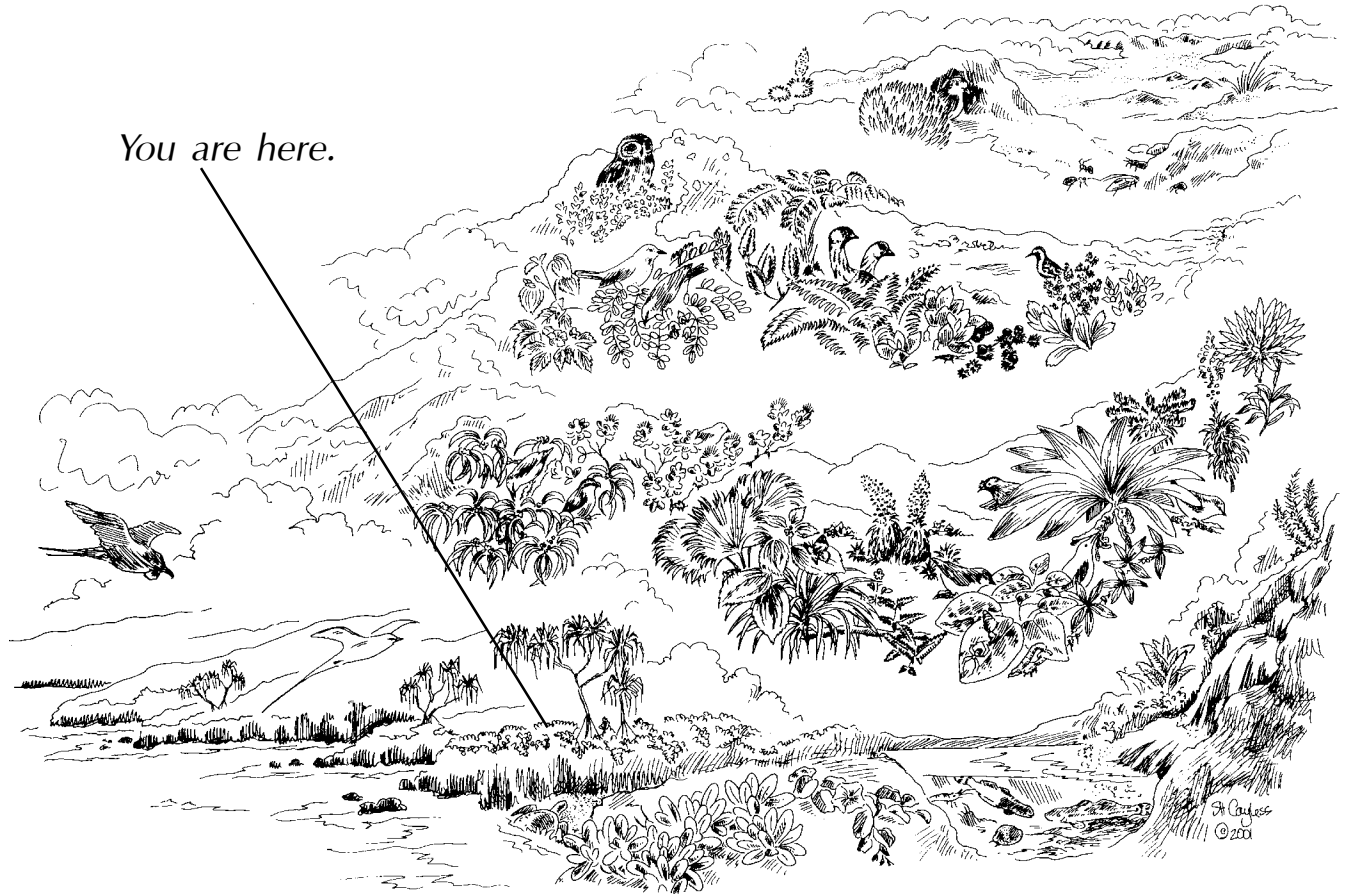
Beyond the Classroom & Beyond This Curriculum

With the help of *Hō'ike o Haleakalā*, you can bring Haleakalā into your classroom, helping to make the unique natural history and ecology of the island a part of your students' lives. The activities that are included in *Hō'ike o Haleakalā* are an excellent accompaniment to field trips, service projects, and other activities that take students outside the classroom to experience the unique natural environment they are studying. Each module contains suggestions and contact information for field-based learning.

Whether you select a single activity or teach an entire course using *Hō'ike o Haleakalā*, we thank you for joining us in spreading the word about the unique and imperiled environment of our island home.



Coastal Module



You are here.

● ● ● What Does the Coastal Zone Mean to You?

These reflections are offered by individuals involved in studying and protecting the native ecosystems of Haleakalā.

I think of seabirds on the cliffs, of magnificent waterfalls cascading into the rough, deep, sapphire-blue waters of Kīpahulu and Kaupō.

—Kalei Tsuha

Sand, salt, ‘opihi, limu
Watching *hunakai* (sanderlings) at the water’s edge
Exploring tidepools

—Kim Martz and Forest Starr

This is where the land meets the sea. All the forces of the universe play in this realm of tides and dunes, of drifters and colonizers. Here the embrace to those who have come ashore: to those who were set adrift and found a home, and to those who searched the skies upon a journey home. Here a people have nurtured Papa, their mother, who has in turn sustained generations of offspring from *Hāloa* to *honu‘ea*.

—Eric Andersen

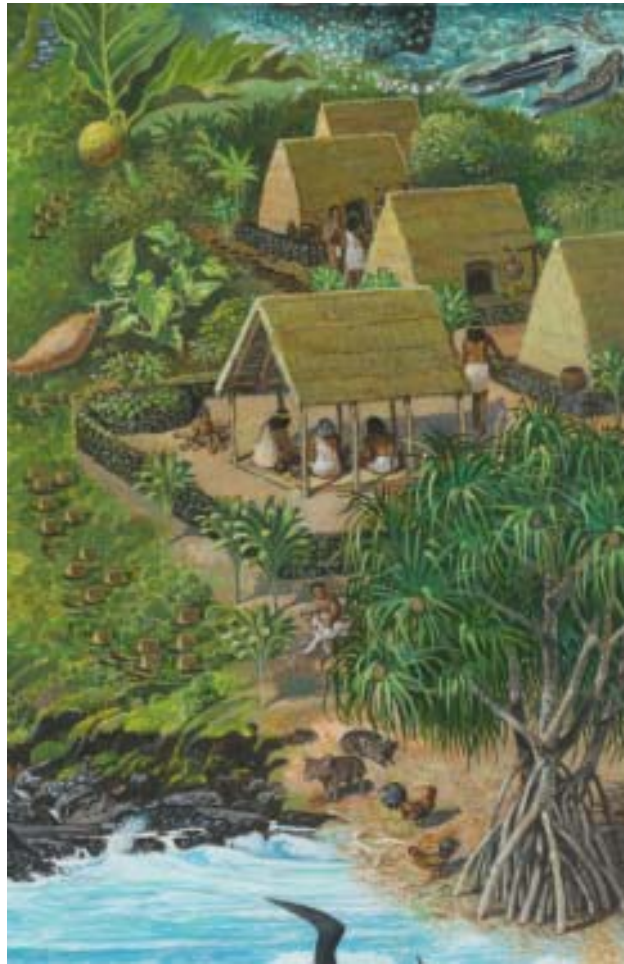
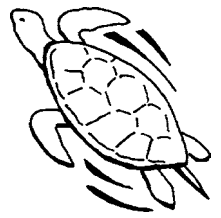


Illustration: John Dawson

`ōlelo no`eau

Ka `ili hau pā kai o `Alio.

Wet be the sea sprays of `Alio.

This is a reference to a strong shore-dweller. Salt air and sea sprays make the bark of the *hau* trees on the shore stronger than those of the upland. `Alio is a place on Kaua`i.

Ka i`a a ka wai nui i lawe mai ai.

The fish borne along by the flood.

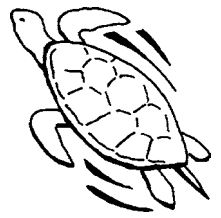
The `o`opu, which was often carried to the lowlands in freshets.

Ne`eaku, ne`e mai keone o Punahoa.

That way and this way shifts the sand of Punahoa.

Said of a group that divides, or of an undecided person who shifts one way and then another.

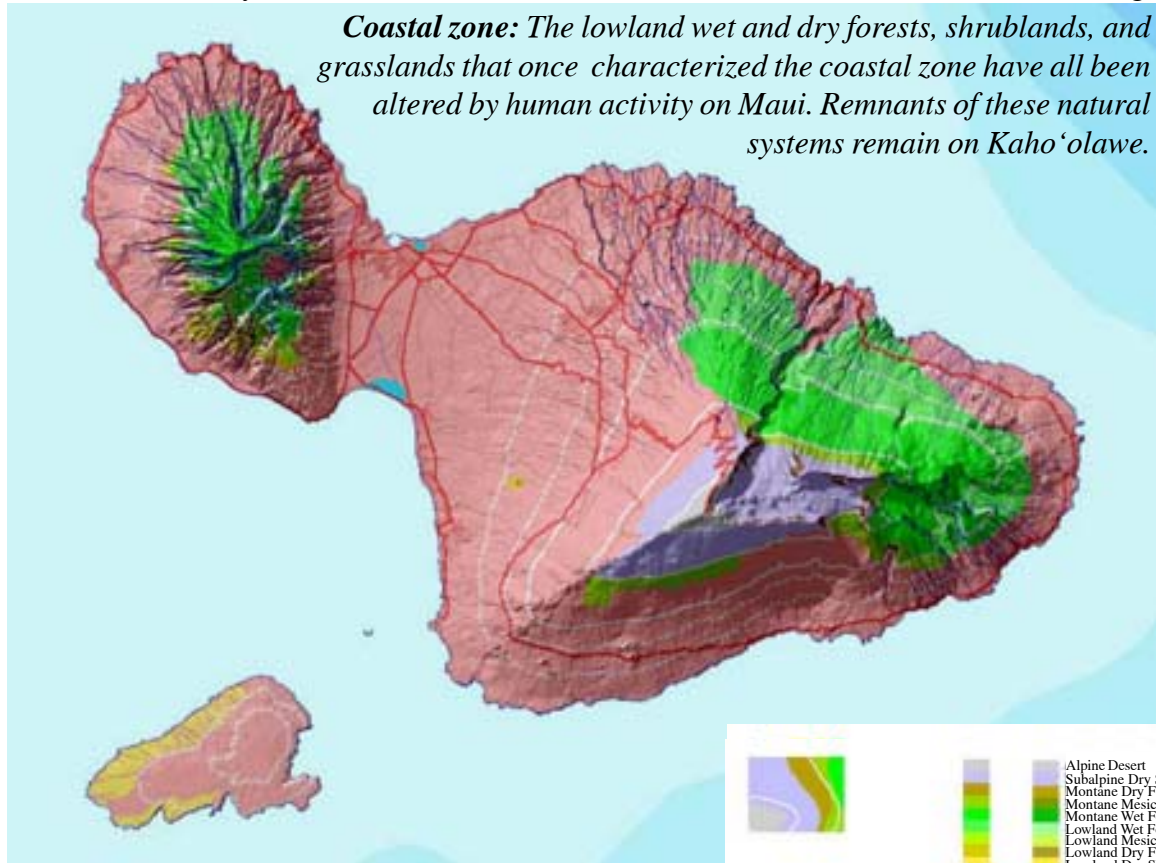
from: *`Ōlelo No`eau*
Hawaiian Proverbs & Poetical Sayings
Mary Kawena Pukui
Bishop Museum Press, Honolulu 1983



Ecosystem Summary

Where on Haleakalā?

The coastal ecosystem is located at low elevations at and near the seashore surrounding the whole of



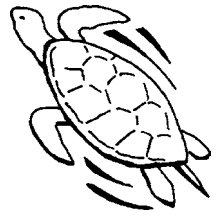
*Location of remaining native ecosystems on Maui
(Map: Hawai‘i Natural Heritage Program, October 1999)*

Haleakalā.

Basic Characteristics

The coastal ecosystem encompasses many different plant and animal communities, the composition of which are greatly influenced by proximity to the ocean. Physical and behavioral adaptations that enable organisms to tolerate high salt concentrations and other drying conditions are common in the *coastal strand*, where salt spray and seawater are strong influences.

In other parts of the coastal zone, salt spray and seawater are not influences, and vegetation is determined more by the amount of rainfall. Windward coastal areas may receive up to four times more rain (up to 300 centimeters or 120 inches per year) than leeward areas, with strong winds being common. Coastal plants grow on substrates that range from old coral colonies to basalt cliffs and boulders, and from sandy beaches to lava and ash.



Compared to other ecosystems on Maui, the coastal zone has a higher ratio of indigenous to endemic species. Proximity to the ocean makes the coastal ecosystem less isolated than other ecosystems. An ongoing influx of new organisms—and genetic input—is more likely here because of the ocean currents, so large numbers of endemic species have not evolved in the coastal zone.

At one time, many coastal areas were covered by shrubby native vegetation including *naupaka* and *ma'o* (Hawaiian cotton), or even forested with trees such as *hala*, *hau*, and *loulou*, the native Hawaiian fan palm.

Did You Know?

The phenomenon of “zonation” is typical in coastal environments, particularly near shoreline. Zonation refers to a progressive change in types of organisms or plant and animal communities linked to habitat conditions. In the coastal zone, the determining conditions are salt concentration and availability of fresh water.

Status and Threats

Of the life zones on Haleakalā, the coastal ecosystem is perhaps the one that has been most altered by human activity. Most coastal areas have been and continue to be heavily used by humans and altered by activities such as cattle grazing, draining or modifying wetlands, and recreational, urban, or resort development. Today, many people know this zone as a place to live, go to school, shop, and play. From the few remnants of native coastal shrublands and forests that remain today, it is difficult to form a clear image of coastal ecosystems before human habitation.

Today, nonnative plants, such as *kiawe* and *koa haole*, dominate many coastal areas. Introduced rats, cats, mongooses, and dogs prey upon and harass nesting turtles, water birds, and seabirds. Development continues to alter this much-used ecosystem.

On the other hand, protected areas, such as Keālia Pond National Wildlife Refuge and 'Āhihi-Kīna'u Natural Area Reserve, do exist. In some coastal areas, dune restoration projects and efforts to plant native coastal vegetation are helping to bring back small patches of the native ecosystem.

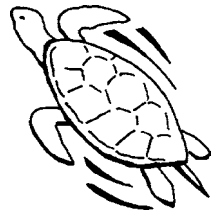


Traditional Hawaiian Significance

In the traditional system of dividing the Hawaiian Islands into political regions, the *ahupua'a* was the most important land division. *Ahupua'a* usually extended from the mountains to the outer edge of the reef in the ocean, cutting through all of the major environmental zones along the way. Each *ahupua'a* encompassed most of the resources Hawaiians required for survival, from fresh water to wild and cultivated plants, to land and sea creatures. Because of their dependence on the land's resources, the Hawaiians developed a complex system of resource management and conservation that could sustain those resources over time.

Coastal areas were the most densely populated lands in ancient times because they provided easy access to abundant food and medicinal plants, as well as ocean resources including food plants and animals, and transportation. They continue to be important in Hawaiian culture, providing *lei* material, medicinal plants, and access to intertidal areas where marine plants and animals such as *limu* and 'opihi are gathered.

Even before the arrival of Europeans, the original vegetation of coastal lowland areas had been dramatically altered by more than 1000 years of Hawaiian use. Agricultural practices such as dryland



farming, and clearing and burning land for cultivation removed native vegetation, and for the most part, plants introduced by the Polynesian settlers took over once the fields were left fallow or abandoned. Native vegetation was also degraded in areas that were not cultivated through practices such as using fire to encourage the growth of grasses for thatching, gathering firewood, and taking timber for construction.



Journal Ideas

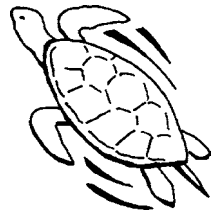
Use some or all of the following topics for student journal entries:

- Listen to each *`ōlelo no`eau* and their exact translations. Finally, listen to the interpretation of the literal translations.
- Pick one *`ōleleo no`eau* and explain why you think this expression was used. What does it tell you about the observational powers of the early Hawaiians, how they viewed the coastal areas, the living things there, and their own place in the landscape? Which *`ōlelo no`eau* shows an understanding of the connections between the upland streams and estuaries?
- What kinds of landscapes come to mind when you think of coastal areas? What are your favorite areas and memories?
- Is there a person who has taught you about the coast? If so, what have you learned from this person?



To Get a Feel for the Coastal Zone

Have students brainstorm all of the different kinds of land areas they can think of near the ocean, such as sandy beaches, gravelly beaches, rocky coastlines, cliffs, benches that contain tidepools, and wetlands such as Keālia Pond. Over a weekend, have students visit a coastal area of their choosing, observing the patterns of vegetation from the shoreline inland.



● ● ● Coastal Units at a Glance

Unit 1

Beach Today, Gone Tomorrow?

Subject

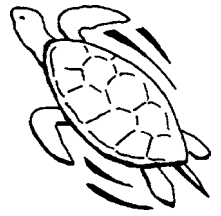
Coastal geology and processes

Importance

The geologic features and processes of the coastal ecosystem are a strong influence on the dynamic environmental zones in which coastal plants and animals live.

Activities in this unit

- **Sand Analysis Lab**
Students analyze sand from two Haleakalā beaches to determine differences in composition and grain size.
- **Where Does the Sand Come From?**
Students use maps and other information to generate hypotheses that explain the differences in sand composition of the two beaches studied in Activity #1.
- **Causes and Consequences of Coastal Erosion**
Students project coastal erosion along two sandy beaches and identify potentially hazardous areas for development.



Unit 2

Coastal Connections

Subjects

Native and introduced plant and animal species

Habitat zonation

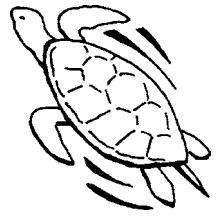
Origin and distribution of species

Importance

Coastal areas were important in ancient Hawaiian society, and they continue to be popular areas for habitation, recreation, and food. They also offer distinct habitats for a wide range of plants and animals. Many Hawaiian coastal species are also found throughout the world, adapted to live near the ocean and disperse through ocean currents.

Activities in this unit

- **Coastal Inhabitants**
Students make visual representations of how species composition of coastal areas has changed since human settlement.
- **Coastal Jeopardy Game**
Students hone and demonstrate their knowledge of Hawaiian coastal species by playing a game.



Unit 3

Anchialine Detectives

Subjects

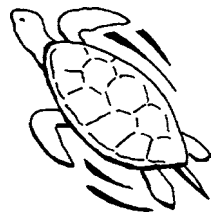
Anchialine pond habitats
Hypothesizing
Tolerance to environmental extremes

Importance

Anchialine ponds are a habitat type found on relatively few islands scattered around the world, including East Maui. These ponds are inhabited by species of small red shrimp that, despite their seeming isolation, are also associated with ponds in far-off parts of the world.

Activities in this unit

- Anchialine Pond Detective Story
Students solve six “mysteries” related to anchialine ponds and red shrimp that are found in these ponds.
- Salinity Tolerance Lab
Students conduct a lab to test brine shrimp tolerance for different salinity levels.



Unit 4

Fire Ants and the Future of Maui Wetlands

Subjects

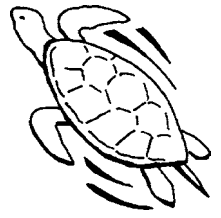
Pest ants and the threats they pose to native coastal ecosystems
Invasive species prevention and management

Importance

No ant species are native to Hawai‘i, but many have become naturalized and are now part of the islands’ ecosystems. Among the pest ants that have not yet been discovered on the island of Maui are two species of “fire ants” known for their painful bite. Many people believe that one of these species, the red imported fire ant, is very likely to become the next severe pest invasion in Hawai‘i unless dramatic steps are taken to prevent its arrival and establishment.

Activities in this unit

- **Finding the Little Fire Ant**
Students collect ants from their homes or other locations around the island. They use a simple key to identify ants that may be the little fire ant, which has not yet been discovered on Maui.
- **Red Imported Fire Ant Prevention and Quick Response Plan**
Students research and develop an island-wide plan to prevent the red imported fire ant from becoming established on Maui and to respond rapidly to control the spread of any populations that are found.
- **Race to the Wetlands Game**
Students play a game that tests their knowledge of fire ants and ant prevention and control strategies.



Unit 5

Coastal Issues in the News

Subjects

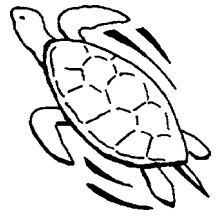
Coastal issues
Media coverage

Importance

Coastal areas tend to be heavily used and inhabited. Disagreements over the appropriate use of these areas are the basis of issues that we often learn about through media coverage. Understanding coastal issues and how they are communicated through the media is critical to prepare students to play a productive role in society.

Activities in this unit

- Coastal Issues in the News
Students collect, analyze, and discuss newspaper articles covering coastal issues on Maui.
- Coastal Journalism Projects
Students research, conduct interviews, and write their own newspaper-style articles on a Maui coastal issue of their choosing.



● ● ● Optional Field Activities

Getting students out in the field puts them in direct contact with the ecosystem and gives them a context for learning. These are excellent supplements to the classroom-based activities of the rain forest module, giving students the excitement and challenge of hands-on experiences. Here is a listing of resources for field trips and other extensions.

Field Trips

Keālia Pond National Wildlife Refuge

Description

Flexible offerings tailored to the class and learning objectives

Most field trips focus on the refuge wetlands, and activity options include identifying birds and plants, water quality testing, collecting and identifying aquatic invertebrates, pulling invasive plants, and outplanting natives. Refuge staff also provide educational tours of the sand dune restoration areas on refuge property. Your class may eat lunch in the picnic area near the refuge office.

Field Trip Time

Approximately two hours (not including travel time)

What to Bring

- Walking shoes that can get dirty or muddy if it's wet (Slippers do not offer much protection against *kiawe* thorns and occasionally muddy trail conditions.)
- Hat and sunscreen
- Water
- Lunch (optional)

Group Size Limits

None

Contact

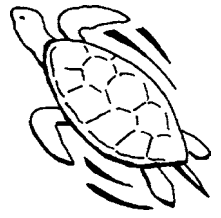
Keālia Pond National Wildlife Refuge office, 875-1582

Fees

No fees

Getting There

The refuge drive is located at milepost six on the Mokulele Highway (Hwy. 311), approximately 11 miles from Wailuku.



Hawaiian Islands Humpback Whale National Marine Sanctuary

Description

Sanctuary staff generally offer field trips for grade school groups, but will work with high school teachers to design an educational experience appropriate to the class and learning objectives. Educational resources include humpback whale exhibits and specialists, a traditional Hawaiian fishing pond and an on-staff Hawaiian culture expert, a *lānai* that offers excellent whale viewing from December through April, and populations of many native coastal plants. Adjacent beach parks offer opportunities to explore sand dune ecology or sea turtle nesting, or collect *limu* as a focal point for learning about its uses.

Field Trip Time

Flexible, depending upon the schedule you arrange with sanctuary staff

What to Bring

Depends upon specific field trip plans

Group Size Limits

None

Larger classes may be divided into smaller groups to rotate through several learning stations.

Contact

Call the education coordinator at 879-2818.

Fees

None

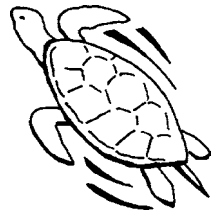
Getting There

The Hawaiian Islands Humpback Whale National Marine Sanctuary office is located at 726 S. Kihei Road, approximately 13 miles from Wailuku.

Connecting Your Field Trip to the Coastal Module

Here are some ideas for student assignments that link the field trip to the classroom activities of the coastal module:

- Have students look for and record signs of human-caused alterations to the coastline such as those they learned about in Coastal Unit 1, Activity #3 “Causes and Consequences of Coastal Erosion.”
- Have students make field sand observations, noting what they think the sand is made of and why. These observations build on Coastal Unit 1, Activity #1 “Sand Analysis Lab.”
- Have students make journal entries about the main threats to coastal ecosystems, how sand dunes are formed and why there are so few left on Maui, or traditional Hawaiian use of coastal areas.



Extensions

- The Hawai'i Department of Land and Natural Resources *Na Ala Hele* Trails and Access Program organizes volunteer trail maintenance opportunities. Individuals or groups of students over age 14 are welcome to volunteer. Trail maintenance takes place in a variety of forested and coastal areas. Call 873-3509 for information about upcoming volunteer opportunities.
- Maui Ocean Center offers volunteer service project opportunities. These include beach cleanup and others to be arranged by calling the Education Director at 270-7000 Ext. 128.
- Keālia Pond National Wildlife Refuge arranges service projects on the refuge for school and community groups. These projects usually involve planting native species or dune fence repair. Contact the refuge office at 875-1582.



Coastal Unit 1

Beach Today, Gone Tomorrow?

Overview

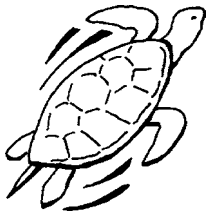
On Maui, coastal areas have been the focal point of human use since people first arrived here. The coastal ecosystem is the most altered of all native ecosystems on the island, in part due to the physical changes that people have brought to the coastal environment. This unit engages students in understanding the natural processes that shape the shorelines, as well as the effects of human use and development.

Length of Entire Unit

Three class periods

Unit Focus Questions

- 1) What factors account for differences in sand composition between beaches?
- 2) How are dunes, beaches, and reefs related in the process of maintaining beaches?
- 3) What factors cause shorelines to change over time?
- 4) What are the implications of shoreline changes over time for human activity in coastal areas?



Unit at a Glance

Activity #1

Sand Analysis Lab

Students analyze sand from two Haleakalā beaches to determine differences in composition and grain size.

Length

One class period, followed by homework

Prerequisite Activity

None

Objectives

- Analyze sand samples to distinguish among different types of sand found on island beaches.

DOE Grades 9-12 Science Standards and Benchmarks

DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.

- Develop and clarify questions and hypotheses that guide scientific investigations.
- Organize, analyze, validate, and display data/information in ways appropriate to scientific investigations, using technology and mathematics. (*Students analyze data, for partial fulfillment of this benchmark.*)
- Formulate scientific explanations and conclusions and models using logic and evidence.

Activity #2

Where Does the Sand Come From?

Students use maps and other information to generate hypotheses that explain the differences in sand composition of the two beaches studied in Activity #1.

Length

One class period

Prerequisite Activity

Activity #1 “Sand Analysis Lab”

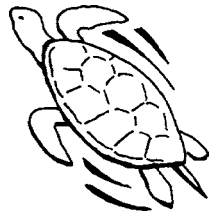
Objectives

- Generate hypotheses that explain the composition of different sandy beaches.

DOE Grades 9-12 Science Standards and Benchmarks

DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.

- Develop and clarify questions and hypotheses that guide scientific investigations.
- Organize, analyze, validate, and display data/information in ways appropriate to scientific investigations, using technology and mathematics.
- Formulate scientific explanations and conclusions and models using logic and evidence.
- Communicate and defend scientific explanations and conclusions.



Activity #3

Causes and Consequences of Coastal Erosion

Students project coastal erosion along two sandy beaches and identify potentially hazardous areas for development.

Length

One class period (may extend into a second period for some classes)

Prerequisite Activity

None

Objectives

- Explain key elements and relationships in the natural processes that shape coastal areas, including the relationships among dunes, beaches, and reefs.
- Illustrate shoreline changes over time and project future changes.
- Explain how this type of projection could be useful in coastal management.

DOE Grades 9-12 Science Standards and Benchmarks

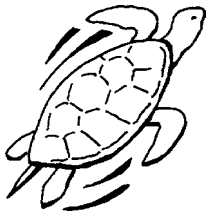
USING UNIFYING CONCEPTS AND

THEMES: Students use concepts and themes such as system, change, scale, and model to help them understand and explain the natural world.

- **SYSTEM:** Explain the function of a given system and its relationship to other systems in the natural world.
- **CHANGE:** Explain the effect of large and small disturbances on systems in the natural world.

Enrichment Ideas

- In Activity #1 “Sand Analysis Lab,” use graduated geology sieves to obtain a more accurate measurement of sand grain sizes. If your school does not have a set of graduated geology sieves, make your own set of substitute strainers of different sizes. To construct sieves, use window screening with different mesh sizes mounted on simple wooden frames or on the bottoms of plastic containers such as those that margarine comes in. Measure and mark the grid size of each sieve, and you’re set!
- In Activity #1 “Sand Analysis Lab,” weigh out a small portion of sand (1/4 tsp.) and separate biotic and abiotic particles. Weigh each portion and record percentage composition.
- For a more detailed sand analysis lab, see E. Barbara Klemm, et al., *The Fluid Earth: Physical Science and Technology of the Marine Environment*, Curriculum Research and Development Group, University of Hawai‘i, Honolulu, 1990, pp. 139-157.
- Analyze sand from other beaches around the island. Use the maps and information included in this unit, along with additional research to hypothesize about the origin of the sand on each beach. Sand collection guidelines are included in the teacher background, Activity #1 “Sand Analysis Lab” (p. 8).
- Compare sand samples taken from the same beach. Take one sample close to the back of the beach and one from the swash zone where water washes up onto the lower beach. There should be a difference in particle size from front to back, demonstrating differences in wave action on different parts of the beach.



- Visit one of the “coastal erosion hotspots or watchspots” identified in the *Beach Management Plan for Maui* at www.soest.hawaii.edu/SEAGRANT/bmpm/introduction.html. Observe the shoreline, looking for signs of erosion, structures that have been put in place to slow erosion, alterations that have been made to dunes, and buildings or other structures that look like they may be threatened by coastal erosion. Illustrate written reports with photos or sketches of the area.
- Research the pros and cons of different techniques for beach preservation. The Maui Beach Management Plan (see Whang and Fletcher in “Resources for Further Reading and Research” section) is a good place to start, as well as Internet research using some of the terms used in the Activity #3 “Causes and Consequences of Coastal Erosion” readings.

Resources for Further Reading and Research

Clark, J. R. K., *The Beaches of Maui County*, University of Hawai‘i Press, Honolulu, 1980.

Davis, Richard A. Jr., *The Evolving Coast*, Scientific American Library, New York, 1997.

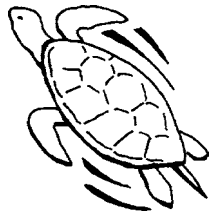
Fletcher, C. H., R. A. Mullane, and B. M. Richmond, “Beach Loss Along Armoured Shorelines on Oahu, Hawaiian Islands,” *Journal of Coastal Research*, Vol. 13, No. 1, 1998, pp. 209-215.

Hawai‘i Department of Land and Natural Resources, Coastal Lands Program, “Coastal Erosion and Beach Loss in Hawai‘i” at www.soest.hawaii.edu/SEAGRANT/CEaBLiH.html.

Macdonald, Gordon A., Agatin T. Abbott, and Frank L. Peterson, *Volcanoes in the Sea: The Geology of Hawai‘i*, University of Hawai‘i Press, Honolulu, 1983.

(Chapter 8 provides detailed background about forces that weather rock and lead to soil formation.)

Whang, Dennis, and Charles Fletcher, Hawai‘i Office of State Planning, Coastal Zone Management Program, “Beach Management Plan with Beach Management Districts” at www.soest.hawaii.edu/SEAGRANT/bmpm/introduction.html.



Activity #1

Sand Analysis Lab

● ● ● Class Period One *Sand Analysis Lab*

Materials & Setup

- “Oneuli and Oneloa Beach” acetates (master, pp. 12-13)
- Overhead projector and screen
- Map of Maui

For each lab group of three to four students

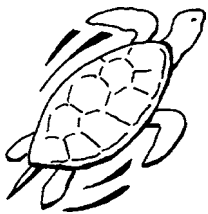
- Student Page “Sand Analysis Lab Procedures and Resources” (pp. 14-17)
- Student Page “Sand Analysis Lab Data Sheet” (pp. 18-20)
- Two 1/4-cup samples of sand, one each from Oneuli and Oneloa beaches (included with this curriculum; instructions for collecting more in “Guidelines for Collecting Sand,” p. 8)
- Four sheets of notebook paper or white paper
- Millimeter ruler (ideally with fractions of millimeters marked)
- Teaspoon
- Two petri dishes or small bowls
- Two tbsp. vinegar
- Two hand magnifying lenses or dissecting microscopes (higher magnification is better)
- Forceps capable of picking up one grain of sand
- Two weighing papers or small squares of construction paper
- Magnet
- Glue and a few toothpicks OR cellophane tape

For each student

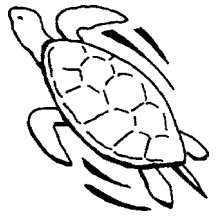
- Student Page “Questions Following the Sand Lab” (pp. 21-22)

Instructions

- 1) Before beginning the lab, ask students to think of their favorite beaches on Maui. What makes these beaches stand out from the others?
- 2) Have each student identify a familiar beach and write a description of the sand at that beach. Challenge students to make that description as detailed as possible. (If students are keeping a journal, have them write these descriptions as entries.) If students are having difficulty, ask them questions such as:
 - What does it feel like when you walk or sit on it? Is it smooth, sharp, gritty?
 - What color or colors is it?
 - Is the sand uniform size, or are there larger pieces of rock, coral, or shells mixed in with smaller sand grains?
 - Does it stick to your body or is it easy to brush off?
 - Are the grains coarse or fine? How do they compare with other beaches?



- 3) Ask several students to share their descriptions until you have heard some clear contrasts. Then have the class draw comparisons among the sandy beaches described. Ask students to brainstorm about what might cause these kinds of differences in sands at different beaches. Write their ideas on the board or overhead.
- 4) Have students brainstorm what sand is made of and record those ideas as well. (There are two basic components of sand: “Biogenic” components are the fragmented or whole remains of marine animals and plants that have hard skeletons of calcium carbonate. These organisms include corals, molluscs, sea urchins, single-celled animals called “foraminifera,” and algae. “Detrital” components are fragments of rock that have been worn down through weathering and erosion. They include eroded basalt, the most common material in lava flows; sharp fragments of lava called volcanic glass; and minerals such as garnet, olivine, and magnetite.)
- 5) Have students brainstorm what could cause differences in grain size (how coarse or fine the sand is) at different beaches. (Particle size is influenced by the materials from which the sand is made and how easily they are broken and worn down. Another key factor in determining particle size is wave size and energy. Each crash of a wave on shore temporarily suspends some sediment—sand—in water. The amount of sediment is directly proportional to the size of the wave. The size of the sediment that can be transported by a wave is also proportional to its size and energy. A beach subject to large crashing waves will generally have coarser sand than one that is lapped by small calm swells because the larger waves can transport the finer sediments out to sea. This factor can account for seasonal differences in the sand size at beaches, as well.)
- 6) Display the acetates of Oneuli and Oneloa beaches. Locate the beaches on the map of Maui (they are just north and south of Pu‘u Ōla‘i, near Mākena). Find out if any students have been to these beaches. They may know the beaches by other names. Oneuli is sometimes called “Black Sand Beach.” Oneloa is also known as “Big Beach.” Tell students they will be studying these two beaches more during this activity.
- 7) Divide the class into lab groups of three to four students. Make sure they have all of the equipment they need and hand out the Student Pages “Sand Analysis Lab Procedures and Resources” and “Sand Analysis Lab Data Sheet.”
- 8) Pass out labeled sand samples from Oneuli and Oneloa beaches. Ask students to look at the beach photos (leave the acetate images up) and the sand samples. Ask them to generate hypotheses about the composition and relative grain size of the sand at each beach, and record these hypotheses on their group’s lab sheet.
- 9) Run the sand analysis lab, following the instructions on the Student Page “Sand Analysis Lab Procedures and Resources.”
- 10) As homework, assign the Student Page “Questions Following the Sand Lab.”



Journal Ideas

- Go to a beach and write down everything you can observe about the sand. Think about why it might be the size and composition that it is, and write your ideas.
- Write a chant or a poem about the sand on Oneuli or Oneloa beach.

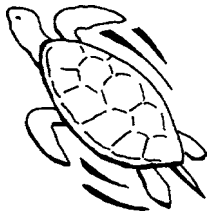
Assessment Tools

- Participation in class discussion
- Lab conduct
- Student Page “Sand Analysis Lab Data Sheet”
- Student Page “Questions Following the Sand Lab” (teacher version, pp. 10-11)

Some teacher-only resources have been omitted from the online document.

They are available as password-protected files at:

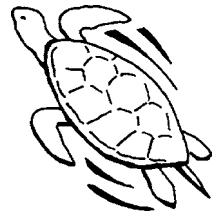
www.hear.org/hoike/teachermaterials



Oneuli Beach



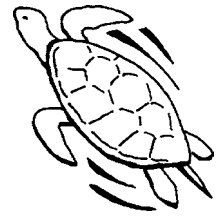
Photos: Ann Fielding



Oneloa Beach



Photos: Ann Fielding



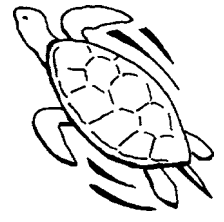
Sand Analysis Lab Procedures & Resources

Materials

- Student Page “Sand Analysis Lab Data Sheet” (pp. 18-20)
- Two 1/4 cup samples of sand, one each from Oneuli and Oneloa beaches
- Two sheets of notebook paper or white paper
- Millimeter ruler (ideally with fractions of millimeters marked)
- Teaspoon
- Two petri dishes or small bowls
- Two tbsp. vinegar
- Two hand magnifying lenses or dissecting microscopes (higher magnification is better)
- Forceps capable of picking up one grain of sand
- Two weighing papers or small squares of construction paper
- Magnet
- Glue and a few toothpicks OR cellophane tape

Sand-Size Lab Procedure

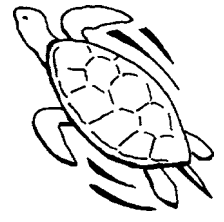
- 1) Make a sand-size grid by drawing four squares of different sizes on a piece of notebook or white paper. The squares should measure: 1.5 mm, 1 mm, .5 mm, .1 mm.
- 2) Spread out a small amount of sand from the first sample on a piece of notebook paper, making a single layer of sand rather than a pile. Use the forceps to select 25 grains of sand from the sample, and measure each using your sand-size grid. Record your measurements on the data sheet. Calculate the percentage of grains that fall into each size range given on the lab data sheet.
- 3) Repeat this procedure for the second sample.
- 4) Now, observe the color of each sand sample, recording your observations on the data sheet. Record how the samples compare to each other in color.
- 5) Record your group’s hypothesis about which sample contains the most “biogenic” sand components, based on comparing the color of the samples. Explain your reasoning. Biogenic sands are made up of the remains of once-living organisms such as shellfish, coral, coralline algae, and sea urchins.
- 6) Using the hand lens or dissecting scope, observe each sample for remains of plants and animals. Use a forceps to pick up individual sand grains for closer inspection. See the lab resource sheets for images of some of the biogenic sand components you might see. Estimate the percentage of biogenic sand in each sample based on your observations.



- 7) Place 1/4-1/2 teaspoon of sand from each sample into a clean, dry petri dish (or bowl). Label each dish with the corresponding beach name. Spread the sand out into an even layer in the bottom of the dish. Pour one tablespoon of vinegar into each dish.

Vinegar and calcium carbonate, the major component of the shells and skeletons that make up biogenic sand particles, react chemically when exposed to each other. The bubbling you will see is the evidence of that reaction. Observe both samples and note whether one of them bubbles more than the other. Record your observations and note which samples seem to contain the most biogenic components.

- 8) Using the hand lens or dissecting scope, look for particles of rocks or minerals in each sand sample. These are “detrital” sand components, meaning they are produced by disintegration or erosion. These components are also referred to as “terrigenous” (originating from land) or “abiogenic” (of a non-living origin). Use the reference sheets provided to help you identify different components. Place samples of your findings on the data sheet with tape or glue.
- 9) Place a small amount of each sand sample on a weighing paper (or square of construction paper). Hold a magnet under the weighing paper and look for particles of sand that are attracted to the magnet. If you find any of these, they are probably magnetite, a mineral that is an oxide of iron. Note their presence on the data sheet.
- 10) After you have finished identifying sand components, answer the questions that follow the data tables.



Lab Resource Sheets

Common Biogenic Sand Components

Some animals (such as corals and molluscs) and plants (including some algae and coralline algae) that live on reefs and in shallow marine waters make hard skeletons of calcium carbonate. Fragments of their skeletal remains form much of the sand found on Hawaiian beaches.

Corals and coralline algae build the framework of reefs, which are then broken down into sand by “bioerosion” and “mechanical erosion.” Bio-erosion refers to the actions of animals that break down the reef, such as grazing fish and urchins, boring sponges and worms, and bivalves that attach themselves to the reef. Mechanical erosion refers to the forces of wave action.

Some living organisms, such as molluscs, “echinoderms” (a phylum of marine animals including starfish, brittlestars, sea urchins, and sea cucumbers), and other plants and animals that form “calcareous” (calcium-based) skeletons, contribute to sand production directly as their remains are broken and polished by wave action and washed up on beaches.

Fragments of coralline algae

These marine algae secrete large quantities of calcium carbonate to form a robust skeleton. Although they are reddish while they are alive, the skeletal fragments are orange, tan, gray, or whitish.



Coral fragments

Countless individual polyps secrete calcium carbonate to form the reefs in which they live. This reef structure is broken down into pieces and grains of various sizes primarily by the action of waves and marine animals. These fragments are white to gray in color and feel gritty.



Calcareous algae

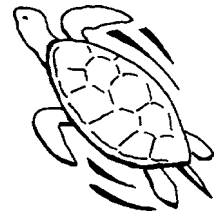
Halimeda is a genus of green algae that secrete small amounts of calcium carbonate to form a delicate skeleton. The fragments of these skeletons are a whitish color.



Molluscs

Marine organisms such as cowries secrete protective shells of calcium carbonate.





Foraminifera

These tiny “shells” are actually skeletons of single-celled animals, “foraminifera.” They are usually tan to yellow in color, and generally round, smooth, and shiny.



Echinoderm spines

Fragments of sea urchin skeletons (or “tests”) and spines are common sand components. They range in color from reddish to greenish, brown, or gray. They may be ornamented with beadlike dots.



Images: Jodi Harney

Common Detrital Sand Components

Other sand components are formed as volcanic land wears down through the weathering and erosive forces of running water, plants, temperature changes, chemical reactions, and wave and wind action. These components are referred to as abiogenic, terrigenous, or detrital grains.

Basalt

This is the primary component of lava flows. Eroded basalt forms dull black, gray, or brownish red grains of sand.

Garnet

These crystals are usually amber-colored but may range to a light pink color. Perfect crystals, which have 12 faces, are rare because wave action rounds off the edges quickly.

Olivine

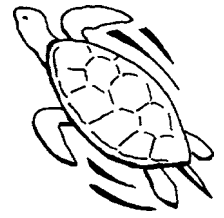
This is shiny, transparent or translucent crystal sometimes found in basalt. It varies from olive green to brownish, and may contain specks of other crystals.

Magnetite

This is a common magnetic mineral with opaque black crystals resembling double pyramids.

Volcanic glass

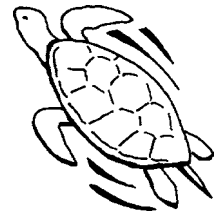
These shiny, black, irregular particles have sharp edges and are formed as hot lava cooled rapidly, often from contact with water.



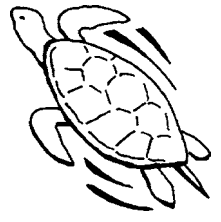
Sand Analysis Lab Data Sheet

Record your hypothesis here:

	Oneloa Beach		Oneuli Beach	
Sand grain size	# of grains > 1.5mm	% >1.5mm	# of grains > 1.5mm	% >1.5mm
	# of grains 1-1.5 mm	% 1-1.5 mm	# of grains 1-1.5 mm	% 1-1.5 mm
	# of grains .5-1 mm	% .5-1 mm	# of grains .5-1 mm	% .5-1 mm
	# of grains .1-.5 mm	% .1-.5 mm	# of grains .1-.5 mm	% .1-.5 mm
Sand size description	Circle the description that best fits: Coarse=>2mm Medium=1-2mm Fine=<1mm Mixed=grains range from coarse to fine		Circle the description that best fits: Coarse=>2mm Medium=1-2mm Fine=<1mm Mixed=grains range from coarse to fine	
Sample color				
Comparison of sample colors				



	Oneloa Beach	Oneuli Beach
Based on color, which sample contains the greatest proportion of biogenic components? Explain.		
Based on the vinegar test and color, estimate the percentage of biogenic components. Explain.		
<p>Detrital components</p> <p>Tape or glue and label an example of each one you find:</p> <ul style="list-style-type: none"> • Basalt • Garnet • Olivine • Magnetite • Volcanic glass 		
Magnetic metals present? Estimate percentage of sample that is magnetic.		



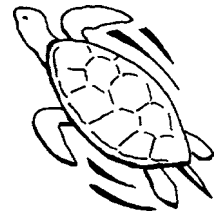
1) Write a one-paragraph description of each sand sample you analyzed. Include information about location, particle size, color, and composition.

•

•

2) Compare the two samples you analyzed.

3) Based on your analysis, was your hypothesis correct? Explain.

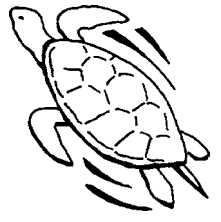


- 3) Scientists who study sand and coastal areas have observed that the average size of particles on a beach is correlated to the slope of the beach. In general, the steeper a beach is, the larger the particle size.

The table below shows part of the Wentworth scale, a system of classifying sediments by particle size. Look at the table and think about how you would set up a study to test whether these relationships are accurately described. Write a description of this study.

Type of sediment	Diameter (mm)	Average beach slope
Cobble	65-265	19°-25°
Pebble	4-64	13°-19°
Granule	2-4	11°
Very coarse sand	1-2	9°
Coarse sand	0.5-1	7°
Medium sand	0.25-0.5	5°
Fine sand	0.07-0.25	5°

*Wentworth grain size scale adapted from E. Barbara Klemm, et al.,
The Fluid Earth: Physical Science and Technology of the Marine
Environment, Curriculum Research and Development Group, Univer-
sity of Hawai'i, Honolulu, 1990, p. 139.*



Activity #2

Where Does the Sand Come From?

● ● ● In Advance *Setting Up Information Stations*

- Set up four information stations around the room using the “Information Station Graphics” (master, pp. 25-30) for three of them and vials of sand from Oneuli and Oneloa beaches for the fourth. (See class period one materials & setup below.)

● ● ● Class Period One *Where Does the Sand Come From?*

Materials & Setup

- Small, labeled vials containing sand samples from Oneuli and Oneloa beaches (samples included with Activity #1, or instructions for collecting more in “Guidelines for Collecting Sand,” p. 8)
- “Information Station Graphics” (master, pp. 25-30)

For each student

- Student Page “Where Does the Sand Come From?” (pp. 31-32)

Instructions

- 1) Hand out a copy of the Student Page “Where Does the Sand Come From?” to each student.
- 2) Have students visit the stations, transferring relevant information to their own maps, and answering the questions on the student page.
- 3) Near the end of class, discuss students’ hypotheses about where the sand that comprises Oneuli and Oneloa beaches originates, and what accounts for the differences in particle size and composition that they observed during Activity #1 “Sand Analysis Lab.”

Journal Ideas

- Find out the meaning of the Hawaiian names, Oneuli and Oneloa. Write a chant or poem, or draw a picture that illustrates where the sand from each of these beaches seems to originate and how it might be deposited on the beach.

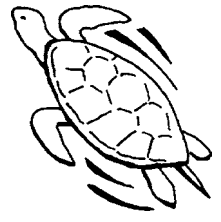
Assessment Tools

- Student Page “Where Does the Sand Come From?” (teacher version, p. 24)
- Journal entries

Some teacher-only resources have been omitted from the online document.

They are available as password-protected files at:

www.hear.org/hoike/teachermaterials



Information Station Graphics

Station #1: Aerial Photos of Oneuli and Oneloa Beaches

Oneuli Beach

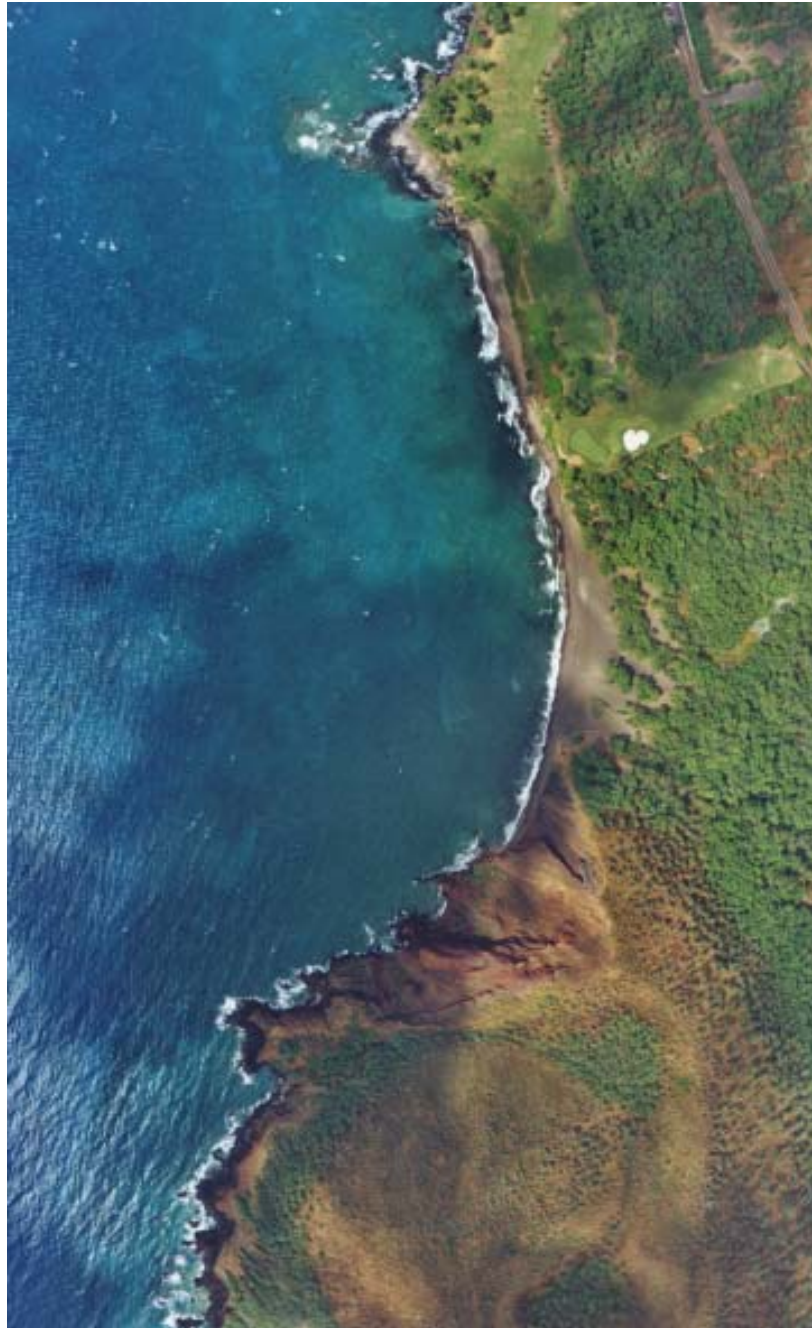
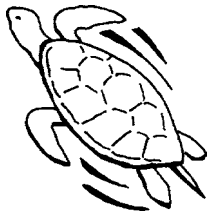


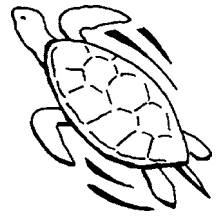
Photo: Air Survey Hawai'i



Oneloa Beach



Photo: Air Survey Hawai'i

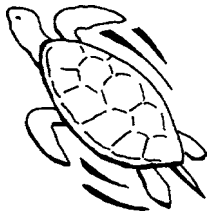


Station #2: Photos of Oneuli and Oneloa Beaches

Oneuli Beach



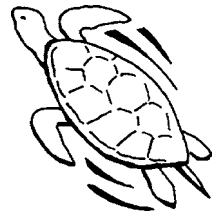
Photos: Ann Fielding



Oneloa Beach

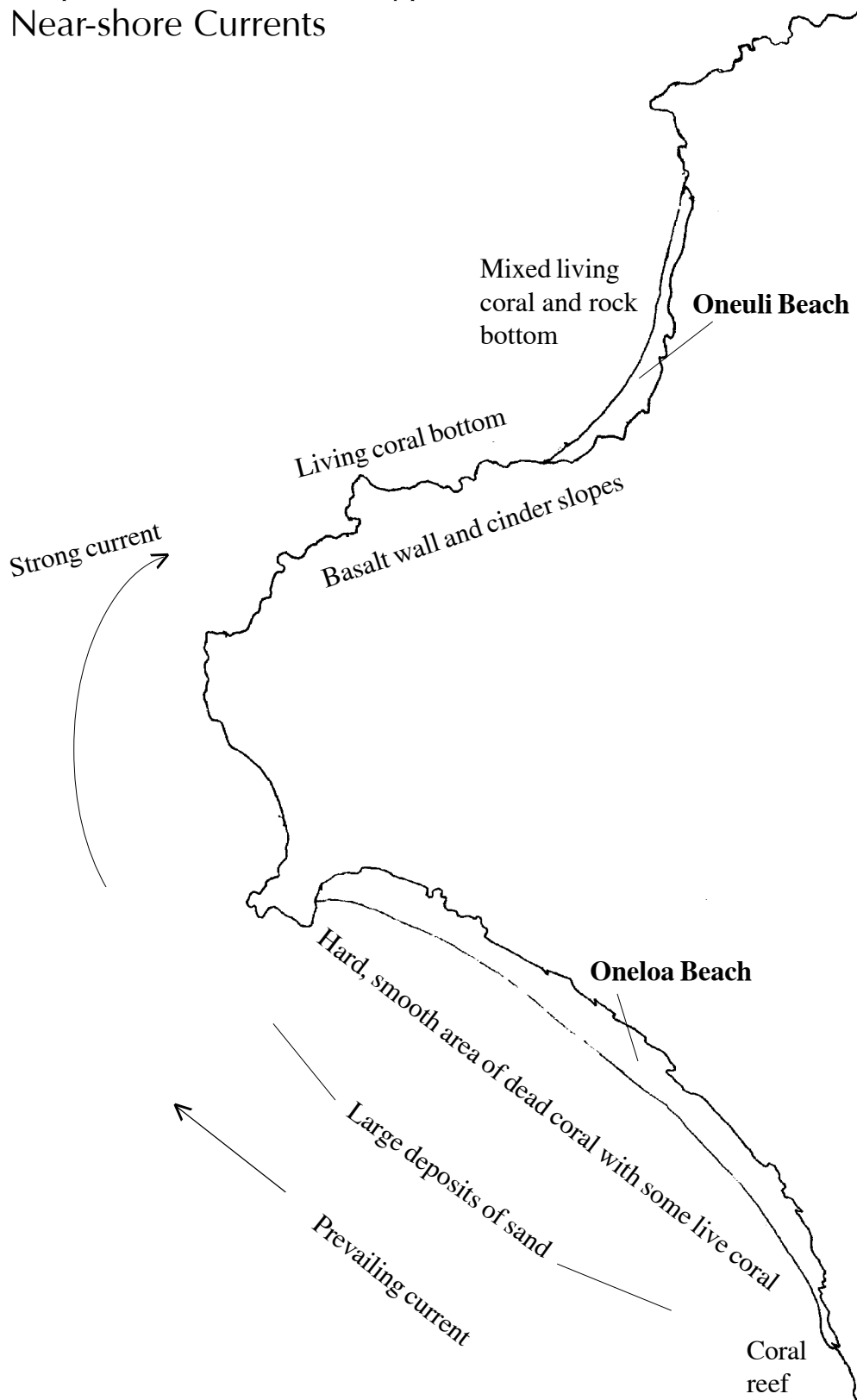


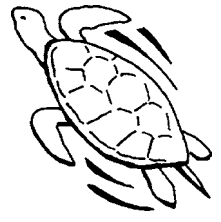
Photos: Ann Fielding



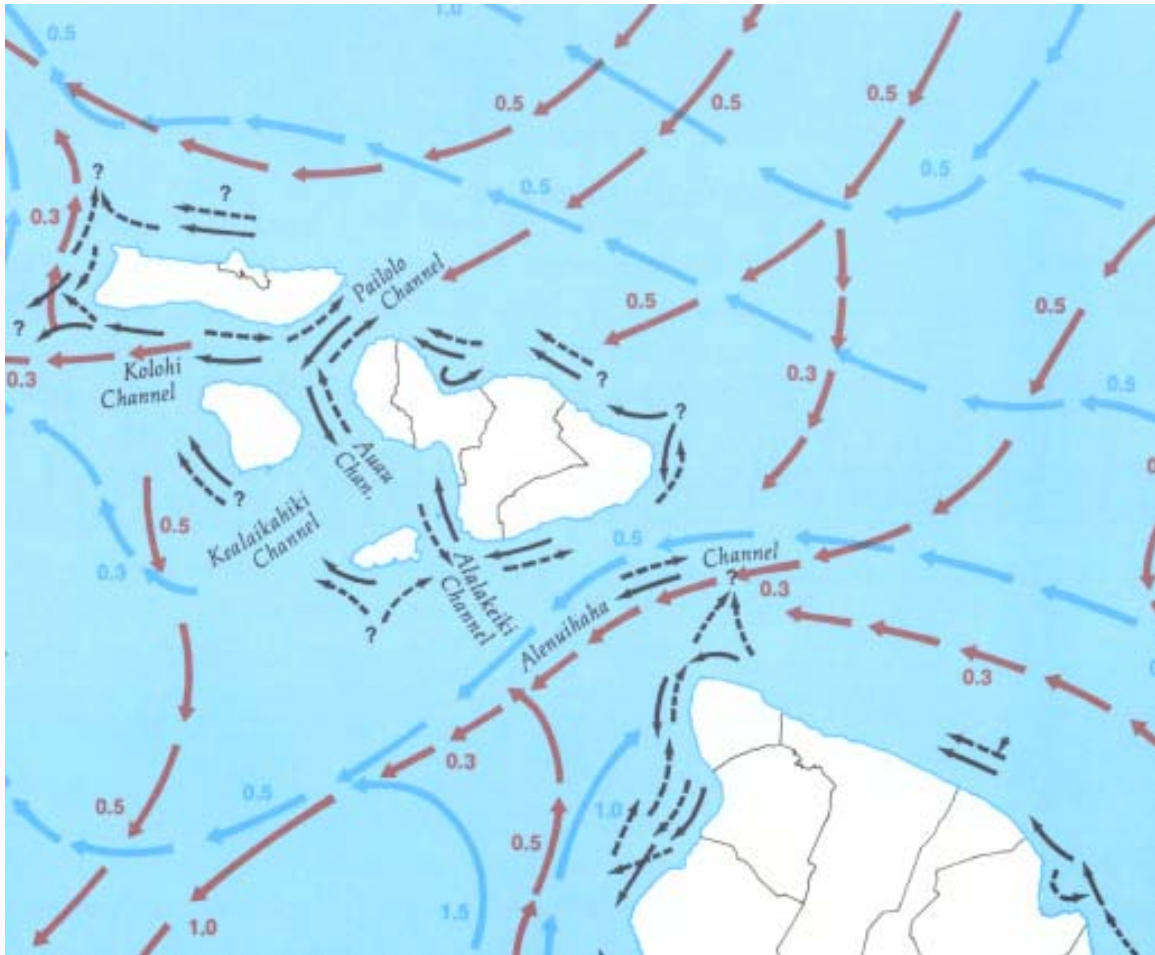
Station #3: Maps Showing Bottom Types and Major Currents

Map of Ocean Bottom Types and
Near-shore Currents

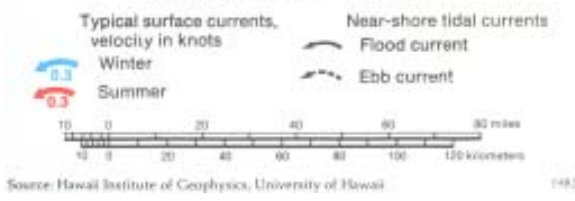




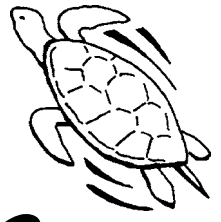
Map of Major Ocean Currents Around Maui



SURFACE CURRENTS

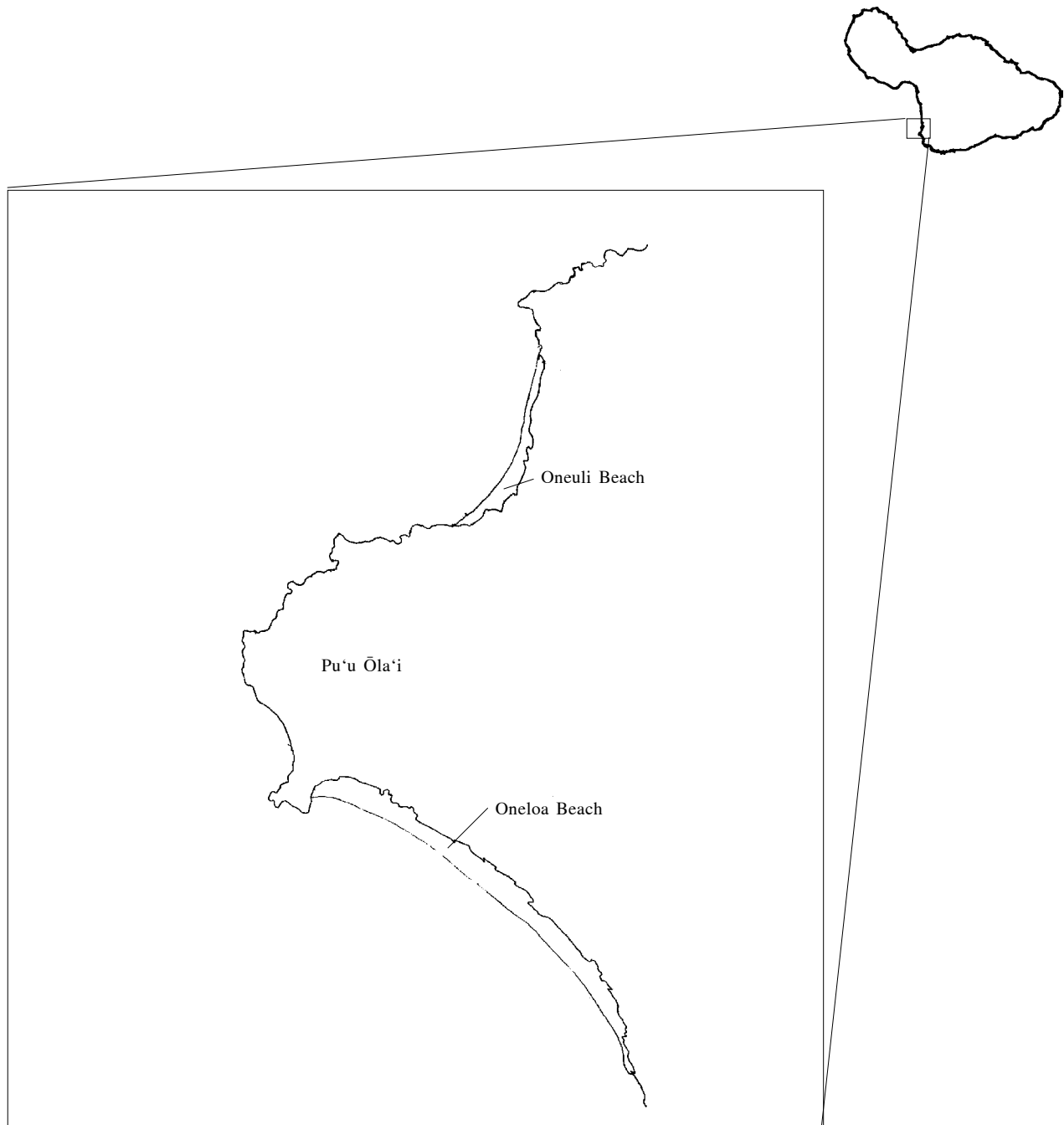


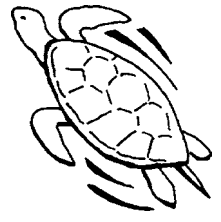
Department of Geography, University of Hawai'i, Atlas of Hawaii, 2nd edition, University of Hawai'i Press, Honolulu, 1983, p. 57



Where Does the Sand Come From?

Read the questions that follow the map. Use the maps and graphics at the information stations to help you answer them. Record relevant information from those maps and graphics onto this page. Make additional sketches and notes as needed.





Activity #3

Causes and Consequences of Coastal Erosion

● ● ● In Advance *Student Reading and Questions*

- As homework, assign the Student Pages “Beaches on a Budget: Why Do Beaches Come and Go?” (pp. 42-45) and “Beaches on a Budget: Questions About the Reading” (pp. 46-48).

● ● ● Class Period One *Coastal Erosion Projections*

Materials & Setup

For each lab group of three to four students

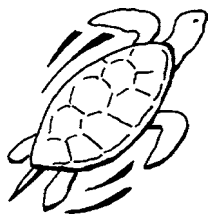
- “Baldwin and Kanahā Beach Aerial Photo” acetates (master, pp. 40-41)
- Baldwin and Kanahā “Beach Study Maps and Graphs” (legal-size masters included with this curriculum). Each lab group should have the information that corresponds to its assigned beach.
- Two copies of the Student Page “Coastal Erosion Projections” (pp. 49-51)
- Overhead projector
- One sheet of legal-size or larger paper
- Colored pens or pencils
- Masking tape

For each student

- Student Page “Beaches on a Budget: Why Do Beaches Come and Go?” (pp. 42-45)
- Student Page “Beaches on a Budget: Questions About the Reading” (pp. 46-48)
- Student Page “Beach Management Alternatives” (pp. 52-53)

Instructions

- 1) Review student questions and responses to the homework, especially question #7 in which they explained the impact of shoreline armoring and longshore currents on beach erosion and accretion. This question is designed, in part, to help students understand how longshore currents transport and deposit sediment along coastlines, and how disrupting this current can lead to changes in the normal patterns of beach erosion and accretion.
- 2) Divide the class into lab teams of three to four students. Give each team a copy of the Beach Study Map and Graph for *either* Kanahā or Baldwin beach.
- 3) Explain that the black-and-white photos and maps are excerpts from a study published in 1991. The study looked at coastal erosion by comparing aerial photos taken in 1950, 1964, 1975, 1987,



and 1988. At each of several transects, the authors calculated the rate of coastal erosion during intervals between photos. They looked at the changing location of the coastal vegetation line to track erosion and accretion. The results are presented in the graphs that accompany each map.

- 4) Project the “Baldwin Beach Aerial Photo” and “Kānahā Beach Aerial Photo” acetate onto the groups’ legal-sized or larger papers taped to the wall. Have each group trace its assigned beach from this image, including the water line and the vegetation line, along with any shoreline armoring that appears on the map and important reference points such as roads or large, recognizable facilities. Students can use the line-drawn maps from the 1991 study as a guide for which features could be useful to include on their tracing. When they have finished tracing the color image, they should add and number the transect lines from the corresponding “Beach Study Map and Graph.”
- 5) Have students complete the steps and answer the questions on the Student Page “Coastal Erosion Projections.”
- 6) After lab groups finish their work, have a class discussion to compare results and talk about how these kinds of projections can contribute to coastal management decisions.
- 7) Assign the Student Page “Beach Management Alternatives” as homework.

Journal Ideas

- How should projections for future shoreline erosion affect people’s decisions about where and how to build houses, hotels, condominiums, roads, and other structures?
- How far into the future do you think people should look when weighing the benefits and drawbacks of shoreline armoring such as seawalls and groins?

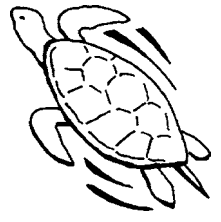
Assessment Tools

- Student Page “Beaches On a Budget: Questions About the Reading” (teacher version, pp. 35-37)
- Traced paper maps (evaluate for neatness and accuracy)
- Student Page “Coastal Erosion Projections” (teacher version, pp. 38-39)
- Short paper describing how Baldwin or Kānahā beaches should be managed
- Participation in group work and class discussion
- Journal entries

Some teacher-only resources have been omitted from the online document.

They are available as password-protected files at:

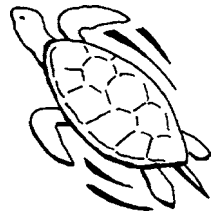
www.hear.org/hoike/teachermaterials



Baldwin Beach Aerial Photo



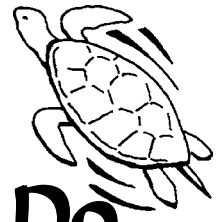
Photo: Air Survey Hawai'i



Kanahā Beach Aerial Photo



Photo: Air Survey Hawaii 'i



Beaches On a Budget: Why Do Beaches Come and Go?

Adapted from the Hawai'i Seagrant website, Beach Plan for Maui, "Coastal Ecosystems" and "Coastal Erosion, Beach Loss, and Coral Reef Degradation," accessed May 25, 2000 at <www.soest.hawaii.edu/SEAGRANT/bmpm/coastal_ecosystems.html> and <www.soest.hawaii.edu/SEAGRANT/bmpm/coastal_erosion.html>.

Long stretches of sand usually come to mind when we hear the word "beach." But a beach is actually an accumulation of any sediment along a coastline. A sediment is any material that is deposited by waves. Usually that is sand or gravel, but there are mud beaches and beaches made up of much larger rock fragments, too. The make-up of a beach depends on the type of sediment available and on the ability of the waves, tides, and currents to move it.

Beaches are naturally dynamic, changing from wave to wave, season to season, and year to year. That is because wind, waves, and currents move the sediments around. The part of the beach where sediment transport occurs is called the "active beach." As the figure below shows, the active beach is divided into three parts: the backshore, foreshore, and offshore. Behind the active beach is the coastal upland. This upland might be a dune, a cliff, a constructed seawall, a soil embankment, or another geological formation that provides a landward barrier for the beach.

Beaches on a Budget

Each beach has a "littoral budget." "Littoral" refers to the shoreline. The "budget" is the amount and movement of sediments between different parts of the active beach, onto

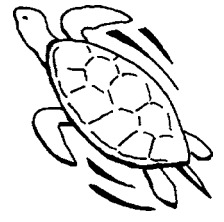
the beach from elsewhere, and away from the beach to another location offshore or down-current. Healthy beaches have balanced budgets—the net influx of sediment equals the net loss of sediment. It's like earning and spending the same amount of money in a month.

Where do the sediments come from and where do they go? Coastal geologists refer to "sources" and "sinks" of beach sediment. Sources include:

- Skeletal material from coral reef ecosystems,
- Offshore deposits of sand that may be transported onshore by waves and currents,
- Other beaches from which wind or currents that run along the shoreline can transport sediments,
- Erosion of coastal uplands and points of land that jut out into the ocean,



Photo: Ann Fielding



- Materials from new volcanic eruptions and lava flows, and
- Sediments carried from inland by streams and rivers.

Sediment sinks include:

- Loss of sediments to deep water,
- Harbors and channels, which trap sand moving along or across the near-shore area,
- Transport of sediments offshore by currents and waves to underwater “sand banks” from which beaches can be replenished seasonally or after large storms,
- Transport of sediments along the shoreline to other beaches by currents and waves,
- “Impoundment” (trapping) behind seawalls, revetments, and other structures,
- Over-wash by high storm waves and surges, which flush sand inland where it cannot be redeposited onto the beach, and
- Wind loss inland due to strong onshore winds.

When there is an imbalance between sources and sinks, the beach will either erode or “accrete” (build up).

The Beach System

Many of the sandy beaches on Maui are part of a beach system that includes dunes and coral reefs, as well as the beach itself. Each element of the whole system is important in the natural cycle of beach erosion and accretion.

Beaches naturally erode and accrete in cycles that correspond with seasonal weather changes and episodic storm events. During a storm, or through the course of a high-wave season, nearly all of the sand may seem to disappear from a beach, and the dune may be almost entirely washed away.

But after a couple of weeks or a few months of calmer weather, the beach and dunes rebuild. On undeveloped beaches, this cycle usually results in the complete rebuilding of the beach and dune

profile to what it was like before the storm event or high-wave season began.

Sand Dunes

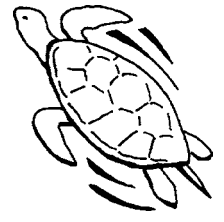
Along the coast, just as inland, dunes are accumulations of windblown sand. Some coastal dunes are unvegetated, but most are covered with coastal plants. The thick root systems of most native plants help hold the sand in place, slowing the rate at which the dune erodes during high winds and waves. Plants such as *naupaka* and beach morning glory also help dunes rebuild by trapping windblown sand and growing up through the new layers of sand to build larger and wider dunes.

Like beaches, dunes are dynamic. They erode during times of high waves and accrete during normal wave conditions. Dunes are like sand savings accounts for beaches. High waves during storms and large swells erode the beach. They erode the dunes, too. This process, known as “scarping,” releases sand that was stored in the dunes to the active beach. The influx of sand from the dunes is often carried offshore where it accumulates into sandbars. These sandbars intercept large waves before they reach shore, lessening their impact on the coastline.

When the high-wave event subsides and normal wave patterns return, the waves dismantle the offshore sandbars and rebuild the beach. Sand blown inland from the beach can then rebuild the dunes. Although some sand may have been permanently washed away from the beach system into deep water by the storm, eventually the beach and the dunes regenerate to their prestorm profile. Most of the sand transported offshore during storms and stormy seasons is eventually reincorporated into the dune.

Coral Reefs

Coral reefs act as natural breakwaters in the beach system. They absorb much of the incoming wave energy and help protect the shoreline from wave erosion. Coral reefs and the invertebrates



and algae they support are also important sources of sand production for beaches as the skeletons and other hard structures they produce are eroded by waves and animal activity. Most of the light-colored sand on beaches comes from coral reef ecosystems. Because coral reefs buffer waves and produce sand, they slow the rate of coastal erosion and beach loss.

Interfering with Nature

Coastal erosion is at least partly a natural process. One contributing factor is the rising sea level. Since the last ice age, the sea level has risen nearly 110 meters (361 feet), and as it rises, the whole littoral (shoreline) system moves further inland. Coastal uplands are eroded, and the influx of sediment released to the active beach helps maintain the beach width. We can expect that coastal erosion will continue as sea level rise is currently averaging 2.5 centimeters (about one inch) per decade on Maui.

But sea level rise is only one cause of changing coastlines, and not the most visible and dramatic cause. In many cases, coastal erosion has been aggravated by human activities that reduce the amount of sand available to the beach. Sand mining, dune destruction, and harbor and channel construction, for example, have led to increased rates of coastal erosion on some beaches.

Sand Mining

Taking sand from the beach system leads to beach narrowing and a decrease in sand volume. Until the early 1970s, large volumes of sand were mined from beaches around Maui to provide cement aggregate for construction and lime for sugar cane processing. In fact, on Baldwin Beach, a large structure that once protected the lime kiln from the encroaching sea is now well out in the water because of subsequent coastal erosion.

Dune Destruction

During building construction, dunes are often bulldozed to flatten their tops, allowing better views of the ocean or to make way for construction. Changing the shape of the dunes changes how they respond to storm waves and reduces their ability to serve as a natural buffer. Further, if the dune is then covered with soil for landscaping, future storms will erode the fine sediments of the soil, carrying silt into the ocean.

Dunes are also damaged by people walking or driving over them. This destroys dune vegetation, which is critical to holding the sand in place. A dune with damaged or reduced vegetation cover is more susceptible to erosion and less able to rebuild.

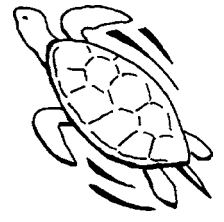
Harbor Construction

Maintaining and expanding harbors and navigational channels change natural patterns of sediment transport. Sand transported by near-shore waves and currents is deposited into these artificial depressions and removed from the littoral system. Also, constructing harbors and channels can entail dredging parts of coral reefs, allowing larger waves to reach the shoreline and accelerate coastal erosion.

Protecting Property

Waves and currents naturally transport sediments along shorelines, within the active beach zone, and sometimes offshore. Episodic and seasonal erosion is a fact of life along the coastlines—and so is the landward migration of the shoreline. But that reality does not always fit well with people’s ideas about property. When people build in coastal areas, they want their homes, hotels, roads, and other structures to be standing on solid ground in ten, 50, or 150 years. And we want our beach parks to stay beach parks!

“Shoreline armoring” is a common approach to slowing coastal erosion, stabilizing coastlines, and protecting beachfront property. Armoring



structures include “seawalls,” “revetments,” and “groins” (see the figure on this page for an explanation). These structures usually halt coastal erosion in the immediate area, but they can lead to unintended consequences. On shorelines that

have been retreating over time anyway, they often lead to beach loss. You’ll see this effect in action during your next class as you map changes in two Maui beaches over time.



Photo: Dolan Eversole



Photo: Dolan Eversole

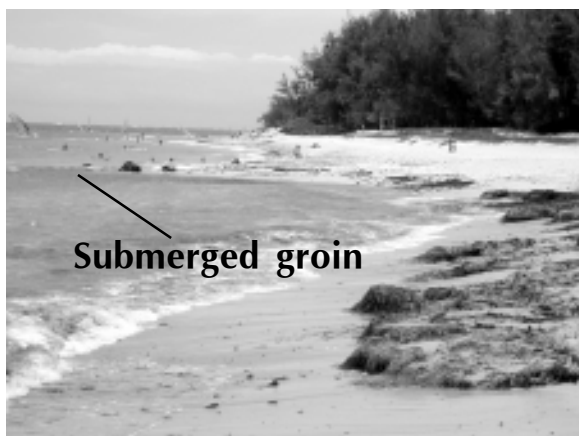


Photo: Kim Martz and Forest Starr

Types of Shoreline Armoring

Seawall

A vertical or near-vertical type of shoreline armoring characterized by a smooth surface

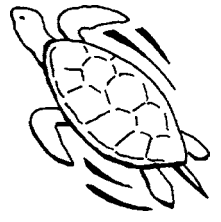
Revetment

A sloping type of shoreline armoring often constructed from large, interlocking boulders

Revetments tend to have a rougher (less reflective) surface than seawalls.

Groin

A structure resembling a wall, constructed perpendicular to the shoreline and extending into the ocean from the beach

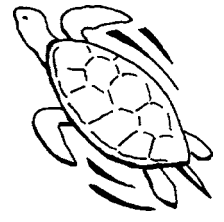


Beaches On a Budget: Questions About the Reading

- 1) What is an active beach?

- 2) What is the opposite of shoreline erosion?

- 3) Explain the term “littoral budget,” using at least two examples of sources and sinks.

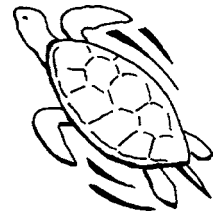


4) Describe the cycle of sand dune building, scarping, and rebuilding that happens during and after large storms.

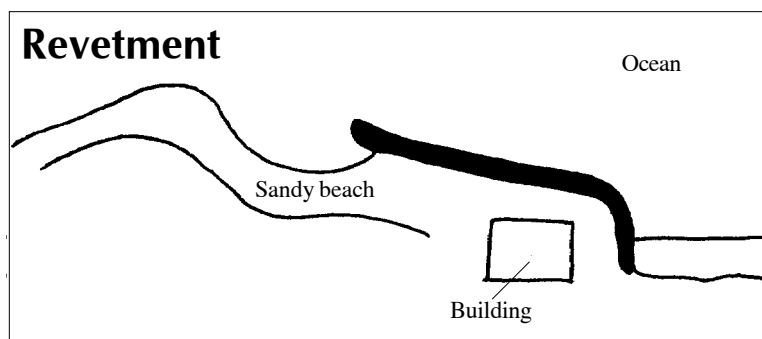
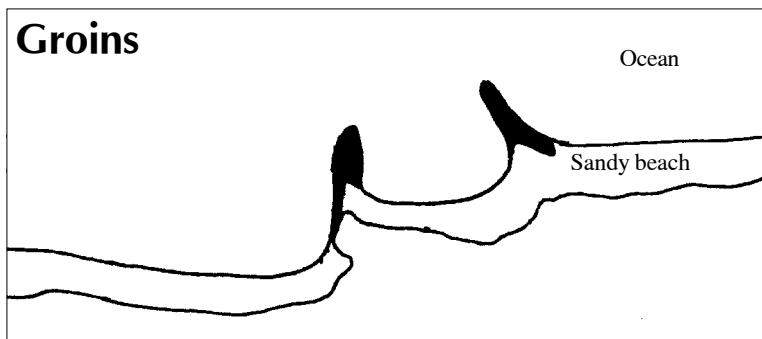
5) Name two reasons why coral reefs are important to healthy beaches.

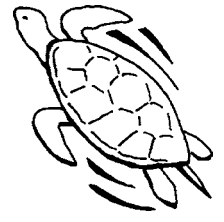
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6) Describe two human activities that aggravate coastal erosion and reduces the amount of sand available to the beach.



- 7) True to their name, “longshore” currents run along or parallel to the shore. These currents are important mechanisms for transporting sediment within the beach system. Sediment transported along shore feeds beaches along the entire coastline. Shoreline armoring interferes with longshore sediment transport. The diagrams below illustrate two different types of shoreline armoring that have been in place for several years. For each diagram:
- Draw in the direction of the longshore current, and
 - Explain how the pattern of beach erosion and/or accretion is related to the armoring structure and the longshore current.





Coastal Erosion Projections

Use your traced paper image of your beach and the space provided on this page to project changes in the coastline over time.

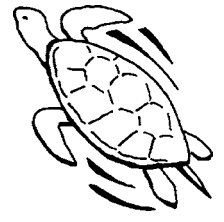
BEACH NAME: _____

- 1) The 1991 study graphs changes in the vegetation line between 1950 and 1988. For each transect on your beach segment, calculate an average annual rate of change, and record your calculations and answers below:

Transect #	Annual rate of change (+ or -)
------------	--------------------------------

- 2) You are going to be mapping projected shoreline changes based on the annual rate of change you calculated above. You will do this using the 1997 aerial photo (your traced paper image of it) as a baseline. Before you start mapping, you need to do some more calculations. Using the annual rate of change for each transect line, calculate the total erosion or accretion likely to occur by 2027 and 2057. Calculate these changes using 1997 as your starting date.

Transect #	Change (+ or -) by 2027	Change (+ or -) by 2057
------------	-------------------------	-------------------------



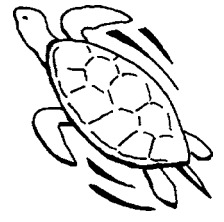
- 3) Now mark the 2027 and 2057 vegetation lines on each of the transects on your traced paper map. (Extrapolate the scale on your traced paper map using the “Beach Study Map and Graph.”)

Use these points and any clues you can glean from the existing shoreline features to draw an anticipated vegetation line for 2027 and 2057. (Using different-colored pens or pencils for each line helps make the map clearer.)

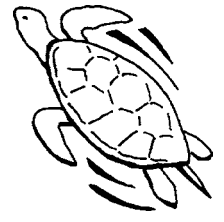
With a dashed line, indicate where you think the water line will be in 2027 and 2057.

Label your map clearly.

- 4) Looking at your traced paper map, as well as the photos, maps, and information from the 1991 study, describe any patterns of erosion and accretion that you see. What might explain these patterns?



- 5) In 1992, researchers estimated that 62 percent of the Maui shoreline is eroding at a rate of 1.25 feet per year. How do the erosion/accretion rates you calculated compare with that average?
- 6) Use your projections to identify areas where you think development should be restricted because of the potential for shoreline erosion, and areas that you think would be appropriate for development. Explain your reasoning for these areas here.



Beach Management Alternatives

When protecting coastal property comes at the expense of adjoining beaches, it can set up a conflict that no one really wins—not the property owners, not beach-goers, not the government agencies charged with managing coastal areas, and certainly not the natural system.

There are alternatives. Here are some management tools that are being used to make Maui beaches and coastlines healthier for everyone:

Beach Nourishment

This process is used to create a new sandy shoreline where a beach is eroding or has been lost. It is the only management tool that protects coastal development without degrading the beach.

Beach nourishment involves placing sand fill along the shoreline to widen the beach. The sand may come from inland dunes or coastal plains, or from offshore sources such as dredge spoils from harbor maintenance, and underwater sand fields and banks.

So far on Maui, only small-scale beach nourishment projects have been undertaken, funded by homeowners associations such as Sugar Cove Condominiums in Pā‘ia and Kana‘i o Nalu in Mā‘alaea. The sand for these projects has come from inland sand mines that also ship sand to O‘ahu for cement manufacturing.

The potential for beach nourishment on Maui is limited by the availability of high-quality sand. Maui does not have dredging equipment or the knowledge of offshore sources to be able to tap them for nourishing beaches.

Restoring and Protecting Dunes

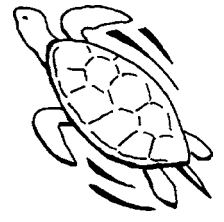
The first step in restoring damaged dunes is usually to erect fences that help trap windblown sand. In 1997, for example, drift fences were erected to restore Keālia Beach’s sand dunes. By 1999, sand had buried the fences in spots. Volunteers, including students and adults involved in the Kīhei Canoe Club, took the next steps by helping replant native vegetation on the growing dunes. Native dune plants have dense root systems and spreading vegetation that trap even more windblown sand. They grow up through the new layers of sand to build larger and wider dunes.

Native plants and the dunes they help keep in place are sensitive to trampling. Plants can be uprooted by people walking across dunes going to and from the beach. Another approach to protecting dunes is to build moveable walkways that provide access without the danger of trampling. These walkways can easily be moved when needed.

Building Setbacks

According to the Hawai‘i Department of Land and Natural Resources document *Coastal Erosion and Beach Loss in Hawaii* at www.soest.hawaii.edu/SEAGRANT/CEaBLiH.html, much of the beach loss in Hawai‘i “could have been avoided if houses were not built so close to the water. The law presently allows homes 40 feet from the shoreline. On coasts experiencing chronic erosion this is too close and leads to hardening [building sea walls and revetments] in order to protect houses from the waves.”

“Shoreline setbacks” (the required distance from a structure to the shoreline) are intended to establish a buffer zone to protect beachfront



development from high waves and coastal erosion. In 1990, the Maui County Planning Department revised its rules so that some building setbacks were based on the average depth of the lot, rather than on the state's 40-foot minimum. But according to the Maui Beach Management Plan, more effective setbacks would be site-specific, based on projected shoreline erosion 30, 60, or even 90 years in the future.

Even if coastal erosion hazard maps are not used to guide government rules about building setbacks, these projections could be used to give planners and landowners information that will help them plan and design coastal developments.

Construction Guidelines

Many coastal landowners and developers are not fully aware of shoreline erosion, the potential impacts of development on the beach, and design and construction options that could minimize the threat to their property and the adjacent beach. Consulting with experts and government agencies could help them design projects with minimum impact. Since county and state governments are aware of the problems associated with coastal development and protection measures such as seawalls and revetments, they need to advise and educate coastal landowners on environmentally compatible alternatives.

In order to choose which strategies to use and where, we need to consider the history of erosion and accretion for each specific stretch of beach. These processes can vary dramatically even from one end of a beach to the other. Knowing more about how each stretch of the coastline has changed over time will help point out areas in which different approaches are most likely to work.

Your Assignment

On a separate piece of paper, write a one- to two-page paper describing how you think either Baldwin beach or Kanahā beach should be managed to protect the beach and the shoreline property behind it. Your paper should include suggested actions and explain your reasoning. In writing your paper, consider your coastal erosion projections for different stretches of this beach.



Coastal Unit 2

Coastal Connections

Overview

Coastal areas of Hawaiian Islands can be thought of as a single natural system but one with multiple “neighborhoods.” The plant and animal community structure is influenced by proximity to the ocean—the more salt-tolerant plant species, for example, inhabit the coastal strand, where they are subject to frequent salt spray. Substrates range from coral to basalt cliffs, from sandy beaches to volcanic ash to boulders. There are dunes, wetlands, ponds, tidepools, and back beaches. Windward areas can receive up to 308 centimeters (120 inches) of rain per year; leeward shores may receive less than 128 centimeters (50 inches). Some areas such as the coastline near Makena receive less than 38 centimeters (15 inches) of rain each year.

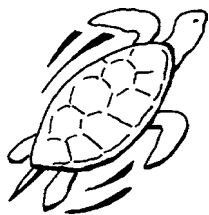
In this unit, students learn about some of the most common coastal plant and animal species, how the species composition of the coastal zone has changed over time, and the patterns of dispersal and migration that affect species composition in this ecosystem.

Length of Entire Unit

Four class periods

Unit Focus Questions

- 1) What are some of the main native and non-native plant and animal species represented in the coastal ecosystem on Haleakalā?
- 2) How have coastal areas in Hawai‘i changed since humans settled the islands?
- 3) How have coastal plant and animal species reached the islands, and from where?



Unit at a Glance

Activity #1

Coastal Inhabitants

Students make visual representations of how species composition of coastal areas has changed since human settlement.

Length

Two class periods

Prerequisite Activity

None

Objectives

- Differentiate between native and nonnative species represented in the coastal ecosystem.
- Make a schematic that represents the species composition of native Hawaiian coastal ecosystems prior to human settlement.
- Make a schematic that represents how humans have altered the landscape and species composition of Hawaiian coastal ecosystems.
- Identify and explain patterns having to do with the origins of native and nonnative Hawaiian coastal species.

DOE Grades 9-12 Science Standards and Benchmarks

USING UNIFYING CONCEPTS AND

THEMES: Students use concepts and themes such as system, change, scale, and model to help them understand and explain the natural world.

- CHANGE: Explain the effect of large and small disturbances on systems in the natural world.
- MODEL: Design or create a model to represent a device, a plan, an equation, or a mental image.

Activity #2

Coastal Jeopardy Game

Students hone and demonstrate their knowledge of Hawaiian coastal species by playing a game.

Length

Two class periods

Prerequisite Activity

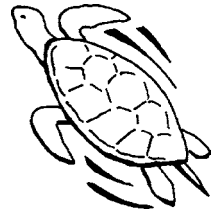
Activity #1 “Coastal Inhabitants”

Objectives

- Identify characteristics of coastal species such as habitats, relationships to other species, adaptations to the coastal environment, past or current use by humans, and cultural significance.

DOE Grades 9-12 Science Standards and Benchmarks

None



Enrichment Ideas

- Determine the accuracy of student schematics of today’s coastal areas (Activity #1 “Coastal Inhabitants”). Make field observations on a blank “Coastal Schematic” copied onto a sheet of paper.
- Investigate what the coastal ecosystem may have been like prior to human settlement. Research topics such as fossil evidence of extinct bird species and how Polynesian and European settlers may have changed vegetation patterns and caused bird extinctions.
- Make up and play other games using the species cards from Activity #1 “Coastal Inhabitants.”
- Do the Activity #1 “Coastal Inhabitants” exercise of mapping the origins of coastal species with native species only. Then create another map that represents introduced species only. Compare the two.
- Play additional rounds of Coastal Jeopardy (Activity #3) using more complicated “Final Jeopardy” questions that require critical thinking and a mastery of the unit subject matter. Have teams challenge each other with questions of their creation based on what they have learned about Maui coastal species.

Resources for Further Reading and Research

Eyre, David L., *By Wind, By Wave: An Introduction to Hawai‘i’s Natural History*, The Bess Press, Honolulu, 2000.

Hawai‘i Audubon Society, *Hawaii’s Birds*, Hawaii Audubon Society, Honolulu, 1997.

Howarth, Frank G. and William P. Mull, *Hawaiian Insects and Their Kin*, University of Hawai‘i Press, Honolulu, 1992.

Medeiros, Arthur C. and Lloyd L. Loope, *Rare Animals and Plants of Haleakalā National Park*, Hawai‘i Natural History Association, Hawai‘i National Park, 1994.

Merlin, Mark, *Hawaiian Coastal Plants: An Illustrated Field Guide*, Pacific Guide Books, Honolulu, 1999.

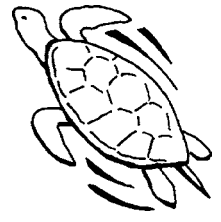
Olson, Storrs L., and Helen F. James, “The Role of Polynesians in the Extinction of the Avifauna of the Hawaiian Islands,” in Martin, P. S., and Klein, R. G. (eds), *Quaternary Extinctions*, University of Arizona Press, Tucson, Arizona, 1984, pp. 768-780.

Polhemus, Dan and Adam Asquith, *Hawaiian Damselflies: A Field Identification Guide*, Bishop Museum Press, 1998.

Pratt, H. Douglas, *A Pocket Guide to Hawai‘i’s Trees and Shrubs*, Mutual Publishing Company, Honolulu, 1998.

Pratt, H. Douglas, *A Pocket Guide to Hawai‘i’s Birds*, Mutual Publishing Company, Honolulu, 1996.

Stone, Charles P. and Linda W. Pratt, *Hawai‘i’s Plants and Animals: Biological Sketches of Hawaii Volcanoes National Park*, Hawai‘i Natural History Association, Hawai‘i National Park, 1994.



Activity #1

Coastal Inhabitants

● ● ● In Advance *Enlarge Coastal Schematic*

- Have a few students make enlarged coastal schematics for use during the first class period. Tape a large piece of newsprint on the wall and project the Coastal Schematic acetate onto the newsprint. Have students use a marker to trace the image onto the newsprint. Make two for each group of six to ten students. (See class period one materials & setup for materials needed.)

● ● ● Class Period One *Coastal Areas Then and Now*

Materials & Setup

In advance

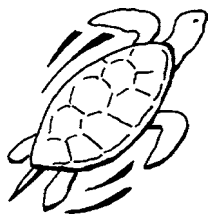
- “Coastal Schematic” acetate (master, p. 9)
- Several large sheets of newsprint (two for each group of six to ten students)
- Masking tape
- Large marking pens
- Overhead projector

For each group of six to ten students

- One blank enlarged “Coastal Schematic” on newsprint
- Colored marking pens or colored pencils
- Cellophane tape
- Set of 44 “Coastal Species Cards” in color (master, pp. 10-32)

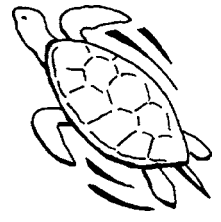
Instructions

- 1) Ask students to brainstorm the plants and animals they have seen in coastal areas. Write their ideas on the board or overhead.
- 2) Ask students which plants and animals on this list they think are native, and which are not. Note what the majority of students think next to the plant or animal name on the list. After you have gone through a good selection from the list, ask students whether they think most plants and animals in coastal areas are native or nonnative.
- 3) Tell students that the coastal ecosystem on Maui has been dramatically altered by human use from the time of the original Polynesian settlers through today, and in fact is the most altered ecosystem on the island. Ask students to discuss why that is, brainstorm about questions such as why people would want to live in the coastal zone, and how people use coastal areas. Write student ideas on the board or overhead.



Activity #1
Coastal Unit 2

- 4) Divide the class into groups of six to ten students. Give each group a newsprint version of the “Coastal Schematic,” some colored marking pens or pencils, and a set of laminated color species cards.
- 5) Have groups separate native from nonnative species cards. (Note: Be sure students understand that the label, “endemic,” signifies species that are endemic to the Hawaiian Islands. Also make sure students know the meaning of the term “indigenous.” It refers to a species that is native, but not unique, to an area.) During this process, they should notice whether any of the species they thought were native are actually nonnative, or vice versa.
- 6) Using the native species cards only, have each group create a representation of what the coastal ecosystem might have looked like before people came to Maui. The cards contain habitat information that will help students place species in the correct parts of the coastal ecosystem. They may tape the species cards onto the newsprint schematic and/or draw the species in the appropriate places on the schematic. Students should fill in the schematic with their own drawings of species, especially those that they think would have been more abundant than taping the species card to the schematic would suggest.
- 7) Ask students to consider their representations of the native coastal ecosystem in light of the fact that the coastal ecosystem is the most altered ecosystem on Maui. Have students brainstorm what might be missing from their representations, which have been created using only species that still exist today. Summarize the discussion by using the following points:
 - Fossil evidence indicates that large flightless geese and flightless ibis that are now extinct once inhabited the coastal area.
 - The coastal area was once predominantly forested. Scientists estimate that it was eighty percent or more forested prior to human settlement. Intensive cultivation in coastal areas led to the demise of these forests.
 - Based on historical accounts and fossil evidence, scientists know that native honeycreepers such as the *‘apapane* and *‘amakihi* once inhabited coastal areas. As the native vegetation has been largely removed and replaced by alien plants, these birds no longer inhabit the coastal ecosystem.
 - Human use and development of coastal areas has eliminated many wetlands areas and sand dunes.
 - Scientists acknowledge that they cannot know for certain what the coastal ecosystem was like prior to human settlement because so much has changed.
 - Many plant and animal species that were once abundant in the coastal area are rare today.
- 8) Allow groups a short time to add to or adjust their coastal ecosystem representations based on the discussion.
- 9) Have each group briefly present its representation to the rest of the class. (Keep the newsprint representations and the nonnative species cards for the next class period.)



● ● ● Class Period Two *Where Did Coastal Species Come From?*

Materials & Setup

- World Map acetate (master, p. 33)
- Four colors of nonpermanent overhead markers
- Overhead projector and screen

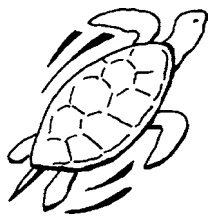
For each group of six to ten students

- Native coastal areas representations and non-native species cards from previous class
- One blank enlarged “Coastal Schematic” on newsprint
- Colored marking pens or colored pencils
- Cellophane tape

Instructions

- 1) Divide the class into the groups from the previous class period. Each group should have its representation and species cards from the previous class period, along with a blank “Coastal Schematic” on newsprint and colored markers or pencils.
- 2) Have each group brainstorm a list of everything they can think of that’s been introduced into coastal areas on Maui. They may use the species cards to generate ideas and their lists may include living and nonliving things (e.g., roads, hotels, houses, beach access, harbors, dune restoration fences).
- 3) Have each group use its list and all the species cards (including those from the previous day’s schematic) to create a representation of what the coastal ecosystem on Maui looks like today. They may tape species cards onto the newsprint schematic in addition to drawing other living and non-living elements found in today’s coastal areas.
- 4) Have each group briefly show its representation to the rest of the class and explain the differences between it and the native coastal ecosystem they represented during the previous class period.
- 5) Ask students to brainstorm all the different ways coastal plants and animals could have gotten to the Hawaiian Islands. Write student ideas on the board or overhead.
- 6) Project the “World Map” acetate. Tell students they are going to work with information on the species cards to identify patterns in how species got here, where they came from, and where Hawaiian species are found elsewhere in the world. They will consider five main categories:
 - Indigenous species (these illustrate natural patterns of dispersal),
 - Migratory species,
 - Endemic species,
 - Polynesian introductions, and
 - Species introduced after European contact.

Assign a different color marker to each of these five categories.



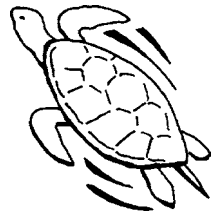
- 7) Have students review species cards for information about the origins of Hawaiian coastal species and geographic distribution patterns of species found in Hawai'i. As they discover information, call on one student at a time to say the name of the species, where it came from originally, and how it got to Hawai'i. Use the appropriate colored marker to draw a line on the map connecting the place of origin with the Hawaiian Islands. For indigenous species without a clear place of origin, put marks on the map to indicate where else in the world the species are found. For each endemic species, simply draw a dot near the Hawaiian Islands.
- 8) When the map is filling up or you have covered most of the cards, ask students to identify and explain patterns based on the lines and dots on the map. If students need help, ask them to look for:
- Regions where many species originate (e.g., tropical Pacific Islands, throughout the tropics worldwide, Indian Ocean),
 - Regions where few species originate (e.g., American continent, Australia, India, Europe),
 - Similarities and differences between the origins or geographic distribution of species that dispersed naturally and those introduced by humans (e.g., most indigenous species are distributed throughout the Pacific islands, throughout the tropical Pacific and Indian Oceans, and more broadly throughout the tropics; human introductions expand the geographic connections of Hawaiian species to include places such as Europe, Australia, India, and the American continent), and
 - The number of endemic species. (Many Hawaiian ecosystems are comprised of a high number of endemic species because the isolation of the islands makes ongoing genetic exchange with other places unlikely. Coastal ecosystems have relatively few endemic species because of the increased likelihood of continuing inflow of genetic material from off-island in areas where many plants are dispersed on ocean currents or carried in the digestive tracts of migratory birds.)

Journal Ideas

- Why is the coastal ecosystem the most human-altered ecosystem type on Maui? Since there is very little native coastal habitat left, what do you think people should do?
- How would you describe how you thought about coastal areas before this activity? What have you learned about the coastal ecosystem? How do you feel about the coastal areas on Maui now?
- If you did the dispersal mapping exercise that you did during class separately for native species and nonnative species, what differences would you expect to see in the maps? Why?

Assessment Tools

- Group representations of native coastal ecosystems and the coastal ecosystems of today
- Group lists of living and nonliving things humans have introduced to coastal areas
- Participation in group work and class discussions
- Journal entries



Coastal Schematic

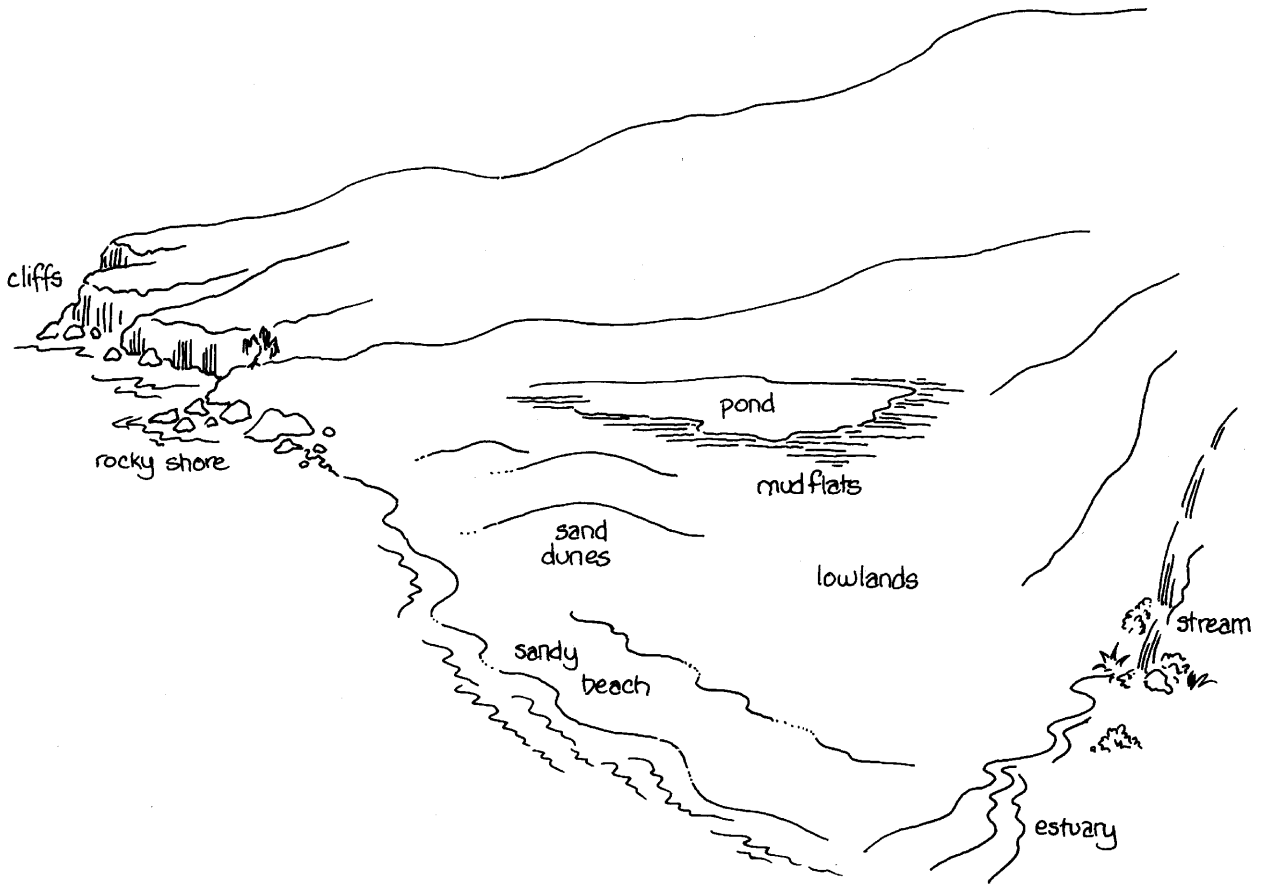
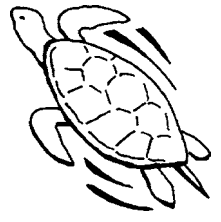


Illustration: Sophie Cayless



Coastal Species Cards

Cut apart along dotted lines.

Photo: Forest Starr and Kim Martz



***Hala* or Screwpine (*Pandanus tectorius*)**

Order Pandanales, Family Pandanaceae

- This indigenous tree is also found along or near the coast of most Pacific islands.
- Although it was propagated by Hawaiians, *hala* is thought to have colonized the Hawaiian Islands naturally. Fossilized *hala* fruit a million years old have been found on Kaua'i.

Habitat

- This tree is usually found in coastal areas, but it can also grow at elevations up to 610 meters (2000 feet).

Adaptations & Interactions

- Its fruit floats and is easily dispersed through ocean currents.

- Its somewhat fleshy leaves help it retain water.
- Numerous “prop” roots that support a relatively weak main trunk enable this tree to survive in windy coastal areas, even though it grows up to thirty feet tall. Its fibrous leaves also withstand wind.

Human Connections

- Its seeds and parts of the male flower were sometimes eaten, although mostly in times of famine.
- Fresh fruit sections were strung together in *lei*. Dried sections were used to apply dye to *kapa* cloth.
- The *lau hala*, the tree’s long spiny leaves, were stripped of their spines and woven into mats, baskets, canoe sails, and other objects. Where *pili* grass was unavailable, the *lau hala* were used to thatch houses.

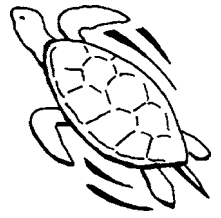


Photo: Forest Starr and Kim Martz

***Naupaka Kahakai* or Beach Naupaka** (*Scaevola sericea*)

Order Campanulales, Family Goodeniaceae

- This indigenous shrub is also found elsewhere throughout the tropical and subtropical regions of the Pacific and Indian Oceans.
- It is a common plant in coastal shrublands in windward and leeward areas, on sand or rock, and often along with other native vines and shrubs. It can be low-lying, or grow to twelve feet tall.

Habitat

- This highly salt-tolerant shrub grows in the coastal or beach strand, an environment affected by salt spray and seawater.

Adaptations & Interactions

- Its round, white fruits float and tolerate saltwater. It can germinate when washed ashore after a year at sea.
- Its succulent leaves help it retain water.
- Its fruits are eaten by pigeons and seabirds, especially in places where there are few other fruits available.

Human Connections

- In Hawaiian legend the “half flower” of the *naupaka* is from a flower torn in half by the heartbroken princess Naupaka who was not allowed to marry her love. She went to live in the mountains and her half of the flower became the *naupaka kuahiwi*. At the seashore, her lover’s half of the flower became *naupaka kahakai*.
- The bark of this shrub has been used in traditional Hawaiian medicine, and fruits were occasionally eaten.

***‘Ōhelo Kai* (*Lycium sandwicense*)**

Order Solanales, Family Solanaceae

- This indigenous shrub is endemic to Polynesia, where it is found on scattered islands in areas such as Tonga and Rapa.
- It grows low to the ground.

Habitat

- ‘Ōhelo kai normally grows on arid, rocky shorelines within reach of the salt spray.

Adaptations & Interactions

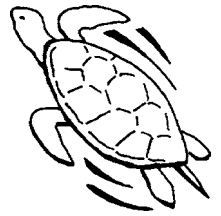
- Its succulent leaves help it retain water.
- Livestock may graze on this plant during dry times.

Human Connections

- Its bright red, juicy fruits are sometimes eaten, although the flesh is salty and not too tasty.



Photo: Forest Starr and Kim Martz



***Pōhinahina* or Beach Vitex**

(Vitex rotundifolia)

Order Lamiales, Family Verbenaceae

- This indigenous shrub is also native to parts of India, southern Japan, and many tropical Pacific islands.
- It grows low to the ground.

Habitat

- It grows on sand dunes, sandy beaches, and rocky shores.
- As beaches and coastal areas are developed, this plant is becoming increasingly rare.

Adaptations & Interactions

- *Pōhinahina* rarely reaches more than two feet high, a growth form that helps protect it from the wind and salt spray.
- Its silvery or grayish leaves help reflect the harsh and direct sunlight.

Human Connections

- This plant is sometimes used in traditional Hawaiian medicine.
- Its Hawaiian name refers to the light green leaves of the *pōhinahina*, which can look silvery or grayish.



Photo: Forest Starr and Kim Martz

‘Ūlei or Hawaiian Rose

(Osteomeles anthyllidifolia)

Order Rosales, Family Rosaceae

- This indigenous woody vine or shrub also occurs in the South Pacific on the Cook Islands and Tonga.

Habitat

- ‘Ūlei grows from sea level up to at least 1829 meters (6000 feet) on arid parts of the Hawaiian Islands.



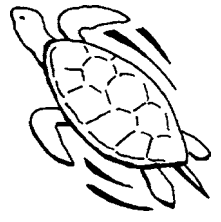
Photo: Forest Starr and Kim Martz

Adaptations & Interactions

- It is sometimes overgrown by the parasitic *kauna‘oa* plant, which absorbs nutrients from it.

Human Connections

- ‘Ūlei wood was used for making fish spears. It was also used to make a musical instrument called the ‘*ūkēkē*. This bowed piece of wood was fitted with two or three strings that were strummed. The supple, viny branches were used for weaving fish traps and baskets.



‘Ilima (*Sida fallax*)

Order Malvales, Family Malvaceae

- This indigenous shrub is also found along arid coastlines of many other tropical Pacific islands and as far west as China.
- *‘Ilima* grows low to the ground in small clumps.

Habitat

- It is found just behind the open, outer beach strand in sandy or rocky spots or high above the ocean on cliffs. Inland, it can grow as an upright shrub.

Adaptations & Interactions

- The hairy leaves help keep salt off the surface of the leaf, preventing damage from salt spray. Their silvery color helps reflect sunlight.

Human Connections

- Its beautiful yellow-orange flowers are prized for making *lei*.
- In traditional Hawaiian medicine, *‘ilima* flowers were used as a general tonic. Juice from the pressed flowers, or chewed flowers, was given to children and pregnant women as a mild laxative.



Photo: Forest Starr and Kim Martz

Pōhuehue or Beach Morning Glory

(*Ipomoea pes-caprae* subsp. *brasiliensis*)

Order Solanales, Family Convolvulaceae

- This common indigenous vine is also found extensively throughout the tropics.
- It is a low-growing, trailing, woody vine with pinkish-red, bell-shaped flowers.

Habitat

- Its thirty- to one hundred-foot creeping stems typically grow right up to the water’s edge on sandy beaches. It is also found on rocky shorelines.

Adaptations & Interactions

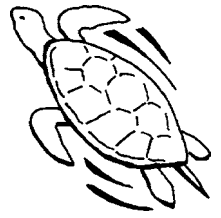
- *Pōhuehue* seeds float well and are salt water-tolerant.
- The smooth, thick leaves with waxy surfaces help retain water and protect from salt spray.

Human Connections

- In ancient Hawai‘i, the long roots were cooked and eaten, despite the fact that they can be poisonous.
- *Pōhuehue* stems were sometimes used by ancient Hawaiian surfers to induce the surf to come up. Slapping the stems on the water was accompanied by special chants.



Photo: Forest Starr and Kim Martz



***Pā‘ū o Hi‘iaka* or Small Blue
Morning Glory (*Jacquemontia ovalifolia*
subsp. *sandwicensis*)**

Order Solanales, Family Convolvulaceae

- This common vine is found from west Africa to the Pacific Islands, but the Hawaiian Islands are the only Polynesian islands on which the species is found. The *pā‘ū o Hi‘iaka* is an endemic subspecies.
- It is a low-growing plant with vines up to ten feet long.



Photo: Forest Starr and Kim Martz

Habitat

- It sprawls over shorelines of bare rock and sand, often with ‘ilima, and sunny inland spots to 457 m (1500 ft) in elevation.

Adaptations & Interactions

- *Pā‘ū o Hi‘iaka* plants usually have leaves covered with many whitish hairs that reflect sunlight and help protect the plant from saltwater damage.

Human Connections

- In Hawaiian legend, the fire goddess Pele named this plant when she came back from a morning of fishing. She had left her baby sister, Hi‘iaka, on the beach and the trailing vines of the plant had grown over the child, protecting her from the sun. The name means “skirt of Hi‘iaka.”
- In ancient Hawai‘i, its roots and leaves were served as food.

***Kauna‘oa Kahakai*, or Hawaiian Dodder
(*Cuscuta sandwichiana*)**

Order Solanales, Family Cuscutaceae

- This endemic vine is found on all of the main islands except Kaua‘i.

Habitat

- It grows on plants found in the coastal or beach strand, an environment affected by salt spray and seawater, as well as plants found behind the beach strand.



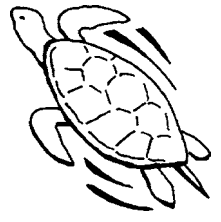
Photo: Forest Starr and Kim Martz

Adaptations & Interactions

- This parasitic plant lacks chlorophyll. Its yellow stems grow over other beach plants, absorbing nutrients from these hosts.
- Common host plants include *naupaka kahakai*, ‘ilima, and *pōhuehue*.

Human Connections

- Strands of *kauna‘oa* were used in braiding *haku lei*. *Kauna‘oa* is the lei flower of Lāna‘i.



‘*Ākulikuli* or Sea Purslane

(*Sesuvium portulacastrum*)

Order Caryophyllales, Family Aizoaceae

- This indigenous vine is native to many tropical coastal areas.

Habitat

- ‘*Ākulikuli* is one of the most salt-tolerant plant species, growing in areas that are splashed by waves and in and around salt marshes and other saline zones. Its habitats include sandy and rocky beaches and surrounding sandy lagoons.



Photo: Forest Starr and Kim Martz

Adaptations & Interactions

- This low-growing plant has narrow, succulent leaves that help retain water.

Human Connections

- Sea purslane is an edible herb—although salty—and may be eaten raw or cooked.

‘*Aki‘aki* or Beach Dropseed

(*Sporobolus virginicus*)

Order Cyperales, Family Poaceae

- This indigenous grass is native to tropical and subtropical areas worldwide.
- ‘*Aki‘aki* is a wiry grass that sends up a flower spike that can be up to 20 inches tall.



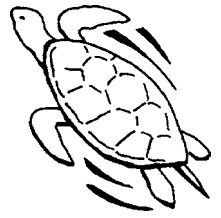
Photo: Forest Starr and Kim Martz

Habitat

- It grows near the high tide line.

Adaptations & Interactions

- ‘*Aki‘aki* plays an important role in stabilizing sand dunes. It spreads by means of an underground root structure, creating a dense, interconnected web of roots that help hold sand in place.



***Ma‘u ‘Aki‘aki* or Button Sedge**

(*Fimbristylis cymosa*)

Order Cyperales, Family Cyperaceae

- This indigenous sedge is distributed throughout the Pacific from Malaysia to tropical America.

Habitat

- It is often the dominant species—sometimes the only one—on rocky and sandy coasts.
- *Ma‘u ‘aki‘aki* rarely grows far from shore.

Human Connections

- The *ma‘u ‘aki‘aki* stem was used as an ear cleaner.



Photo: Philip Thomas

***Niu* or Coconut Palm (*Cocos nucifera*)**

Order Arecales, Family Arecaceae

- This Polynesian-introduced tree is distributed throughout the tropics.

Habitat

- Like other seashore trees, *niu* grows behind beaches. At higher elevations and around old village sites, the presence of *niu* offers evidence of the widespread planting of this tree from early Hawaiian times to the present.

Adaptations & Interactions

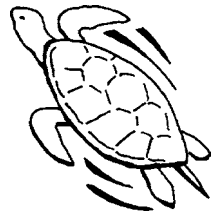
- The coconut (the fruit of the coconut palm) floats and can survive in the ocean for about four months. So, although it was first introduced to Hawai‘i by Polynesians, it could spread from island to island on the currents.
- *Niu* can grow taller than 100 feet, carrying its sturdy, fleshy leaves only at the top of the trunk.

Human Connections

- *Niu* is a useful plant in traditional Hawaiian society. The nut provided food, oil, and material for making utensils. The husks provided fiber for cordage, and the leaves were used as thatch and to make baskets. The trunks were used as structural posts.



Photo: Forest Starr and Kim Martz



***Milo* or Portia Tree** (*Thespesia populnea*)

Order Malvales, Family Malvaceae

- This Polynesian-introduced tree is found throughout the tropics.
- It varies in size from a shrub to an upright tree over 20 feet tall.

Habitat

- *Milo* forms part of the understory of what is sometimes called the “beach forest,” the area behind the beach where the taller trees and shrubs tend to grow. Highly salt tolerant, this tree often grows in exposed coastal areas, mixed with *hau* and *hala*. Its form is often sculpted by strong coastal breezes.

Adaptations & Interactions

- In winter, *milo* trees may lose many leaves due to salt spray from high surf. But the leaves grow back in summer.
- *Milo* seeds are buoyant and salt water-resistant.
- The shiny, waxy leaf surfaces provide protection from salt spray and water loss.

Human Connections

- *Milo* wood is used by carvers, especially for beautiful wood bowls. The wood was traditionally used for canoe hulls. Parts of the tree were used to make dye, and the young leaves are edible either raw or cooked.
- In traditional Hawaiian medicine, *milo* seeds are taken as a laxative.



Photos: Forest Starr and
Kim Martz

***Hau* (*Hibiscus tiliaceus*)**

Order Malvales, Family Malvaceae

- This Polynesian-introduced shrub/tree grows up to 12 feet tall. It is common along many tropical Pacific beaches.
- It is considered by some to be an indigenous species, although Polynesians probably brought *hau* cuttings to Hawai‘i with them.

Habitat

- Salt-resistant, it grows most often near the coast, although it was also cultivated further inland.

Adaptations & Interactions

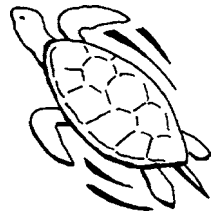
- The fleshy leaves help retain water.

Human Connections

- *Hau* was a valuable plant in traditional Hawaiian society. Its light, buoyant wood was used for canoe outriggers, net floats, and adz handles. Its fiber was used to make cordage and fishing nets. *Hau* fiber is still used in making *haku* and *wili lei*.
- *Hau* was a popular shade tree around homes.
- In traditional Hawaiian medicine, sap yielded from the bark and branches was used as a mild laxative. Buds of the *hau* flower were chewed and swallowed to relieve dry throats, and the bark was used to make a medicine for chest congestion and childbirth.



Illustration: Joan M. Yoshioka



Kou (Cordia subcordata)

Order Lamiales, Family Boraginaceae

- This Polynesian-introduced tree is native to southeast Asia and many western Pacific islands.
- It is a small tree that rarely gets taller than thirty feet.

Habitat

- *Kou* grows in dry, scrubby lowland areas including arid sea-shores.

Human Connections

- *Kou* was a favored shade tree among Hawaiians, and its light, strong wood was made into utensils and religious statues.
- The flowers were used in *lei*, and the leaves were used to make a light tan dye for *kapa* and to color fishing lines.
- The seeds were sometimes eaten.



Photos: Forest Starr
and Kim Martz

Noni or Indian Mulberry (Morinda citrifolia)

Order Rubiales, Family Rubiaceae

- This Polynesian-introduced shrub/tree is found on many South Pacific islands.
- It is a short evergreen tree or shrub.

Habitat

- *Noni* grows wild in many places along the rocky coasts of Hawai‘i. It has naturalized in moist and arid areas from sea level to about 400 meters (1312 feet).

Adaptations & Interactions

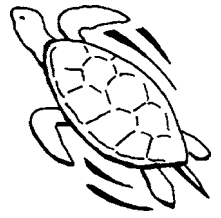
- *Noni* has thick, glossy leaves.

Human Connections

- *Noni* has many uses in traditional Hawaiian medicine and is considered a natural cure-all. Leaves were crushed and applied to bruises, sores, and wounds. The bark was used to treat cuts, and juice from the roots was used for skin problems. The green fruits were mashed and used over broken bones and to treat concussions.
- The bad-smelling fruits are edible, but in early Hawai‘i were eaten only during times of famine.
- Yellow and red dyes for *kapa* were made from the root.



Illustration: Joan M. Yoshioka



***Kiawe or Mesquite* (*Prosopis pallida*)**

Order Fabales, Family Fabaceae

- This nonnative tree is a native of tropical South America (Peru, Colombia, Ecuador).
- It can grow to heights of over 50 feet.

Habitat

- *Kiawe* dominates the landscape in lowland dry areas, especially disturbed sites. It is common near sandy shores as well.

Adaptations & Interactions

- Its deep roots allow it to tap ground water in dry areas, possibly lowering the water table in coastal zones.
- It is well known for its long, piercing thorns. This is the only tree in the coastal dry forest that can form a canopy (continuous covering of tree branches).



Photos: Forest Starr
and Kim Martz

Human Connections

- The first *kiawe* tree was planted in Hawai‘i in 1828.
- This tree is now very useful in Hawai‘i. It is cut for firewood, its flowers yield delicious honey, and its pods are used to feed pigs and cattle. It is sometimes planted to reforest dry lowlands.

***Koa Haole* (*Leucaena leucocephala*)**

Order Fabales, Family Fabaceae

- This nonnative shrub/small tree is native to tropical America. It has been spread by humans to many tropical areas around the world.
- *Koa haole* can reach 30 feet in height.

Habitat

- This plant is now abundant and widespread in Hawai‘i, where it has successfully invaded extensive areas of the coast and dry lowlands, especially disturbed sites.

Adaptations & Interactions

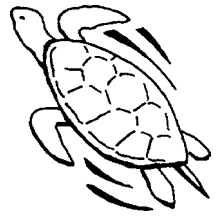
- Its long tap roots give it access to ground water and can make it difficult to remove from areas in which it is established.

Human Connections

- This shrub provides cattle feed and firewood. It is used for erosion control, to improve the soil (by attracting nitrogen-fixing bacteria to its root system), and to provide shade for natural regeneration of native species.
- Seeds from *koa haole* are strung to make *lei*.



Photo: Forest Starr
and Kim Martz



Indian Pluchea or Indian Fleabane

(*Pluchea indica*)

Order Asterales, Family Asteraceae

- This nonnative shrub is native to southern Asia. Its name is pronounced *ploo-key-a*.

Habitat

- It grows on marshy shorelines and muddy areas around ponds.

Adaptations & Interactions

- It bears clusters of dull purple flowers. The seeds are wind-borne, and when they blow away, they leave behind what looks like fuzzy dry flowers that make Indian pluchea distinguishable from a distance.

Human Connections

- In traditional Hawaiian medicine, this plant was used internally to treat fevers and externally for poultices.



Photo: Forest Starr and Kim Martz

‘Ākulikuli Kai or Pickleweed (*Batis maritima*)

Order Batales, Family Bataceae

- This nonnative shrub is native to tropical and subtropical America.

Habitat

- Introduced to Hawai‘i by 1859, it now grows in dense stands and large clumps in marshy coastal areas, around ponds, and in estuaries.

Adaptations & Interactions

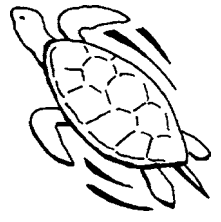
- The smooth, fleshy, cylindrical leaves help the plant retain water.

Human Connections

- The leaves are edible and taste salty. They are said to have medicinal value.



Photo: Forest Starr and Kim Martz



***Paina* or Common Ironwood**

(Casuarina equisetifolia)

Order Casuarinales, Family Casuarinaceae

- This nonnative tree is native to northern Australia.
- It is a rapidly growing tree that may grow to 80 feet in ten years.

Habitat

- Introduced within the last 200 years, it is now widespread throughout the islands, especially in dry environments with poor soil. It ranges from sea level to about 915 meters (3000 feet).

Adaptations & Interactions

- In many areas, it grows in thick stands that choke out virtually all other plant life.

Human Connections

- The inner bark is used to soothe sore throats and other illnesses.
- It is planted as a windbreak, to hold soil or sand in place, or to enrich soil with nitrogen.



Photo: Michele Archie

***‘Iwa* or Great Frigatebird**

(Fregata minor palmerstoni)

Order Pelecaniformes, Family Fregatidae

- This indigenous seabird is widespread throughout the tropical Pacific.

Habitat

- It is often seen in flight around the main Hawaiian Islands, but nests primarily on the Northwestern Hawaiian Islands.

Adaptations & Interactions

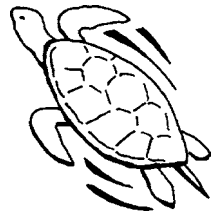
- Its Hawaiian name means “thief.” The *‘iwa* can often be seen harassing boobies and shearwaters until they drop the prey they are carrying. The *‘iwa* then catches the food in midair and flies off with it.

Human Connections

- In Hawaiian, the saying “*kikaha ka ‘iwa he la makanī*” refers to a well-dressed person. Literally, it means, “The *‘iwa* bird soars over the cliffs.”



Photo: Forest Starr and Kim Martz



***Koa'e Kea* or White-Tailed Tropicbird**

(*Phaethon lepturus dorotheae*)

Order Pelecaniformes, Family Phaethontidae

- This indigenous seabird can be found nesting throughout most mountainous Pacific island groups.

Habitat

- It is often seen along windward coasts and inland valleys of all of the main Hawaiian Islands. It nests in inaccessible rock crevices and cliff faces on these islands.



Photo: Forest Starr and Kim Martz

Adaptations & Interactions

- The *koa'e kea* feeds by making plunging dives into the ocean to catch fish and squid.

Human Connections

- Like the related *koa'e 'ula* (red-tailed tropicbird), *koa'e kea* feathers were used in traditional Hawaiian featherwork.

***Noio* or Black Noddy**

(*Anous minutus melanogenys*)

Order Charadriiformes, Family Laridae, Subfamily Sterninae

- The *noio* is an endemic seabird. This subspecies is a year-round resident throughout the Hawaiian Islands. The species breeds on islands in the tropical Atlantic and Pacific.

Habitat

- On the main Hawaiian Islands, it is found most frequently in rocky coastal areas.
- On the main islands, *noio* nest in caves or on rocky cliff ledges. In the Northwestern Hawaiian Islands, they often build nests in ironwood trees or *naupaka*.



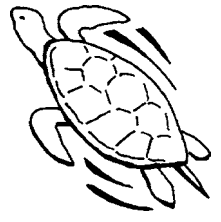
Illustration: Joan M. Yoshioka

Adaptations & Interactions

- It uses its long, sharp beak to feed on small fish near the surface of the ocean, as well as on hatchling hawks-bill sea turtles making the journey across beaches from nest to ocean.

Human Connections

- Even today, traditional Polynesian voyagers look for *noio* as a sign that they are close to islands.
- The name, “noddy,” comes from the nodding or bobbing of males feeding fish to females before egg laying.



‘Ua‘u Kani or Wedge-Tailed Shearwater (*Puffinus pacificus*)

Order Procellariiformes, Family Procellariidae

- This indigenous seabird is found throughout the tropical and subtropical Pacific and Indian Oceans.
- ‘Ua‘u kani is the most common seabird seen around the main islands.

Habitat

- It nests throughout the Northwestern Hawaiian Islands and along the coasts and offshore islets of the main islands.

Adaptations & Interactions

- ‘Ua‘u kani nest in colonies, digging burrows with their feet or nesting in natural crevices.

Human Connections

- Young birds leaving their colonies are often stranded on beaches and disoriented by urban lights. They can be hit by cars or killed by cats and dogs.



Photo: Forest Starr and Kim Martz

Kōlea or Pacific Golden Plover (*Pluvialis fulva*)

Order Charadriiformes, Family Charadriidae

- This indigenous shore bird is the most abundant migratory winter visitor to Hawai‘i.
- Kōlea nest in the arctic and return here in August. Most birds fly north again by early May. A few oversummer here, often first-year birds.

Habitat

- They are found on mudflats, lawns, fields, and grassy mountain slopes from sea level to above 3050 meters (10,000 feet). Kōlea are highly territorial and return to the same area year after year.

Adaptations & Interactions

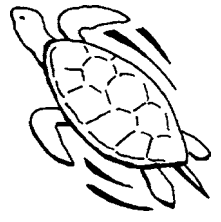
- Kōlea feed by running in short spurts, then stopping to search for insects and other invertebrates.
- Plant seeds from the digestive tracts of kōlea and other shore birds remain viable and able to sprout upon arrival in Hawai‘i. Seeds may also be transported stuck to feathers or mud-encrusted feet.

Human Connections

- Its Hawaiian name has come to mean “boaster.”
- In Hawaiian legend, kōlea and tree snails have a mutually beneficial relationship. Kōlea bring the snails nectar and in return the snails sing for the birds.



Photo: Eric Nishibayashi



‘Ūlili or Wandering Tattler

(*Heteroscelus incanus*)

Order Charadriiformes, Family Scolopacidae

- This indigenous shore bird is a common migratory winter visitor to Hawai‘i.
- ‘Ūlili nest in Alaska and arrive here in August. Most birds fly north again by late April or early May.

Habitat

- These birds are most often found in mud flats, on sandy beaches, rocky coastlines, and rocky streams inland.

Adaptations & Interactions

- ‘Ūlili bob up and down as they probe into the mud or under rocks searching for mollusks and other invertebrates.

Human Connections

- Its Hawaiian name mimics the call of the ‘ūlili.



Photo: Eric Nishibayashi

Hunakai or Sanderling (*Calidris alba*)

Order Charadriiformes, Family Scolopacidae

- This indigenous shore bird is a common migratory winter visitor to Hawai‘i.
- *Hunakai* arrive in Hawai‘i by August and fly north to their arctic breeding grounds in April.

Habitat

- They are commonly seen on mud flats and sandy beaches, often with plovers and turnstones.

Adaptations & Interactions

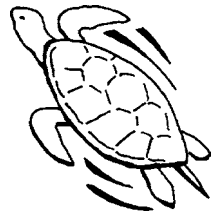
- *Hunakai* feed by picking at the surface of the mud flat or in shallow water for invertebrates. They also search for exposed prey by chasing receding waves.

Human Connections

- In Hawaiian, its name means “sea foam.”



Photo: Eric Nishibayashi



'Akekeke or Ruddy Turnstone

(Arenaria interpres)

Order Charadriiformes, Family Scolopacidae

- This indigenous shore bird is a very common migratory winter visitor to Hawai'i.
- 'Akekeke nest in the Arctic, leaving Hawai'i in April or May and returning in August. A few over-summer here.

Habitat

- They are commonly found along shorelines and mud flats as well as in fields and lawns.

Adaptations & Interactions

- In their search for insects and crustaceans, they turn over stones with their bills. They sometimes break open and eat seabird eggs.
- They often join small flocks of other shore birds.

Human Connections

- The Hawaiian name means "talkative."



Photo: Eric Nishibayashi

Ae'o or Hawaiian Stilt or Black-Necked Stilt

(Himantopus mexicanus knudseni)

Order Charadriiformes, Family Recurvirostridae

- This endemic race of water bird is a year-round resident on all of the main Hawaiian Islands, and is endangered.

Habitat

- Ae'o nest in wetlands, including Kanahā and Keālia ponds on Maui. Nesting sites are adjacent to or on low islands in fresh, brackish, or salt water.
- They spend time in open mud flats, pickleweed mats, and open pastureland, where visibility is good and predator pressure is low.

Adaptations & Interactions

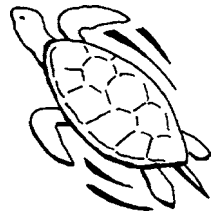
- Their nests are usually shallow depressions lined with stones and twigs.
- Hawaiian stilts feed in shallow water, where they find a variety of invertebrates and other aquatic organisms.

Human Connections

- The stilt's Hawaiian name means "one standing tall."



Photo: Eric Nishibayashi



'Alae Ke'oke'o or Hawaiian Coot (*Fulica americana alai*)

Order Gruiformes, Family Rallidae

- This endemic water bird is found on all the main Hawaiian Islands. It is an endangered species.

Habitat

- 'Alae ke'oke'o are found in fresh and saltwater marshes and ponds. They build floating nests in aquatic vegetation.

Adaptations & Interactions

- When ponds dry up, coots fly long distances looking for suitable habitat, sometimes flying between islands.
- 'Alae ke'oke'o eat seeds and leaves of aquatic plants, insects, tadpoles, and small fish.

Human Connections

- In Hawaiian, 'alae ke'oke'o means "white forehead."

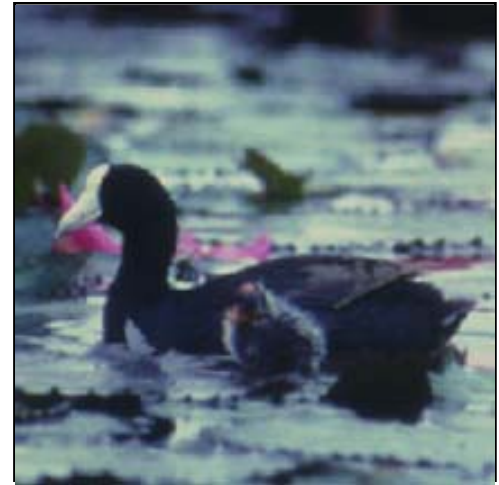


Photo: Eric Nishibayashi

'Auku'u or Black-Crowned Night-Heron (*Nycticorax nycticorax hoactli*)

Order Ciconiiformes, Family Ardeidae

- This indigenous water bird is resident on all the main Hawaiian Islands and is also found on the American continent.

Habitat

- 'Auku'u build nests made of sticks, off the ground in trees.
- These herons are often seen flying between roosting sites and feeding areas in ponds, streams, marshes, lagoons, exposed reefs, and tide pools.

Adaptations & Interactions

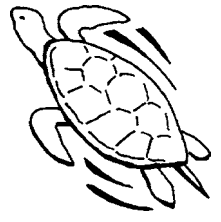
- 'Auku'u stand still in the water, waiting for their prey to appear. They strike with lightning quickness, catching fish, crustaceans, and frogs. They also eat mice, insects, and the chicks of other birds.

Human Connections

- The Hawaiian saying "'auku'u hapapa ka ha'i loko" literally means "heron groping in somebody else's fish pond." In common usage it means "a man groping for someone else's woman."



Photo: Eric Nishibayashi



Koloa or Hawaiian Duck (*Anas wyvilliana*)

Order Anseriformes, Family Anatidae

- This endemic water bird was once found on all of the main islands except Lāna‘i and Kaho‘olawe. There are now small populations on Kaua‘i, Maui, O‘ahu, and Hawai‘i. It is an endangered species.

Habitat

- These ducks are found in lowland wetlands, river valleys, and mountain streams.

Adaptations & Interactions

- *Koloa* build their nests on the ground, lining them with down and feathers.
- They feed on freshwater vegetation, mollusks, and insects.
- Many *koloa* have hybridized (crossbred) with mallard ducks, meaning that there are fewer of this endangered species than there may appear to be.

Human Connections

- In Hawaiian, *koloa* means “duck.” This species is sometimes called *koloa maoli* or “native *koloa*,” to distinguish it from migratory or introduced ducks, also called *koloa*.



Cattle Egret (*Bubulcus ibis*)

Order Ciconiiformes, Family Ardeidae

- This nonnative bird is native to the Old World.

Habitat

- Cattle egrets are common on most of the main Hawaiian Islands. On Maui, they breed at Kanahā and Keālia ponds.
- Cattle egrets can be found in a variety of habitats including cattle pens and pastures, garbage dumps, watercress ponds, and taro patches.

Adaptations & Interactions

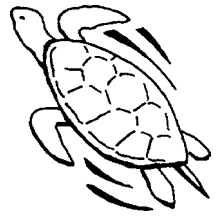
- They nest in large colonies (or “heronries”), often in trees.
- They feed on flies, grasshoppers, other insects, and crayfish.
- This species may pose a threat to native species by competing for nesting sites and food, and by preying on young birds.

Human Connections

- The cattle egret was introduced in 1959 to help control pest insects on cattle ranches.



Photo: Eric Nishibayashi



Common Myna (*Acridotheres tristis*)

Order Passeriformes, Family Sturnidae

- This nonnative bird is native to India.

Habitat

- Mynas are common on all of the main islands, usually at elevations below 2500 meters (8200 feet). They have recently become established on Midway Atoll.

Adaptations & Interactions

- Mynas share communal roosting trees. They nest in tree hollows, cavities in buildings, or in dense foliage.
- Mynas prey on the eggs and nestlings of other birds.

Human Connections

- Mynas were introduced in 1865 to help control army worms.
- They help clean up after humans, eating garbage or animals killed by cars along roadsides.



Illustration: Joan M. Yoshioka

***Pinao* or Big Blue Darner (*Anax strenuus*)**

Order Odonata, Family Aeshidae

- This endemic insect's ancestors probably colonized the Hawaiian Islands by flight.
- It is the largest native Hawaiian insect, with a wingspan of up to six inches, which also makes it the largest insect in the United States.

Habitat

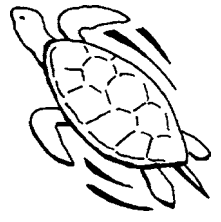
- *Pinao* are widespread on all the islands and probably move from island to island.

Adaptations & Interactions

- The large compound eyes, moveable head, biting mouthparts, long gripping legs, and four independently moving wings are all adaptations for catching insects in flight.



Photo: Eric Nishibayashi



***Pinao ‘Ula* or Orange-Black Damselfly**

(*Megalagrion xanthomeles*)

Order Odonata, Family Coenagrionidae

- This endemic insect’s ancestors probably colonized the Hawaiian Islands by flight.
- It was once found on all the main islands, but is now extirpated on Kaua’i and nearly so on O’ahu. On Maui this species is rare and potentially threatened, with highly localized populations.



Photo: Hawai’i Biological Survey

Habitat

- It is a small damselfly with red and black males and brown females.
- It is found in the lowlands in a variety of habitats, most commonly occurring in coastal wetlands.
- On Maui, the *pinao ‘ula* known to breed in “brackish” (somewhat salty, but not as salty as ocean water) ponds near the La Perouse lighthouse.

Adaptations & Interactions

- The “naiads” (larvae) are eaten by mosquito fish and possibly long-legged ants.

Seashore Splash-Zone Cricket

(*Caconemobius* spp.)

Order Orthoptera, Family Gryllidae

- This endemic insect is found on all the main Hawaiian Islands.

Habitat

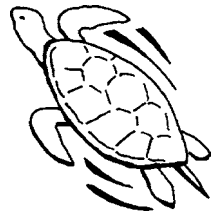
- It is found only in wet rock habitats in the ocean splash zone.



Illustration: Joan M. Yoshioka

Adaptations & Interactions

- This salt water-tolerant species may have originally “rafted” here on floating debris or vegetation from a far-off place.
- It feeds on flotsam in rocky areas.
- Active mainly at night, it is sometimes the most abundant animal on wet boulders.
- This is one of the “crickless” Hawaiian crickets. Unlike many other cricket species, the seashore splash-zone cricket is wingless and does not rub body parts together to make the characteristic cricket chirp.



Big-Headed Ant (*Pheidole megacephala*)

Order Hymenoptera, Family Formicidae

- This nonnative arthropod is thought to be a native of southern Africa. It is now widespread throughout the tropical and subtropical regions of the world. It was first recorded in Hawai‘i in 1886. Hawai‘i has no native ant species.



Illustration: Joan M. Yoshioka

Habitat

- The big-headed ant is found from sea level to about 750 meters (2460 feet). It has been recorded in ‘ōhi‘a canopies as well as on the ground. Nests are generally underground or beneath an object.
- It is not tolerant to cold nor to extremely low or high humidity.

Adaptations & Interactions

- The big-headed ant is believed to be largely responsible for the disappearance of most native insects and spiders, and perhaps some native bird species, in lowland areas in Hawai‘i.
- During the mating season, winged males and reproductive females fly from the nest to mate and begin new colonies.

Large Centipede (*Scolopendra subspinipes*)

Order Chilopeda, Family Scolopendridae

- This nonnative arthropod has been introduced throughout the world and is abundant on tropical islands. Its native region is unknown.
- This is the largest of 24 species of centipedes in Hawai‘i. It can reach over 15 centimeters (six inches) in length, with 20 pairs of walking legs.



Illustration: Joan M. Yoshioka

Habitat

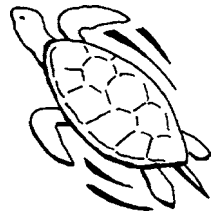
- It is found largely in lowland areas.

Adaptations & Interactions

- Chewing mouthparts and a pair of poisonous claws allow these arthropods to prey on various insects, including cockroaches, and earthworms.

Human Connections

- In humans, centipede bites can lead to localized pain, swelling, vomiting, dizziness, headaches, and an irregular pulse.



***Mo‘o Niho ‘Awa* or Lesser Brown Scorpion**

(Isometrus maculatus)

Order Scorpiones, Family Buthidae

- This nonnative arthropod is found in tropical areas all over the world. Its native region is unknown.
- It is related to insects and spiders and resembles a small lobster, with claws and a long tail that ends in a poisonous stinger.

Habitat

- It is widely distributed in lowland areas of the Hawaiian Islands.

Adaptations & Interactions

- It feeds on spiders and insects at night, grasping the prey with its pincers and paralyzing the prey with its stinger.

Human Connections

- This scorpion may sting humans in self-defense, but its venom is not dangerous.



Illustration: Joan M. Yoshioka

***Honu* or Green Sea Turtle (*Chelonia mydas*)**

Order Chelonia, Family Cheloniidae

- This indigenous reptile is federally listed as a threatened species. It is likely that fewer than 200,000 mature females remain, where tens of millions of these turtles once populated the oceans.
- These large sea turtles weigh from 150 to 400 pounds.

Habitat

- *Honu* are found in offshore waters and coastal beaches.
- They nest mostly in the summer on Northwestern Hawaiian Islands beaches. Other times, they are found near the main islands.
- *Honu* migrate up to 800 miles to reach the French Frigate Shoals and other islands in the northwestern part of the Hawaiian chain.

Adaptations & Interactions

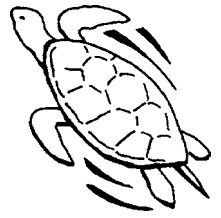
- These turtles feed largely on *limu* (algae) growing on coral and rocks.
- The females dig nests in the sand, deposit their eggs, and then cover the nests with sand again.

Human Connections

- Green turtles are a traditional Hawaiian source of meat.
- Fishing crews once killed green turtles in large numbers, and they are still taken illegally despite legal protection. Turtles are also killed when they eat marine debris or are accidentally caught in fishing nets. They are affected by coastal habitat destruction and water pollution, and threatened by a growth of tumors called fibropapilloma, the cause of which is unknown.



Photo: Forest Starr and Kim Martz



Honu 'Ea or Hawksbill Turtle

(Eretmochelys imbricata)

Order Chelonia, Family Cheloniidae

- This indigenous reptile is federally listed as an endangered species.

Habitat

- This turtle is found in offshore waters and coastal beaches.
- It nests primarily on beaches on the eastern shores of the island of Hawai'i, although it also nests on other islands. Nesting season is from July to November.
- The females dig nests in the sand, deposit their eggs, and then cover the nests with sand again.

Adaptations & Interactions

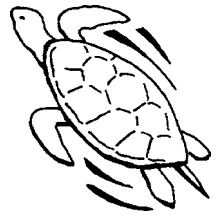
- The pointed beak may be an adaptation to feeding on sponges.
- During the two-month incubation period, the eggs may be dug up by feral cats, mongooses, dogs, and humans.

Human Connections

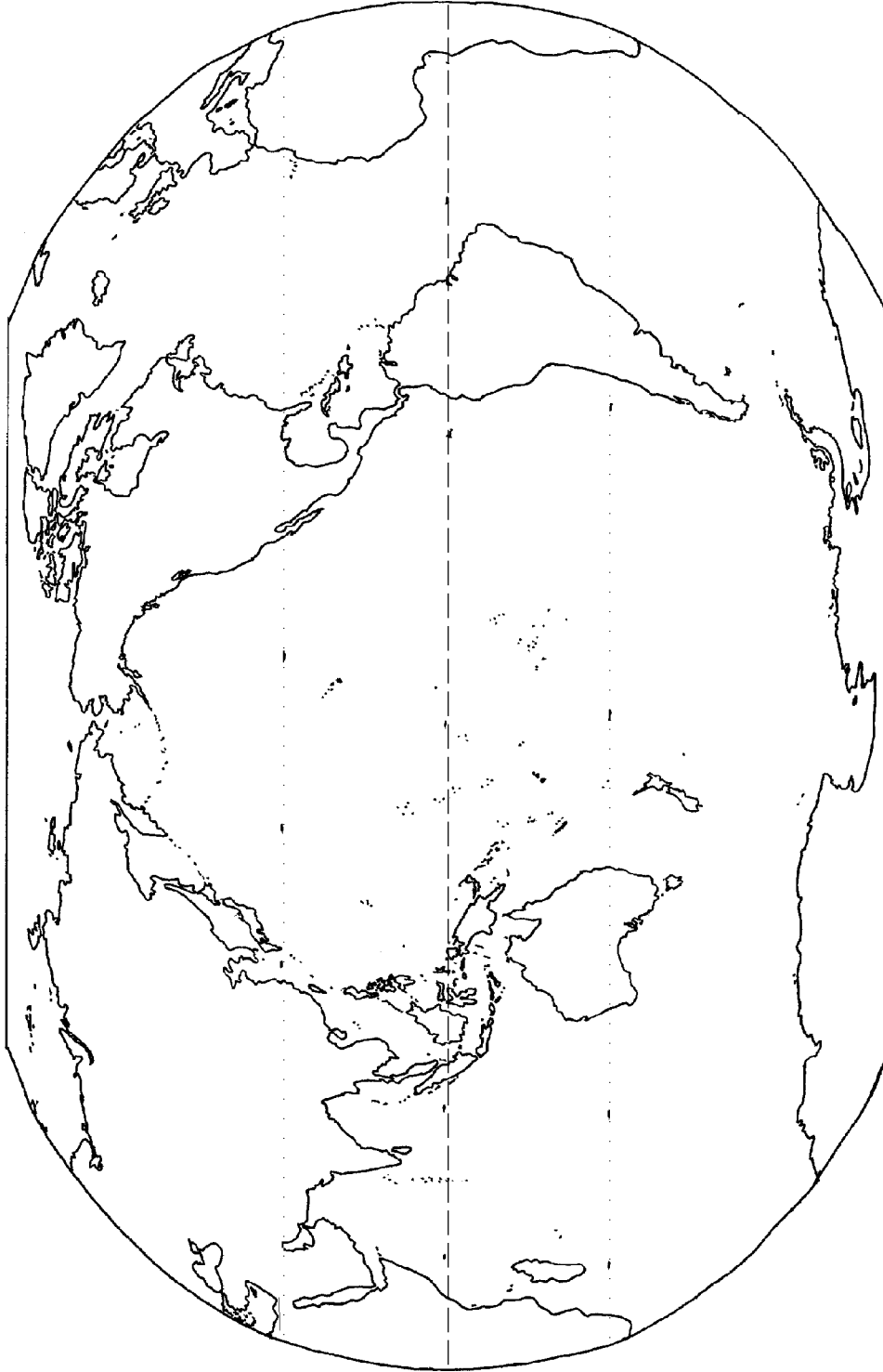
- People interfere with nesting hawksbill turtles by activities such as compacting sand and leaving nearby buildings lighted at night, which disorients both nesting females and hatchlings moving to the ocean.

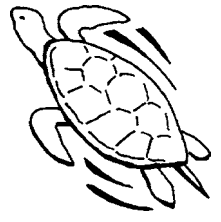


Illustration: Joann M. Yoshioka



World Map





Activity #2

Coastal Jeopardy Game

● ● ● Class Period One *Coastal Jeopardy*

Materials & Setup

- “Coastal Jeopardy Questions and Answers” (pp. 37-46)
- “Coastal Jeopardy Rules” and Game Board acetates (master, pp. 47-51)
- Overhead projector and screen
- Stopwatch or a watch with a second hand

For each of four student teams

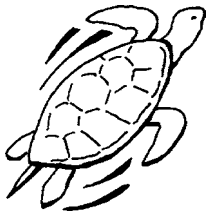
- Set of 44 “Coastal Species Cards” in color (from Activity #1)

For each student

- Student Page “Coastal Species List” (p. 52)

Instructions

- 1) Divide the class into four teams for the Coastal Jeopardy game. Give each team a number from one to four, or have them make up a name for themselves.
- 2) Make sure each group has a set of “Coastal Species Cards,” and allow them some time to study the information on the cards. An effective study strategy is to divide the cards evenly among students on the team and have each student study a small number of cards.
- 3) When the study time is finished, collect the species cards and hand out the Student Page “Coastal Species List” to each student. Explain to them that they will be able to refer to this list during the game but not to the species cards or any notes they may have taken.
- 4) Review the object, rules, and procedures for the game with students using the instructions given here and the rules on the “Coastal Jeopardy Rules” acetate.
- 5) Use the “Round 1 Game Board” acetate to begin the game. Cross off each category and \$ value as it is selected. Read the corresponding statement from “Coastal Jeopardy Questions and Answers.”
- 6) Teams have 15 seconds to respond to questions. Continue play by following the rules, and keep score on the Game Board acetate.
- 7) The team with the largest score wins.



- 8) Play subsequent rounds in the same manner, using the appropriate game sheet acetate and questions.
- 9) Stop whatever round is in session at the end of the first class period, and determine a winner for whatever rounds have been played.

Class Period Two *Coastal Jeopardy, Continued*

●●● Materials & Setup

- See Class Period One
-
- 1) Divide the class into the same teams used during the first class period. If you think students need more time to study the species cards, give groups ten minutes to prepare.
 - 2) Play the remaining rounds of Coastal Jeopardy. Whether you add today's score to the previous scores or start with a clean slate is up to you.

Journal Ideas

- How does knowing more about coastal plant and animal species change how you think about coastal areas on Maui?
- What do you think is important to protect about the coastal ecosystem on Maui and elsewhere in Hawai'i?
- Why do you think coastal species figure prominently in Hawaiian legends?

Assessment Tools

- Individual preparation for and participation in the Coastal Jeopardy game
- Group preparation and performance in the game
- Journal entries

Some teacher-only resources have been omitted from the online document.

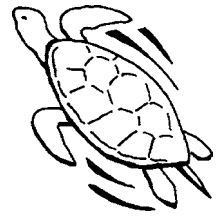
They are available as password-protected files at:

www.hear.org/hoike/teachermaterials

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They are available as password-protected files at:

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Coastal Jeopardy Rules and Game Boards

Object

Accumulate the largest amount of money by providing correct responses in 15 seconds or less.

Rules

- Each team selects a spokesperson. The spokesperson may consult with team members, but only the response given by the spokesperson will count.

- Team #1 begins the game, and play progresses in numeric order through the teams.

- Select a category and a \$ amount. The teacher will read you a statement. Your team will have 15 seconds to answer that statement with one question. Your response must be framed as a question. For example:

Statement: This shore bird has a unique feeding habit, running in short spurts, then stopping to search for insects and other invertebrates.

Your answer: What is the *Kōlea* or Pacific Golden Plover?

- If your answer is correct, the \$ amount is added to your team's total score and your team selects another category and \$ amount, attempting to answer that question. Your team continues as long as you answer the questions correctly. (For answers that involve species names, you may correctly state the Hawaiian *or* English name.)

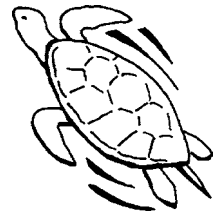
- If you answer incorrectly, the next team gets 15 seconds to answer the same statement. Correct answers always result in adding the \$ amount to the answering team's score and selecting a new question. Incorrect answers always result in subtracting the \$ amount and the next team getting a chance to answer the same statement.

If none of the four teams can answer a statement correctly, the teacher will read the correct response and play continues with the team whose turn it was when that statement was first read.

DOUBLE JEOPARDY

In each round, there is one "double jeopardy" question. If your team chooses the double jeopardy question, you may decide to bet a portion or all of your total score. Tell the class how much you are betting. If you answer the question correctly, you add that amount to your score. If you answer incorrectly, subtract that amount from your score.

Play continues until all questions have been answered or time runs out.



Round 1 Game Board

Native Plants	Hawaiian Connections	Recently Introduced Plants	Birds	Other Critters
\$100	\$100	\$100	\$100	\$100
\$200	\$200	\$200	\$200	\$200
\$500	\$500	\$500	\$500	\$500
\$800	\$800	\$800	\$800	\$800
\$1000	\$1000	\$1000	\$1000	\$1000

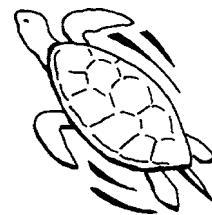
Score

Team #1:

Team #2:

Team #3:

Team #4:



Round 2 Game Board

Polynesian-Introduced Plants	Birds	Other Critters	Hawaiian Connections	Coastal Adaptations
\$100	\$100	\$100	\$100	\$100
\$200	\$200	\$200	\$200	\$200
\$500	\$500	\$500	\$500	\$500
\$800	\$800	\$800	\$800	\$800
\$1000	\$1000	\$1000	\$1000	\$1000

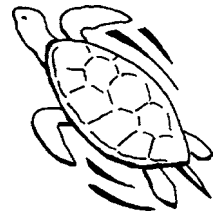
Score

Team #1:

Team #2:

Team #3:

Team #4:



Round 3

Hawaiian Connections	Coastal Adaptations	Eating and Being Eaten	Origins and Distribution	Grab Bag
\$100	\$100	\$100	\$100	\$100
\$200	\$200	\$200	\$200	\$200
\$500	\$500	\$500	\$500	\$500
\$800	\$800	\$800	\$800	\$800
\$1000	\$1000	\$1000	\$1000	\$1000

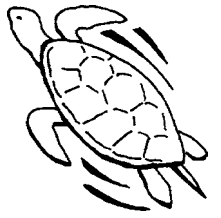
Score

Team #1:

Team #2:

Team #3:

Team #4:



Round 4

Hawaiian Connections	Coastal Adaptations	Human Impacts	Origins & Distribution	Hawaiian Connections II
\$100	\$100	\$100	\$100	\$100
\$200	\$200	\$200	\$200	\$200
\$500	\$500	\$500	\$500	\$500
\$800	\$800	\$800	\$800	\$800
\$1000	\$1000	\$1000	\$1000	\$1000

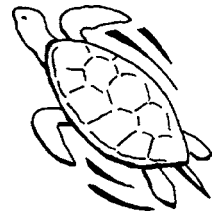
Score

Team #1:

Team #2:

Team #3:

Team #4:



Coastal Species List

Native Plants

Hala or Screwpine
Naupaka Kahakai or Beach Naupaka
‘Ōhelo Kai
Pōhinahina or Beach Vitex
‘Ūlei or Hawaiian Rose
‘Ilima
Pōhuehue or Beach Morning Glory
Pā‘ū o Hi‘iaka or Small Blue Morning Glory
Kauna‘oa Kahakai or Hawaiian Dodder
‘Ākulikuli or Sea Purslane
‘Aki‘aki or Beach Dropseed
Ma‘u ‘Aki‘aki or Button Sedge

Polynesian Introduced Plants

Niu or Coconut Palm
Milo or Portia Tree
Hau
Kou
Noni or Indian Mulberry

Recently Introduced Plants

Kiawe or Mesquite
Koa Haole
Indian Pluchea
‘Ākulikuli Kai or Pickleweed
Paina or Common Ironwood

Native Birds

‘Iwa or Great Frigatebird
Koa‘e Kea or White-Tailed Tropicbird
Noio or Black Noddy
‘Ua‘u Kani or Wedge-Tailed Shearwater
Kōlea or Pacific Golden Plover
‘Ulili or Wandering Tattler
Hunakai or Sanderling
‘Akekeke or Ruddy Turnstone
Ae‘o or Hawaiian Stilt or Black-Necked Stilt
‘Alae Ke‘oke‘o or Hawaiian Coot
‘Auku‘u or Black-Crowned Night-heron
Koloa or Hawaiian Duck

Non-Native Birds

Cattle Egret
Common Myna

Native Insects

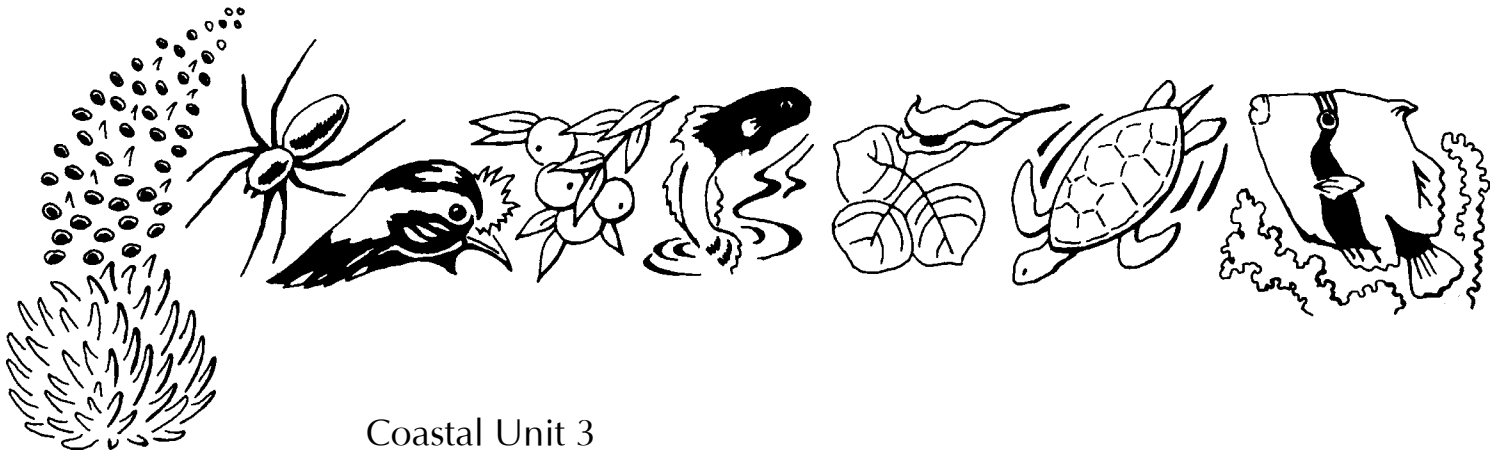
Pinao or Big Blue Darner
Pinao ‘Ula or Orange-Black Damselfly
Seashore Splash-Zone Cricket

Non-Native Arthropods

Big-Headed Ant
Large Centipede
Scorpion

Native Vertebrates

Honu or Green Sea Turtle
Honu ‘Ea or Hawksbill Turtle



Coastal Unit 3

Anchialine Detectives

Overview

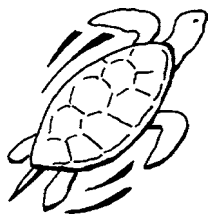
Anchialine ponds are pools containing brackish or salt water that have no surface connection with the ocean. On Maui, they dot the southwest coastline of Maui on Cape Kīnau and Cape Hanamanioa. In this unit, students explore the anchialine pond habitat, using their reasoning abilities to develop hypotheses that explain the ponds' characteristics as well as an interesting distribution pattern associated with the small red shrimp that inhabit many of these ponds. They also conduct an experiment to test the salinity tolerance of brine shrimp, which, like the red shrimp of the Maui ponds, are adapted to a range of habitat conditions.

Length of Entire Unit

Four class periods

Unit Focus Questions

- 1) Why are anchialine ponds a special habitat on Haleakalā?
- 2) What are the unique characteristics of anchialine ponds and what geological and biological factors may help explain these characteristics?
- 3) How do brine shrimp respond to differences in salinity, a key environmental variable in anchialine ponds?



Unit at a Glance

Activity #1

Anchialine Pond Detective Story

Students solve six “mysteries” related to anchialine ponds and red shrimp that are found in these ponds.

Length

One class period

Prerequisite Activity

None

Objectives

- Describe and explain key environmental characteristics of the anchialine pond habitat.
- Generate hypotheses to explain anchialine pond characteristics and adjust these hypotheses based on new information.
- Devise a way to test a scientist’s hypothesis about the distribution of shrimp species associated with anchialine ponds.

DOE Grades 9-12 Science Standards and Benchmarks

DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.

- Formulate scientific explanations and conclusions and models using logic and evidence.

LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF THE INQUIRING MIND: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- **OPEN-MINDEDNESS:** When appropriate, modify ideas, explanations, and hypotheses, based on empirical data or evidence.

Activity #2

Salinity Tolerance Lab

Students conduct a lab to test brine shrimp tolerance for different salinity levels.

Length

Three class periods

Prerequisite Activity

None

Objectives

- Investigate salinity tolerance among brine shrimp, accurately performing lab procedures, making observations, and recording results.

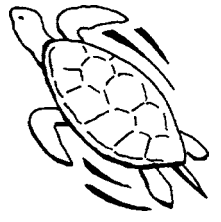
DOE Grades 9-12 Science Standards and Benchmarks

DOING SCIENTIFIC INQUIRY: Students demonstrate the skills necessary to engage in scientific inquiry.

- Develop and clarify questions and hypotheses that guide scientific investigations.
- Design and conduct scientific experiments to test hypotheses.

LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF THE INQUIRING MIND: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- **HONESTY:** Report findings accurately without alterations and draw conclusions from unaltered findings.



Enrichment Ideas

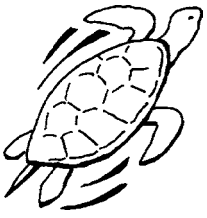
- Devise and conduct an experiment to test the effect of different light conditions and water temperatures on brine shrimp hatching rates, using the salinity concentration that was the most conducive to hatching in the first experiment in Activity #2 “Salinity Tolerance Lab.”
- Build on Activity #2 “Salinity Tolerance Lab” by devising and conducting an experiment to investigate habitat *preference* among adult brine shrimp using environmental variables such as salinity, temperature, and light. One such experiment establishes condition gradients in water contained in flexible plastic tubing, allowing shrimp to congregate in the preferred conditions. By clamping the tubing into sections, students are able to sample along this gradient to determine habitat preferences.

Resources for Further Reading and Research

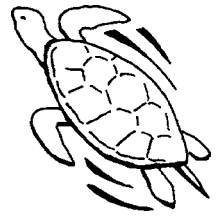
Maciolek, John A., “Distribution and Biology of Indo-Pacific Insular Hypogeal Shrimps,” *Bulletin of Marine Science*, 1983, Vol. 33, No. 3, pp. 606-618.

Science Junction, The Brine Shrimp Project at www.ncsu.edu/sciencejunction/terminal/lessons/brine.html.

Includes a lesson plan for an investigation into the factors that affect the hatching and development of brine shrimp eggs.



Coastal Unit 3



Activity #1

Anchialine Pond Detective Story

● ● ● Class Period One *Anchialine Pond Detective Story*

Materials & Setup

- “The Anchialine Pond Detective Story” acetates (master, pp. 11-19)
- Overhead projector and screen

For each student or group of three to four students

- Student Page “The Anchialine Pond Detective Worksheet” (pp. 20-25)

For each student

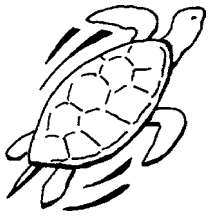
- Student Page “Hypothetically Speaking” (pp. 26-28)

Instructions

- 1) Divide the class into groups of three to four students, or have students work individually. Hand out the Student Page “The Anchialine Pond Detective Worksheet.”
- 2) There are eight acetates.
 - Acetate #1 introduces anchialine ponds and the activity.
 - Acetates #2-6 each pose a mystery for students to resolve to by developing hypotheses. Most include the question, a photo, and a series of observations.
 - Acetate #7 is an “Information Interlude” that provides students with background for the next “mystery” acetate.
 - Acetate #8 is another “mystery” acetate that includes a question, a photo, and a series of observations.

Use the acetates as a “script” for this activity. Go through the acetates, one by one, giving student groups time to come up with a hypothesis for each question and write it on their worksheets. You may incorporate class discussion into this activity by asking students to discuss their ideas openly with each other before recording their hypotheses. Before moving on to the next acetate, review the correct answer using the responses and additional information provided in the teacher background for “The Anchialine Pond Detective Story” (pp. 7-10).

- 3) Hand out the Student Page “Hypothetically Speaking” as homework.



Journal Ideas

- Do you think it's important to protect the anchialine pools on Maui? Why or why not?
- Write a short story about the adventures of a traveling shrimp.

Assessment Tools

- Participation in group work
- Student Page "The Anchialine Pond Detective Worksheet"
- Student Page "Hypothetically Speaking"
- Journal entries

Some teacher-only resources have been omitted from the online document.

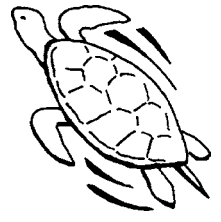
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The Anchialine Pond Detective Story

Acetate #1

What are Anchialine Ponds?

Here and there in the rough 'a'ā flows that dominate the southwest coastline of Maui between Cape Kīna'u and Cape Hanamanioa, lies a scattering of anchialine ponds. Anchialine ponds are brackish or saltwater pools, a unique habitat found on Maui, O'ahu, and Hawai'i, as well as on other islands and coastal areas in tropical regions around the world.

Anchialine ponds are simple natural systems in which the balance is easily disturbed. For example, people sometimes disrupt the system by dumping aquarium fish in the ponds. The fish eat all the red shrimp, which normally feed on algae. With the shrimp essentially removed from the system, the algae can take over the pond.

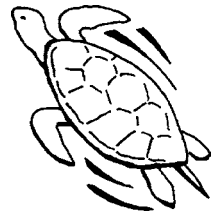


*Anchialine ponds at 'Āhīhi-Kīna'u
(Photo: Forest Starr and Kim Martz)*

Mysteries to Solve

Anchialine ponds in Hawai'i are home to several species of tiny shrimp, some of which are found nowhere else in the world and others which have been found in anchialine ponds thousands of miles away.

You will be asked to solve six mysteries linked to these tiny shrimp. You will develop hypotheses to explain these mysteries based on observations made by scientists who have studied these unique ponds and their tiny inhabitants for many years.



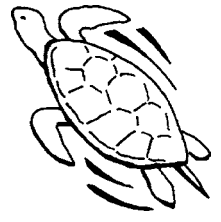
Mystery #1

The water in the ponds is both fresh water and salt water. Where does this water come from?



*Anchialine pool at Kanaio
(Photo: Philip Thomas)*

- Observation #1 If you taste the water, it is slightly salty but not as salty as the ocean.
- Observation #2 While the ponds in the photos are near the coast, they are far enough from the ocean that waves do not break into them.
- Observation #3 The water in the ponds rises and falls with the tides along the shoreline.
- Observation #4 If you swim along the lava rock shoreline, you will swim through water that is very blurry and colder than the surrounding ocean water.
- Observation #5 Hawaiians living along the lava shorelines from Cape Kīna‘u, Kanaio and south to Kahikinui were able to dig wells along the coast or explore coastal lava tubes and find water that was slightly salty but good enough to drink. This was the only source of water for many people living along this coastline.



Acetate #3

Mystery #2

What makes the water turn red each spring at Wai‘ānapanapa?

Popoalaea, a Hawaiian chiefess from the Hāna area above Wai‘anapanapa, was married to a powerful and arrogant warrior chief named Kakae. Kakae became jealous of her affection for her brother, Pi‘ilani, and threatened to kill the chiefess. Popoalaea fled for her life, along with her faithful companion, Manona.

At the last minute, Manona picked up a small *kāhili*. This feathered standard was a symbol of royalty. They fled toward the sea, travelling in lava tubes and under cover until they reached the ocean at Papaloa, near Hāna.

Popoalaea and Manona found a deep cavern in which they hid during the day, emerging only at night to look for food and a way to escape to another island. A pool of water filled the entrance to the cave, and to enter, the women had to dive into the pool and under a jutting ledge. The cavern opened into a low room where Popoalaea and Manona passed their days silently dangling their feet in the water. Manona would sometimes wave the *kāhili* slowly back and forth to distract her mistress’s thoughts.

Meanwhile Kakae searched madly for his wife. At the village of Honokalani, he heard strange tales of spirits wandering the shore at night. Nearby, he stopped to rest on the rocks just above a pool of water at the entrance to a cave. He noticed the perfect reflection of the cave roof in the still surface of the water. Suddenly he saw something move in the reflection, and recognized it as the *kāhili*.

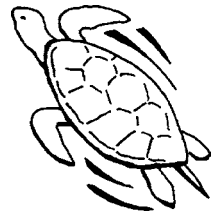
Kakae and his men dove into the cavern and there killed both women by dashing them against the rocks, then throwing their bodies into the pool. To this day, the roof and sides of the cave are dark with the women’s blood. On the nights of Kū, when the moon is in a certain stage, the waters of the pool are said to become red, and there is an eerie light in the cave.

In the spring—the time of year at which the tragedy took place—the stones are said to be a redder hue.

Adapted from Elspeth P. Sterling, Sites of Maui, Bishop Museum Press, Honolulu, 1998, pp. 125-6.



*Wai‘ānapanapa cave
(Photo: Carol Gentz)*



Acetate #4

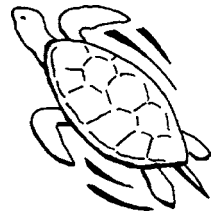
Mystery #3

You often see small, red shrimp in the ponds. If all the water goes out of the ponds at low tide, the shrimp disappear. Where do they go?



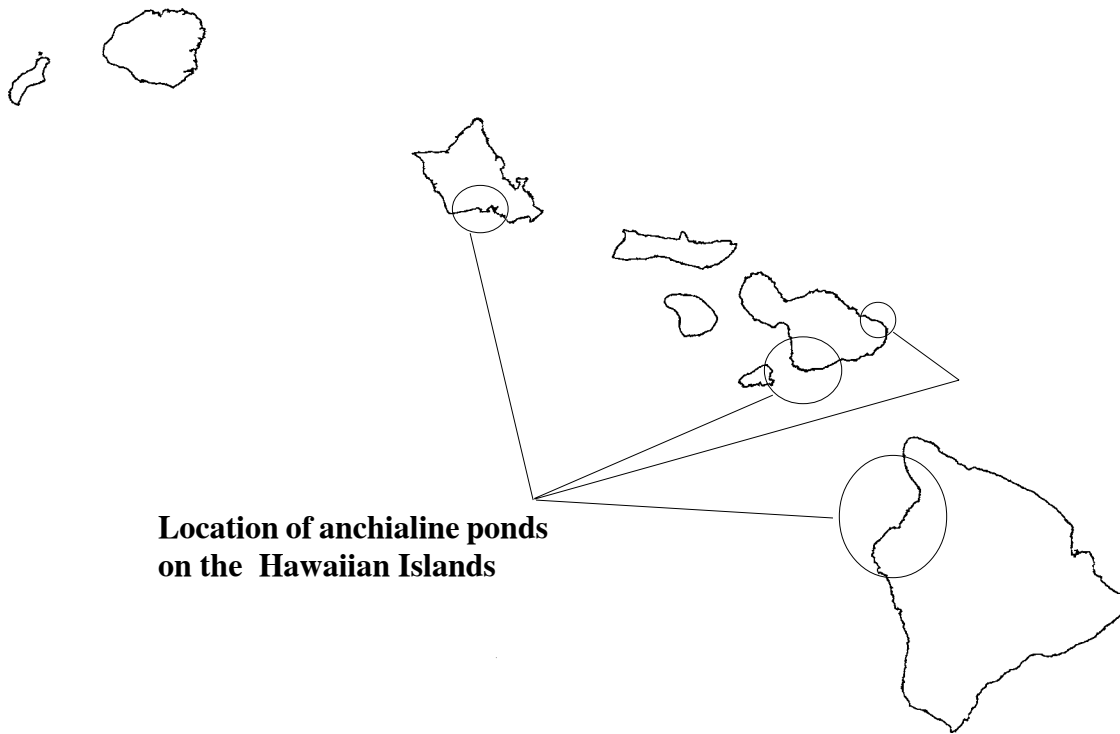
Photo: John Hoover, Hawai'i's Sea Creatures, Mutual Publishing

- Observation #1: When the tide starts rising and the water level rises in the ponds, too, the shrimp enter the ponds.
- Observation #2: If you dig a well along the shoreline, you are likely to have some of these shrimp in your well.
- Observation #3: So far, the shrimp found in the ponds in Hawai'i have not been seen in the ocean. But they are small, so it could be the case that they simply have not been discovered in the ocean yet. Most do not exceed 3.0 cm (1.2 in) in body length.

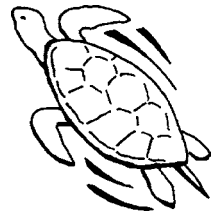


Mystery #4

The same species of shrimp that live in the Maui ponds also live in similar ponds on the Kona coast of Hawai'i and holes in the ancient (and dry) coral reef that is now the 'Ewa plain of O'ahu. How did the shrimp travel between the islands?



- Observation #1 These shrimp can live in a wide range of salinity levels but need some saltiness in the water.
- Observation #2 Maui and the Big Island have a deep-water channel between them, and even when the sea level was lower during the last ice age about 12,000 years ago, there was still a deep channel.
- Observation #3 In their larval stages, reef fish and corals disperse to other places as part of the "plankton" (tiny organisms that float freely through the ocean).

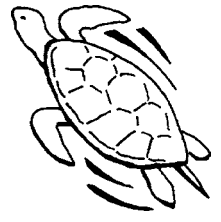


Mystery #5

The larvae reach the shorelines of the other islands. How do they get into the ponds?



*Anchialine ponds at Cape Hanamanoa
(Photo: Forest Starr and Kim Martz)*



Information Interlude

Anchialine ponds are found in coastal areas throughout the tropics. As you can see from the maps in “The Anchialine Pond Detective Story Worksheet,” certain species are found in ponds separated sometimes by thousands of miles of ocean.

Find these examples on the shrimp distribution maps:

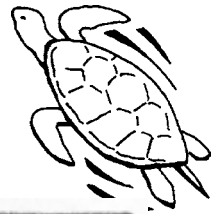
Cp = *Callinectes pholidota*

Found in ponds on Hawaiian Islands, Ellice Islands, and the north end of the Red Sea

Al = *Antecaridina lauensis*

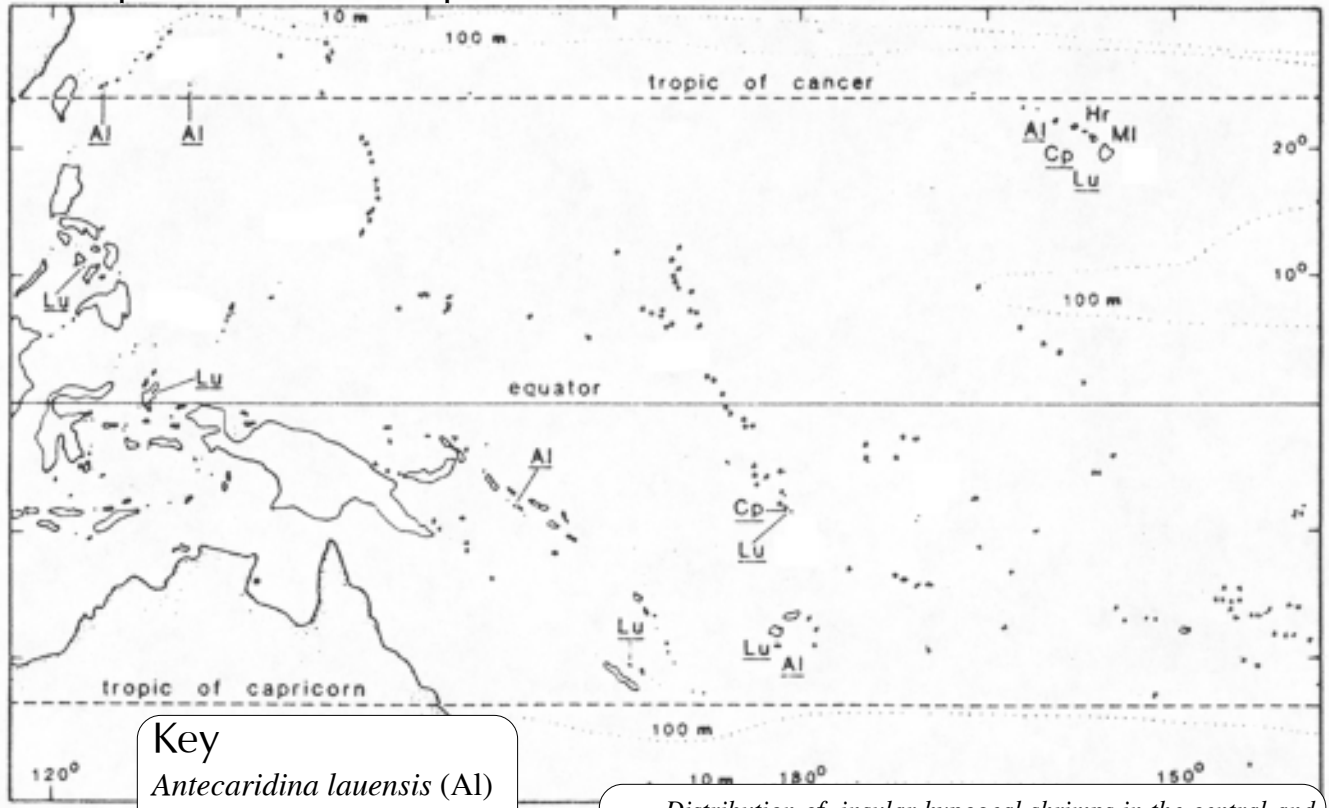
Found in ponds on Hawaiian Islands, Fiji Islands, Mozambique Channel Islands, Solomon Islands, at the south end of the Red Sea, and in Japan

According to widely accepted ideas about isolation and speciation, these widely separated populations should have diverged into separate species because of the limited pool of genetic material and specific local conditions. If these shrimp populations are as separate as they seem, scientists would expect to see more endemic shrimp species and fewer species that were scattered in anchialine ponds around the world.



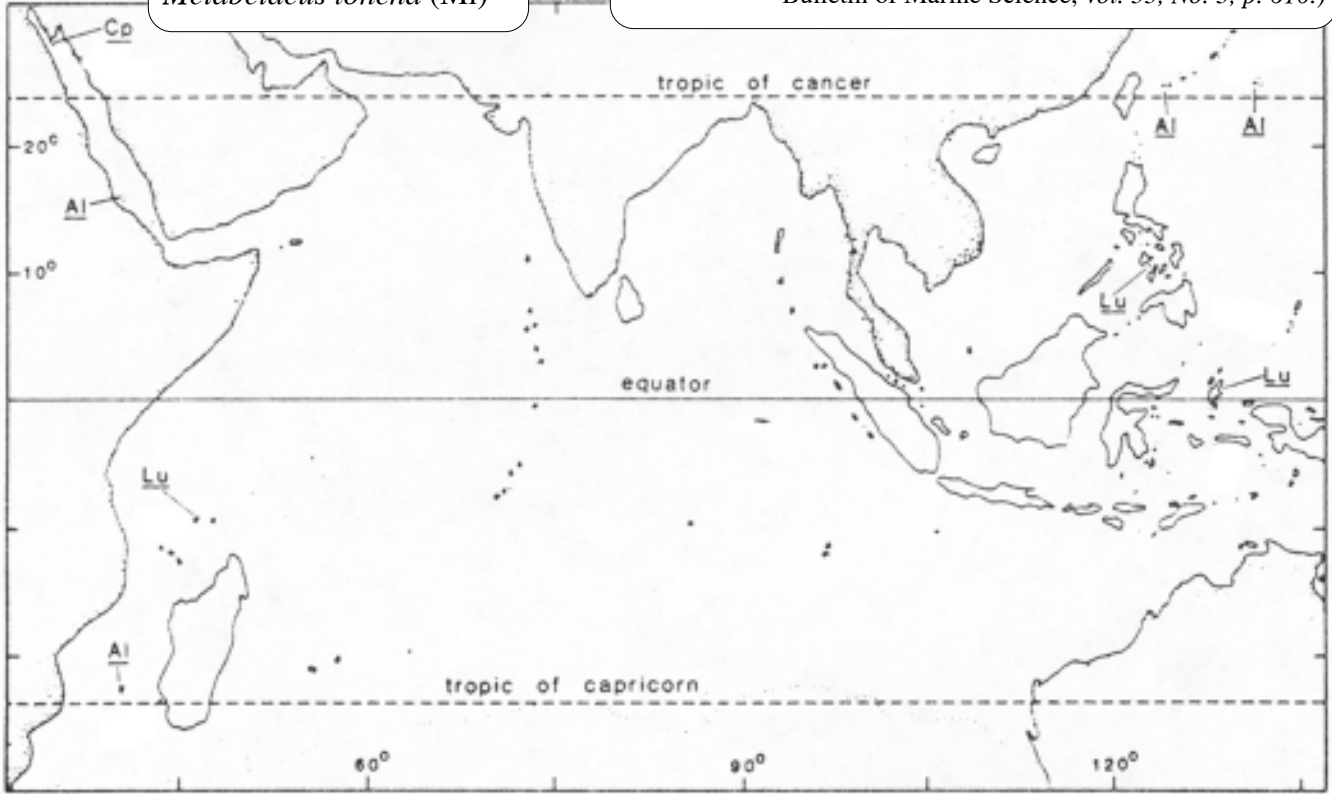
Acetate #8

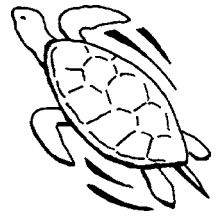
Shrimp Distribution Maps



Key
Antecaridina lauensis (Al)
Calliasmata pholidota (Cp)
Halocaridina rubra (Hr)
Ligur uveae (Lu)
Metabetaeus lohena (MI)

Distribution of insular hypogean shrimps in the central and western Pacific Ocean (above) and western Pacific and Indian Oceans (below) (Adapted from John A. Maciolek, "Distribution and Biology of Indo-Pacific Insular Hypogean Shrimps," Bulletin of Marine Science, Vol. 33, No. 3, p. 610.)





Acetate #9

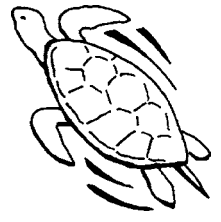
Mystery #6

Theories about isolation and speciation hold that shrimp species that live thousands of miles apart should have evolved into separate species. What can explain the fact that populations of the same shrimp species are found thousands of miles apart?



Photo: John Hoover, Hawai'i's Sea Creatures, Mutual Publishing

- Observation #1 The shrimp *Antecaridina lauensis* (Al), *Halocaridina rubra* (Hr), and *Metabetaeus lohena* (MI) can live up to 5 years in aquariums. They live longer than other types of small shrimp.
- Observation #2. All of the small, red shrimp found in the anchialine ponds can tolerate a wide variation in “salinity” (saltiness of the water), but they must have a little bit of seawater in the mix. They can live in pure ocean water.
- Observation #3 All these shrimp need dark, underground crevices. While human beings have mostly seen them in the ponds, the shrimp probably do not need to come into ponds. While *Ligur uveae* (Lu) is found in ponds in other parts of the world, it has never been seen in a pond in Hawai‘i. Here, it has been seen by divers only in underwater caves. While we tend to associate the shrimp with anchialine ponds, it is possible that they do not *need* to live in or on “emergent land” (land that comes out of the water, an island).
- Observation #4 On islands where populations of the shrimp have been found in anchialine ponds, the shrimp sometimes show up in new holes in the ground such as a bomb crater, wells, and quarries, as well as in ponds in recent lava flows. This suggests that they have migrated through underground crevices to enter these new holes, so there is probably an extensive underground population.
- Observation #5 Only two of the many species of small, red shrimp are endemic to an area. Since isolation generally results in the evolution of new species, this seems to indicate that larvae are passively floating in currents between these various areas. But in many places the currents don't go the right way!

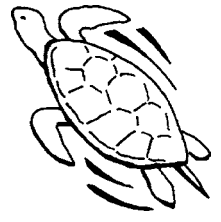


The Anchialine Pond Detective Worksheet

Solve the following mysteries using the information your teacher will present to you. Like a detective, your job is to piece together observations or clues to arrive at a conclusion.

Mystery #1: The water in the ponds is both fresh water and salt water. Where does this water come from?

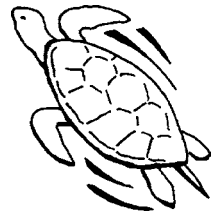
Mystery #2 What makes the water turn red each spring at Wai‘ānapanapa?



Mystery #3 You often see small, red shrimp in the anchialine ponds. If all the water goes out of the ponds at low tide, the shrimp disappear. Where do they go?

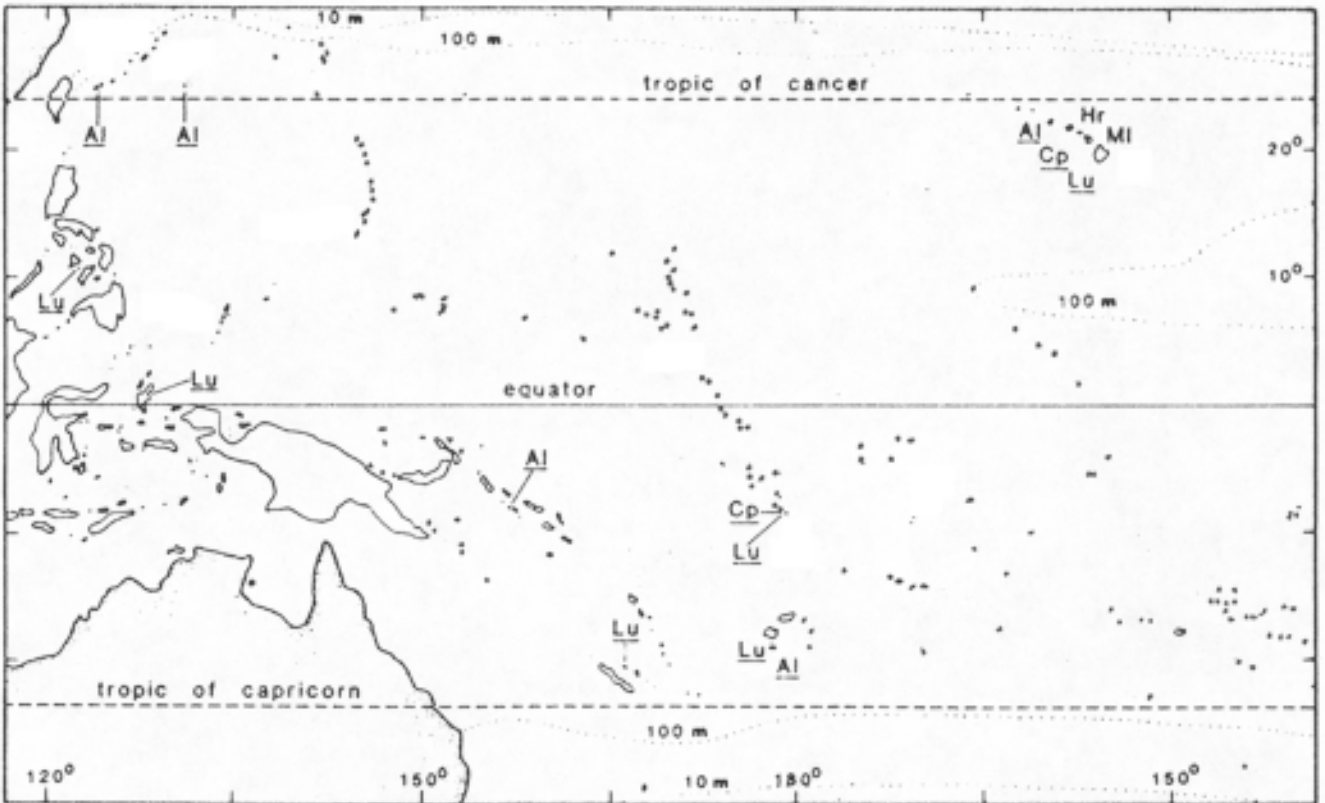
Mystery #4 The same species of shrimp that live in the Maui ponds also live in similar ponds on the Kona coast of Hawai'i and holes in the ancient (and dry) coral reef that is now the 'Ewa plain of O'ahu. How did the shrimp travel between the islands?

Mystery #5 The larvae reach the shorelines of the other islands. How do they get into the ponds?



Information Interlude

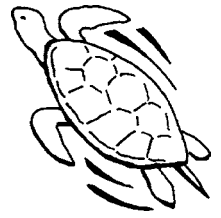
Shrimp Distribution Map: Central and Western Pacific Ocean



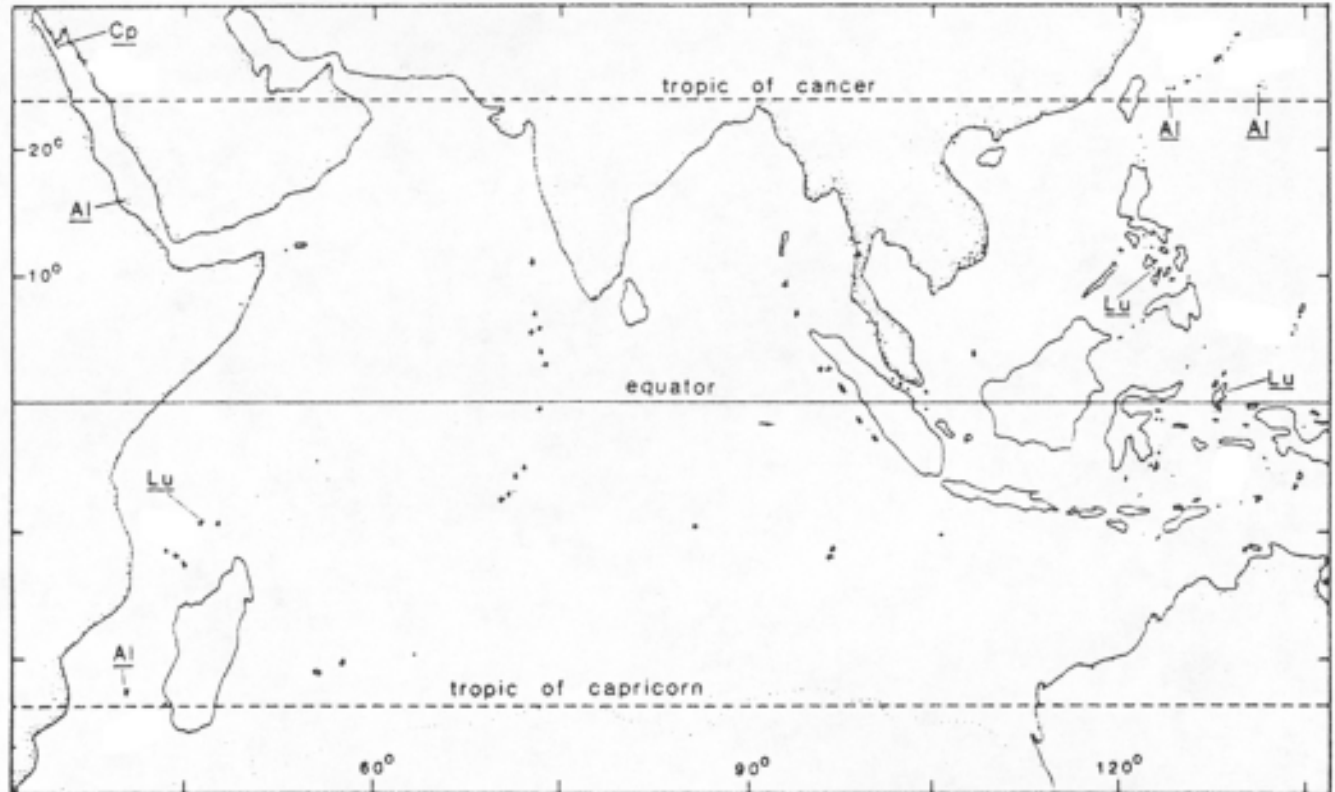
Distribution of insular hypogeal shrimps in the central and western Pacific Ocean (Adapted from John A. Maciolek, "Distribution and Biology of Indo-Pacific Insular Hypogeal Shrimps," Bulletin of Marine Science, Vol. 33, No. 3, p. 610.)

Key

- Antecaridina lauensis* (Al)
- Calliasmata pholidota* (Cp)
- Halocaridina rubra* (Hr)
- Ligur uveae* (Lu)
- Metabetaeus lohena* (MI)



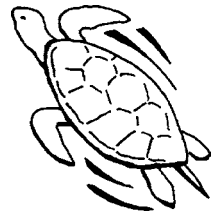
Shrimp Distribution Map: Western Pacific and Indian Oceans



Distribution of insular hypogeal shrimps in the western Pacific and Indian Oceans (Adapted from John A. Maciolek, "Distribution and Biology of Indo-Pacific Insular Hypogeal Shrimps," Bulletin of Marine Science, Vol. 33, No. 3, p. 611.)

Key

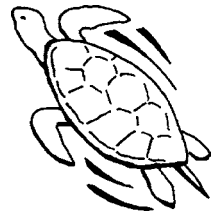
- Antecaridina lauensis* (Al)
- Calliasmata pholidota* (Cp)
- Halocaridina rubra* (Hr)
- Ligur uveae* (Lu)
- Metabetaeus lohena* (Ml)



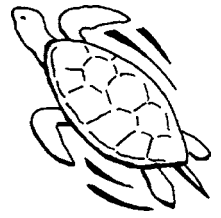
Distribution of Indo-Pacific Caridean Hypogeal Shrimp
Species (the small, red shrimp in anchialine ponds) Found in Hawai'i

Family, Genus, Species	Locality	Island(s)
Alpheidae		
<i>Metabetaeus lohena</i> (Ml)	Hawaiian Islands	Hawai'i, Maui
Atyidae		
<i>Antecaridina lauensis</i> (Al)	Fiji Islands Mozambique Channel Is. Red Sea-Dahlak Hawaiian Islands Daito Islands Ryukyu Islands Solomon Islands	Namuka, Wangava Europa Entedibir Maui, Hawai'i Minami Kuro Uipi
<i>Halocaridina rubra</i> (Hr)	Hawaiian Islands	Hawai'i, O'ahu, Maui, Moloka'i
Hippolytidae		
<i>Calliasmata pholidota</i> (Cp)	Red Sea-Sinai Ellice Islands Hawaiian Islands	Ras Muhammad Funafuti Maui, Hawai'i
<i>Ligur uveae</i> (Lu)	Molucca Islands Loyalty Islands West Indian Ocean Fiji Islands Ellice Islands Philippine Islands Hawaiian Islands	Halmahera Uvea/Sayawa Aldabra Vanua Levu, Vanua Vatu, Vatulele Funafuti Tiniguiban O'ahu, Hawai'i, Maui
Procarididae		
<i>Procaris hawaiiana</i>	Hawaiian Islands	Maui, Hawai'i

Based on John A. Maciolek, "Distribution and Biology of Indo-Pacific Insular Hypogeal Shrimps,"
Bulletin of Marine Science, 1983, Vol. 33, No. 3, pp. 606-618.



Mystery #6 Theories about isolation and speciation hold that shrimp species that live thousands of miles apart should have evolved into separate species. What can explain the fact that populations of the same shrimp species are found thousands of miles apart?



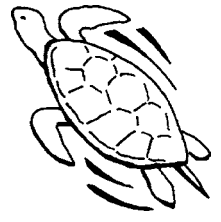
Hypothetically Speaking

- 1) In 1983 a scientist named Dr. John Maciolek offered a hypothesis to explain the widely scattered populations of the small, red shrimp species found in anchialine ponds. Based on the evidence, he thinks that the shrimps' habitat is much broader than is commonly thought. Instead of occurring only in association with a scattering of anchialine ponds and their porous substrates, Maciolek hypothesizes that "the shrimps could occur in the groundwaters of many . . . islands where they have not yet been found, in shallow reefs and seamounts, and possibly in suitable rock of continental shelves." (John A. Maciolek, "Distribution and Biology of Indo-Pacific Insular Hypogean Shrimps," *Bulletin of Marine Science*, 1983, Vol. 33, No. 3, pp. 606-618.)

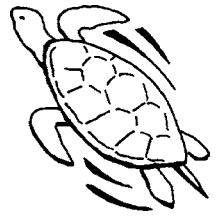
In other words, these shrimp could be hiding out in all kinds of submerged nooks and crannies—reducing the distances between what now seem to be separate populations.

Dr. Maciolek goes on to say he thinks the distribution would be restricted by water temperature. There is evidence to suggest that the shrimp do not survive in water colder than 20° C. In the tropics, that generally means that the shrimp could survive in waters no deeper than 100 m (328 ft).

Do you think Dr. Johan Maciolek offers a reasonable hypothesis? Why or why not?



- 4) Assuming that you were unable to look directly for shrimp in underwater rock crevices, how would you study the shrimp themselves to determine whether the shrimp would be physiologically able to live in these underwater habitats? Keep in mind that these underwater habitats would have the consistent salinity of sea water and may be darker or cooler than exposed or near-surface waters depending on their depth.



Activity #2

Salinity Tolerance Lab

● ● ● In Advance *Obtaining Lab Supplies*

- Order brine shrimp cysts (eggs) from a science supply house such as Carolina Biological Supply, Sargeant-Welch, Flinn, or Frey. Other sources include local pet stores and online aquaculture suppliers. (If you are unfamiliar with any of these sources, an Internet search will quickly help you identify a supplier.)

● ● ● Class Period One *Brine Shrimp Lab*

Materials & Setup

For each student

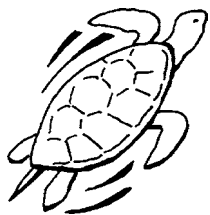
- Student Page “Lab Background and Procedures: Brine Shrimp Salinity Tolerance” (pp. 31-33)
- Student Page “Lab Worksheet: Brine Shrimp Tolerance for Fluctuating Environmental Conditions” (pp. 34-38)

For each lab group of three to four students

- Brine shrimp cysts
- 1/8 tsp measure
- Four test tubes (150 ml) with stoppers
- Labels or labeling pens for the test tubes
- Test tube rack
- Sea salt or noniodized salt
- Graduated cylinder (more than 100 ml)
- Triple beam or electronic balance
- Distilled water or tap water that has been aged 24 hours in an open container to dechlorinate it

Instructions

- 1) Divide students into lab groups of three to four students. Hand out the student pages and make sure each group has a complete set of equipment and supplies.
- 2) Conduct the “Brine Shrimp Salinity Tolerance” lab using the procedures outlined in the student page.
- 3) If more than 24 hours will elapse between the two lab sessions, feed the shrimp on the second day by placing a tiny amount of brewer’s yeast or dried spirulina algae (available in pet stores) in each test tube.



● ● ● Class Periods Two and Three *Brine Shrimp Lab, Continued*

Materials & Setup

For each lab group of three to four students

- Hand lens or dissecting microscope
- Sampling pipette (transparent 1 ml or larger)
- Four petri dishes

Instructions

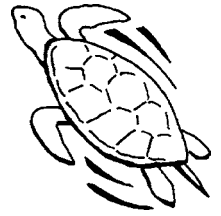
- 1) Continue the brine shrimp lab, covering questions as the lab proceeds.
- 2) At the end of the lab, discuss groups' findings. Bring up the following questions and points in this discussion:
 - What is the advantage of brine shrimp, like hypogeal shrimp, being able to tolerate a range of salt concentrations?
 - What is the difference between a *tolerance* of environmental conditions and habitat *preference*? (In other words, brine shrimp may be able to survive and even reproduce in certain environmental conditions but may not congregate in those conditions if there is a more favorable option.)
 - At low salinity levels and optimal food levels, female brine shrimp can produce 75 free-swimming larvae per day. At salinities above 150 percent and low oxygen levels, the female produces non-developing cysts. In such unfavorable conditions, the female can release 75 cysts. These cysts float and eventually may drift ashore. Development will not continue until the cysts are washed back into the water and reach an area of favorable salinity and oxygen levels.
 - Shrimp reproduction did not factor into this experiment because brine shrimp do not reach adulthood until they are about eight days old.
 - Brine shrimp can live in extremely harsh and variable conditions with temperatures ranging from 43° to 95° F and salinities usually in the range of 28–70 parts per thousand. They can survive in salinities up to 340 parts per thousand.

Journal Ideas

- Explain what a variable is and what is meant by “controlling” a variable. Why is controlling variables important to scientific investigations? Use the brine shrimp experiment to illustrate your definitions and ideas.
- If you were going to study the habitat preferences of the *‘ōpae ‘ula* (endemic Hawaiian shrimp found in anchialine ponds), what variables would you test? Why?

Assessment Tools

- Conduct during lab
- Student Page “Lab Worksheet: Brine Shrimp Tolerance for Fluctuating Environmental Conditions”
- Journal entries



Lab Background and Procedures: Brine Shrimp Tolerance for Fluctuating Environmental Conditions

Introduction

Brine shrimp are crustaceans, like lobsters, crabs, and crayfish. A hard exoskeleton supports their bodies and protects them from injury. Brine shrimp are found throughout the world and are adapted to live in harsh, changing environments. These are not exactly the same environmental conditions as the red shrimp that we've been studying inhabit. However, conditions for both shrimp can vary widely in "salinity" (salt concentration) and temperature.

In this lab, you will test the tolerance of brine shrimp to variations in environmental conditions. The measure of tolerance that you will use is the hatching rate of brine shrimp eggs. The environmental condition that you will vary is salinity.

Brine shrimp eggs are initially housed within a structure called a "cyst," which is similar to an eggshell. Brine shrimp cysts can dry out and the egg inside them will remain viable (able to hatch) for many years. As the egg develops, the cyst bursts. For the first few hours after the cyst bursts, the embryo hangs beneath the cyst in the "umbrella" stage. The embryo continues to develop and will emerge as a free-swimming larva.

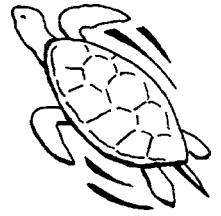
Brine shrimp tend to be brownish-orange in color in this first larval stage. After about 12 hours, they molt (shed their exoskeleton) and begin feeding on tiny algae, bacteria, or nonliving debris. They continue to feed and grow, molting 15 times before reaching adulthood in about eight days.

Adult brine shrimp are generally around 8 mm long. Adult males can be identified by large claspers near their heads, and females by the brood pouch, where the cysts develop, just below the last of their legs. Their lifespan is typically several months.

Materials

Lab Period One

- Brine shrimp cysts
- 1/8 tsp measure
- Four test tubes (150 ml) with stoppers
- Labels or labeling pens for the test tubes
- Test tube rack
- Sea salt or noniodized salt
- Graduated cylinder (more than 100 ml)
- Triple beam or electronic balance
- Distilled water or tap water that has been aged 24 hours in an open container to dechlorinate it



Lab Periods Two and Three

- Hand lens or dissecting microscope
- Sampling pipette (transparent 1 ml or larger)
- Four petri dishes

Lab Period One Procedure

- 1) On the lab worksheet, write the question or problem investigated by this experiment and your hypothesis.
- 2) Using salt and the distilled or aged tap water, mix solutions of the following concentrations:
 - 1 percent salt solution
 - 5 percent salt solution
 - 10 percent salt solution
 - 20 percent salt solution

The formula for creating solutions of a specific concentration is:

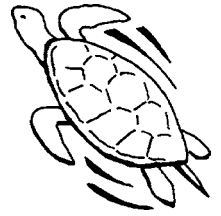
X grams of NaCl (salt) per 100 ml H₂O (X=target percent concentration)

Measure 100 ml of water into the graduated cylinder and pour it into a test tube. Weigh the salt and add it to the test tube. Place the stopper on the test tube and mix until the salt is dissolved. Place the test tube in the rack and label it. Mix all of the solutions before moving on to the next step.

- 3) Unstop all of the test tubes and add 1/8 teaspoon of brine shrimp cysts to each test tube. Leave the tubes open, unless you are moving your test tubes and rack to another part of the room.
- 4) Leave your test tube rack out of direct sunlight, preferably in a dim part of the classroom. All lab groups should leave their test tube racks in the same location in the classroom.
- 5) Answer question #3 on the lab worksheet.

Lab Period Two Procedure

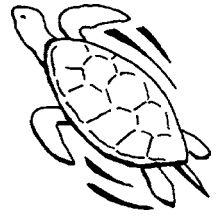
- 1) Observe your test tubes. Write your observations on the lab worksheet (question #4, first row in the table)
- 2) Working with one test tube at a time, make a count of the brine shrimp in a sample volume of water. If the shrimp are not evenly dispersed throughout the water, gently swirl the test tube. Use a pipette to measure 1 ml of water and shrimp (if any have hatched) from the test tube and into a clean petri dish.
- 3) Using the hand lens or dissecting microscope, count the shrimp in that sample of water and record your findings on the lab worksheet (question #4, first row in the table).



- 4) Place the shrimp and water back into the test tube they came from.
- 5) Continue until you have sampled and counted shrimp from each of your four test tubes and recorded your observations on the lab worksheet (question #5, first row of the table). Replace your test tubes and rack to the location where you kept them previously.
- 6) Answer question #6 on the lab worksheet.

Lab Period Three Procedure

- 1) Observe your test tubes. Write your observations on the lab worksheet (question #4, second row of the table).
- 2) Working with one test tube at a time, make a count of the brine shrimp in a sample volume of water. If the shrimp are not evenly dispersed throughout the water, gently swirl the test tube. Use a pipette to measure 1 ml of water and shrimp (if any have hatched) from the test tube and into a clean petri dish.
- 3) Using the hand lens or dissecting microscope, count the shrimp in that sample of water and record your findings on the lab worksheet (question #5, second row of the table).
- 4) Replace the shrimp and water back into the test tube they came from.
- 5) Continue until you have sampled and counted shrimp from each of your four test tubes.
- 6) Answer questions #6-10 on the lab worksheet.



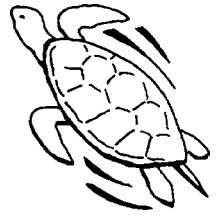
Lab Period Two (Date: _____) **and Three** (Date: _____)

4) Test tube observations

	1% solution	5% solution	10% solution	20% solution
Lab Period Two				
Lab Period Three				

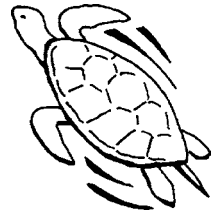
5) Shrimp count per 1 ml water

	1% solution	5% solution	10% solution	20% solution
Lab Period Two				
Lab Period Three				

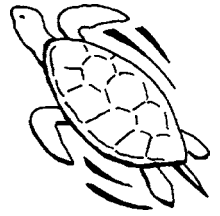


6) Did your group encounter any difficulties counting the brine shrimp in the samples? If so, how were you able to resolve them?

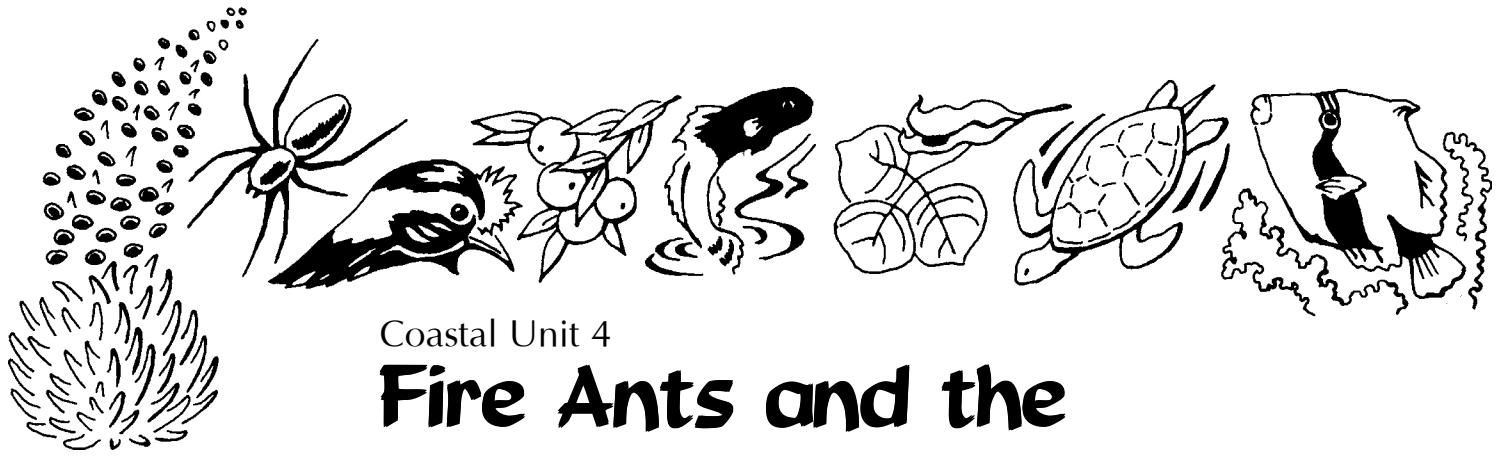
7) Summarize the results of your experiment.



- 8) Based on the results of your experiment, which solution was the best in which to hatch brine shrimp eggs? Explain your answer.
- 9) Design another experiment to measure the tolerance of brine shrimp to a different environmental variable such as light or temperature. Describe it here.



10) What types of field observations (made at the ponds, not in a laboratory experiment) could you conduct to test the habitat preferences of the shrimp that live in the anchialine ponds on Maui?



Coastal Unit 4

Fire Ants and the Future of Maui Wetlands

Overview

No ant species are native to Hawai‘i. However, more than 40 species of ants have been collected here. Many of these have become naturalized and are now part of the islands’ ecosystems.

Among the pest ants that have not yet been discovered on the island of Maui are two species, both of which are referred to as “fire ants.” One species, the “little fire ant” (*Wasmannia auropunctata*), is established on the island of Hawai‘i but has not yet been found on Maui. The other, the “red imported fire ant” (*Solenopsis invicta*), has been spreading across the continental United States since the 1930s but has not yet been discovered in Hawai‘i. Many people believe that the red imported fire ant is very likely to become the next severe pest invasion in Hawai‘i unless dramatic steps are taken to prevent its arrival and establishment.

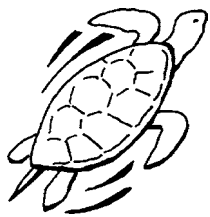
This unit engages students in efforts at early detection of these pest species on Maui, and challenges them to help minimize the potential threat to wetlands and endangered species here by developing a prevention and action plan.

Length of Entire Unit

Five class periods.

Unit Focus Questions

- 1) What threat could pest ants such as the red imported fire ant pose to native ecosystems once they become established on Maui?
- 2) What biological and behavioral characteristics make the red imported fire ant a potential threat?
- 3) How can people protect Maui and its natural areas from invasion by pests such as the red imported fire ant?



Unit at a Glance

Activity #1

Finding the Little Fire Ant

Students collect ants from their homes or other locations around the island. They use a simple key to identify ants that may be the little fire ant, which has not yet been discovered on Maui.

Length

One class period, preceded and followed by homework (the preceding homework assignment entails students collecting ants).

Prerequisite Activity

None

Objectives

- Collect and attempt to identify ants using a simple key.
- Describe the threat the little fire ant could pose to native ecosystems on Maui, humans and domestic animals.
- Explain why early detection is important for pest species such as the little fire ant.

DOE Grades 9-12 Science Standards and Benchmarks

LIVING THE VALUES, ATTITUDES, AND COMMITMENTS OF AN INQUIRING MIND: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- HONESTY: Report findings accurately without alterations and draw conclusions from unaltered findings.

DOING SAFETY: Students demonstrate the importance of safety by applying safety skills in all activities.

- Apply school, classroom, laboratory, and field trip rules, as appropriate, to maintain a safe learning environment.

Activity #2

Red Imported Fire Ant Prevention and Quick Response Plan

Students research and develop an island-wide plan to prevent the red imported fire ant from becoming established on Maui and to respond rapidly to control the spread of any populations that are found.

Length

Three class periods, preceded by homework and interspersed with out-of-class research time.

Prerequisite Activity

None

Objectives

- Describe the potential threat the red imported fire ant poses to Maui wetlands and the endangered Hawaiian bird species that nest there.
- Research topics related to red imported fire ants to devise a plan for protecting Maui and Maui wetlands from invasion.

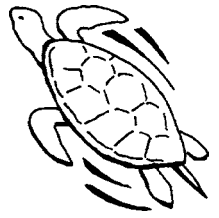
DOE Grades 9-12 Science Standards and Benchmarks

LIVING THE VALUES, ATTITUDES, AND COMMITMENTS CHARACTERISTIC OF AN INQUIRING MIND: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- SELF-DIRECTED: Use research techniques and a variety of sources to complete a report on a project of one's choice.

RELATING THE NATURE OF TECHNOLOGY TO SCIENCE: Students use the problem-solving process to address current issues involving human adaptation in the environment.

- Evaluate alternative solutions for effectiveness based on appropriate criteria.



Activity #3

Race to the Wetlands Game

Students play a game that tests their knowledge of fire ants and ant prevention and control strategies.

Length

One class period

Prerequisite Activity

Activity #1 “Finding the Little Red Fire Ant”

Activity #2 “Red Imported Fire Ant Prevention and Quick Response Plan”

Objectives

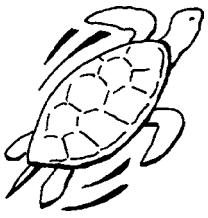
- Demonstrate knowledge of pest ants and strategies used to prevent their establishment or control their populations.

DOE Grades 9-12 Science Standards and Benchmarks

None

Enrichment Ideas

- Watch the video, *Ants: Little Creatures that Run the World* to become familiar with basic ant biology and behavior. (Video included with this curriculum, Alpine/Aeolian Unit 4 “Good Critters, Bad Critters.”)
- Research the native and migratory water birds that use Keālia Pond National Wildlife Refuge and other Hawaiian wetlands. One good place to start is the U.S. Fish and Wildlife Service Pacific Islands Ecoregion website. It includes information about threatened and endangered animals in the Hawaiian Islands at pacificislands.fws.gov.
- Extend the time available for students to develop their management plans, perhaps even over a period of several weeks. Require more in-depth research, and allow in-class time for students to share information and develop strategies. This will increase the likelihood that students will come up with useful and appropriate ideas for protecting Maui from the red imported fire ant.
- Put together one class proposal that draws together the best ideas from all of the small group plans. Present this proposal to the Ant Working Group. (Contact the Ant Working Group through Ellen VanGelder at 572-4472 or evangeld@hawaii.edu.)
- Implement student ideas. Students can design ways to evaluate how effective these ideas are once they are put into action.
- Create a public service announcement, poster, or other educational materials about the red imported fire ant.



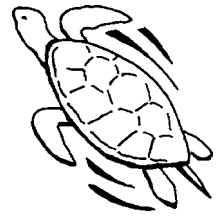
Resources for Further Reading and Research

Ants: Little Creatures that Run the World, a NOVA video with E.O. Wilson (Video is included with Alpine/Aeolian Unit 4 “Good Critters, Bad Critters.”)

California Department of Food and Agriculture,
“Red Imported Fire Ant Information” at
<pi.cdfa.ca.gov/rifa/newfact.htm>.

“Myrmecology” at <www.myrmecology.org>.
Includes general background on ants and the
study of ants as well as a variety of links to other
ant-related sites.

Hawai‘i Ecosystems at Risk, “Pest Ants in
Hawai‘i” at
<[www.hear.org/AlienSpeciesInHawaii/ants/
index.html](http://www.hear.org/AlienSpeciesInHawaii/ants/index.html)>.



Activity #1

Finding the Little Fire Ant

● ● ● In Advance *Collecting Ants*

Materials & Setup

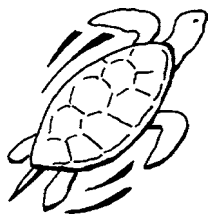
- Three (or more) clean disposable chopsticks
- Optional: Bright orange paint or felt-tip markers
- Peanut butter (the cheaper generic kind works best; the “natural” kind doesn’t work as well)
- A spoon
- Small paper cups
- Small self-sealing plastic bags, such as Ziplocs (sandwich size or the even smaller snack size)
- Sharp or mechanical pencils
- Specimen labels (see Student Page “Survey for Little Fire Ants,” p. 20)
- Optional: tongs or gloves if you do not want to pick up bait sticks without them and possibly get ants on yourself

For each student

- Student Page “Finding the Little Fire Ant” (pp. 12-15)
- Student Page “Survey for Little Fire Ants” (pp. 16-20)

Instructions

- 1) Several days before you start this unit, hand out the Student Page “Finding the Little Fire Ant.” Ask students to collect ants to bring to class on the day you will be starting the unit. The student page contains a list of materials students will need (those listed above).
- 2) Students may collect ants at home or another location of their choosing. With the help of the student page, they should be able to do the ant collections by themselves. You may want to walk students through the steps in the classroom or even take them out on school grounds to do a trial run.
- 3) This activity is part of an ongoing effort to monitor for the presence of the little fire ant on Maui. Because the information students develop may be used by researchers, students **MUST**:
 - Follow the ant collection instructions in the student page precisely, and
 - Be honest about where the ants were collected. Students may be tempted to share ants with each other and claim they were collected in different places. Make sure students understand that being dishonest about where ants were collected could interfere with efforts to eradicate little fire ants if your class discovers them.



● ● ● Class Period One *Little Fire Ant Identification Lab*

Materials & Setup

- Frozen ant specimens collected by students

For each student or lab groups of two to four students

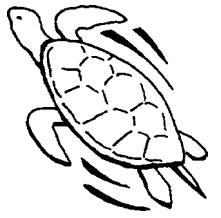
- A hand lens of at least 10x or a dissecting microscope (one for each lab group or student)
- Student Page “*Wasmannia* Identification Key” (pp. 21-22)
- “Color *Wasmannia* Key” (master, pp. 10-11)
- Ruler with mm markings

For each student

- Student Page “Finding the Little Fire Ant” (pp. 12-19)
- Student Page “Little Fire Ant Quiz” (pp. 23-24)

Instructions

- 1) Divide students into lab groups of two to four students each. Or allow students to work on their own if you have enough magnifying lenses or dissecting microscopes to go around.
- 2) Instruct students to keep each specimen with the appropriate bag and label. That way if there are questions about identification or if the specimen appears to be a little fire ant, the correct information about where it was collected will be readily available.
- 3) Hand out the Student Page “*Wasmannia* Identification Key” and the “Color *Wasmannia* Key.” Explain that students will be looking for ants that match the distinguishing characteristics of the little fire ant.
- 4) After your students (with your help, if necessary) have eliminated all ants they know are NOT *Wasmannia auropunctata*, gather all remaining specimens, put them in their bags with the correct label inside, and store them in the freezer. These specimens may include:
 - a) Ants you have identified as *Wasmannia auropunctata*, and
 - b) Ants that MAY be *Wasmannia auropunctata* (i.e., you are uncertain about the identification).
- 5) If there are specimens that you believe are or may be little fire ants:
 - Write your (the teacher’s) contact information on the back of the corresponding specimen label.
 - Put the label in the bag along with the ants and the chopstick. Seal the bag.
 - If there is more than one questionable collection, keep each in its own bag with its own label.
 - Mail the bags to: Ellen VanGelder; Research, Haleakalā National Park, P.O. Box 369, Makawao, HI 96768.A trained biologist will identify the ants and notify you if you have found a little fire ant.
- 6) Assign the Student Page “Little Fire Ant Quiz” as homework.



Journal Ideas _____

- Based on your experience collecting ants, what do you think it would be like to be a field researcher studying insects? Is this a job you think you would like? Why or why not?
- What safety precautions did you take while collecting ants? Why are precautions like these important for people who study insects?

Assessment Tools _____

- Participation in and conduct during the lab
- Student Page “Little Fire Ant Quiz” (teacher version, pp. 8-9)
- Journal entries

Some teacher-only resources have been omitted from the online document.

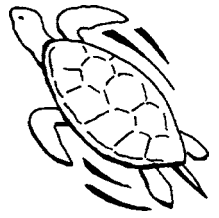
They are available as password-protected files at:

www.hear.org/hoike/teachermaterials

Some teacher-only resources have been omitted from the online document.

They are available as password-protected files at:

www.hear.org/hoike/teachermaterials



Color *Wasmannia* Key

- 1a. Body (not including antennae) 2mm or more in length **NOT WASMANNIA**
- 1b. Tiny, body less than 2mm in length.....2



- 2a. Ant is all dark brown to black in color **NOT WASMANNIA**
- 2b. Ant is not all dark brown to black in color (e.g., red, yellow, or light brown).....3

Dark brown/black ants

Ants not all dark brown/black



Solenopsis papuana



Ochetellus glaber

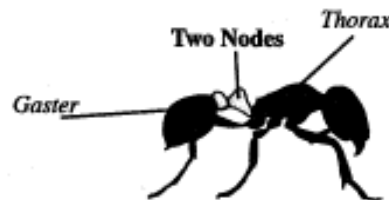
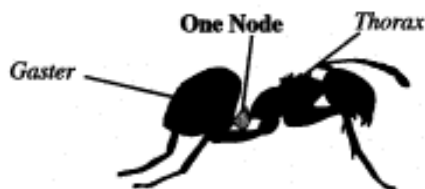


Wasmannia auropunctata
Color=light brown/
orange



Solenopsis geminata
Color=reddish

- 3a. One node on waist between thorax and gaster. **NOT WASMANNIA**
- 3b. Two nodes on waist between thorax and gaster.....4

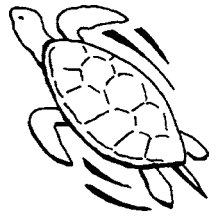


- 4a. Ant is bi-colored (e.g., gaster and/or head are a different color than rest of body) **NOT WASMANNIA**
- 4b. Ant is all one color (yellow, red, orange, light brown).....5

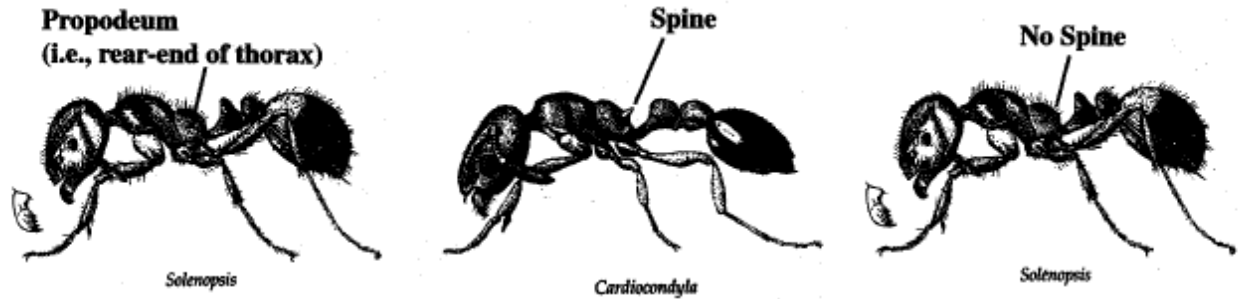
Bi-colored ant
Monomorium floricolor



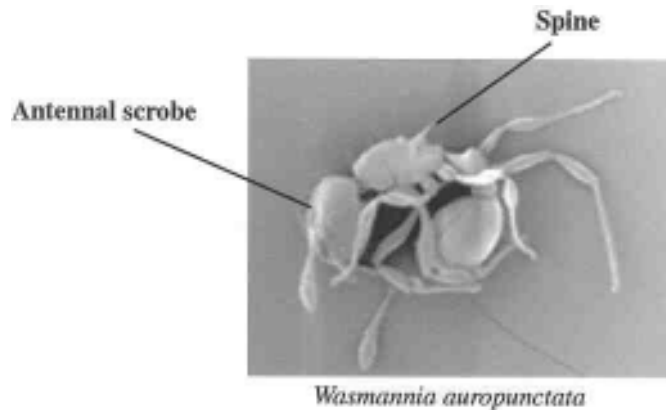
One-colored ant
Wasmannia auropunctata



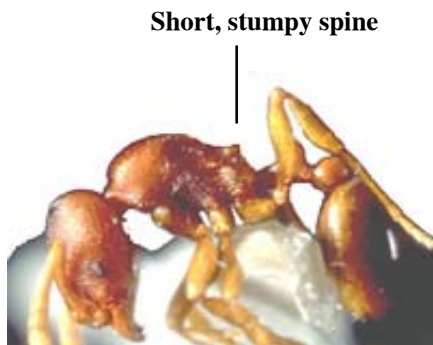
- 5a. Propodeum is smooth, no spines present **NOT WASMANNIA**
5b. Propodeum with a distinct pair of spines present.....6



- 6a. Antennal scrobe (groove) absent, propodeum spines short and stumpy *Tetramorium simillimum*
6b. Antennal scrobe (groove) present, propodeum spines long and pointy **Wasmannia auropunctata**



Wasmannia auropunctata



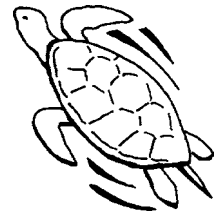
Tetramorium simillimum



Wasmannia auropunctata

Image Credits

- Walter Nagamine, *Hawai'i Department of Agriculture (1a/b Pheidole megacephala, Wasmannia auropunctata; 2b, 4b, 6b Wasmannia auropunctata)*
- Neil Reimer, *Hawai'i Department of Agriculture (2a Solenopsis papuana, Ochetellus glaber; 4a Monomorium floricolor)*
- Hirotami T. Imai and Masao Kubota (2b Solenopsis geminata)
- E. W. Huddleston, A. A. Laplante, and S. S. Fluker, "Pictorial Key of the Ants of Hawaii Based on the Worker Forms," *Proceedings of the Hawaii Entomological Society, Vol. 20, No. 1, 1968, pp. 71-79 (3a/b line drawings, color added)*
- M. R. Smith, *House Infesting Ants of the Eastern United States, Technical Bulletin No. 1326, Agricultural Research Service, U.S. Department of Agriculture, 1965, reprinted in Bert Holldobler and Edward O. Wilson, The Ants, Harvard University Press, Cambridge, Massachusetts, 1990 (5a Solenopsis)*
- M. R. Smith, "A Generic and Subgeneric Synopsis of the United States Ants, Based on the Workers (Hymenoptera: Formicidae)," *American Midland Naturalist, Vol. 37, No. 3, pp. 521-647 reprinted in Bert Holldobler and Edward O. Wilson, The Ants, Harvard University Press, Cambridge, Massachusetts, 1990, (5b Cardiocondyla)*
- Dennis Kunkel Microscopy, Inc., ©2001 (6b Wasmannia auropunctata)
- American Natural History Association (6a Tetramorium simillimum)



Finding the Little Fire Ant

No ants are native to the Hawaiian Islands, yet a total of 44 ant species have been recorded here. All of these species were accidentally introduced by humans. Some ants are especially good at “hitching a ride” with humans, expanding their range by traveling in goods and cargo being shipped around the world. These species are known, fittingly, as “tramp ants.”

Among the ants that have not yet made their way to Maui is one tramp species known as the little fire ant (*Wasmannia auropunctata*). The little fire ant is native to Central America and the northern part of South America. This species gets its name from its powerful sting that can feel fire-like to the person or animal on the receiving end of the sting. The little fire ant could be a big problem for three main reasons:

- It is very destructive to native ecosystems in areas that it has already invaded,
 - It is a serious nuisance to humans and domestic animals, and
 - It has a good chance of getting to Maui.
- Indeed, the little fire ant may already be here.



Scanning electron microscopy image of *Wasmannia auropunctata*
(Photo: © Dennis Kunkel Microscopy, Inc.)

Why we don't want the little fire ant on Maui

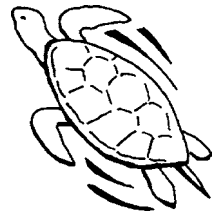
Effects on native ecosystems and species

The little fire ant has invaded several areas around the world. It is a destructive, pervasive, tramp ant species that occurs in very high densities. Little fire ants have a relatively powerful sting, will defend themselves and their nests, eat a wide variety of prey, and are extremely voracious predators of “invertebrates,” (animals without backbones).

The little fire ant wreaks havoc in the native ecosystems it invades. It often completely takes over an area, eliminating other ants and attacking and preying on native invertebrates, and even vertebrates such as reptiles and mammals. In the Galapagos Islands, for example, little fire ants have been reported to attack the Galapagos tortoise, a highly endangered species. The ants attack the tortoises' eyes and reproductive organs, damaging their vision and leaving them unable to

reproduce. On the Pacific islands of New Caledonia, this ant has dramatically decreased populations of several animals, including geckos and lizards. The little fire ant may also sting the eyes of mammals, perhaps because they are attracted to the moisture. Mammals with eye damage believed to be caused by little fire ants include elephants and domestic cats, both in Gabon (Africa).

Little fire ants eliminate or reduce populations of invertebrates and vertebrates either directly, by preying on them, or indirectly, by outcompeting them for resources (such as food, nesting habitat, or territory). Little fire ants



tend to have severe impacts on native invertebrate communities, eliminating some species, reducing the abundance of others, and reducing invertebrate diversity overall.

There are no native ants on the Hawaiian Islands, so as ant species make it to the islands and become established, they may pose a significant threat to our native ecosystems. Hawaiian native plants and animals have evolved over millions of years without having to defend themselves against the predatory abilities of ants like the little fire ant.

Effects on humans and domestic animals

The little fire ant has painful stings, a defensive nature, and the tendency to occur in dense populations. That adds up to bad news for humans and their domestic animals. It is difficult to enjoy being outdoors in areas where they have invaded. Little fire ants sting when they are rolled on or touched, or when people or animals come into contact with the plants in which the ants are nesting or feeding. People get stung while gardening, picking fruits or flowers, or enjoying other outdoor activities. An individual ant can deliver multiple stings, and often several ants attack at once. This ant is also known to move into homes in search of food, seriously annoying inhabitants with their stings. Different people react differently to this ant. Some people feel a painful sting followed by an

itch that goes away in a few minutes. With other people welts may develop on the skin where they were stung, and the itch may last for several days.

Why the little fire ant has a good chance of getting to Maui

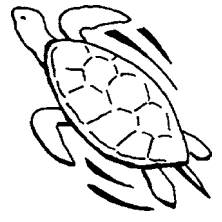
Like other tramp ant species, this ant often gets to new places by stowing away on goods (particularly nursery plants) that are shipped from infested areas. This species is currently “on our doorstep,” having recently become established on the island of Hawai‘i. The little fire ant became established in areas around Hilo by stowing away in nursery plants imported to the island from another country or possibly from Florida. Now, since nurseries on the Big Island often ship plants to neighbor islands, there is a good chance that the little fire ant could get to Maui.

In fact, the little fire ant may *already* be on Maui. It was not discovered on Hawai‘i until March of 1999. However, entomologists studying the little fire ant believe the ant may have been on the Big Island for as many as five or six years before it was discovered.

When the little fire ant was discovered on Hawai‘i, the Hawai‘i Department of Agriculture required that all nursery plants shipped from infested areas of the Big Island be inspected for the ant before being shipped. If the ants are found, the nursery stock is either treated with insecticide before shipping or not shipped at all. But if the ants have been on the island since around 1994, there is a chance that infested nursery stock was shipped from the Big Island without anyone knowing the ants were there. It is reasonable to think that the little fire ant could have made it to Maui by now, from its neighbor island or from another location.



Little fire ants sometimes congregate on plants. (Photo: Ellen VanGelder)



For this species of ant, as with many “pest” species, the key to avoiding its destructive effects on Maui is to prevent it from getting here in the first place. This is done through a series of precautions and inspections called “quarantines.” The Hawai‘i Department of Agriculture has instituted a little fire ant quarantine on agriculture and nursery items destined for uninfested areas of the state. However, if the ant already occurs on Maui (and right now, nobody knows if it does or not), it is very important to find it soon, before it develops large, well established populations. There is a much better chance of eradicating them or controlling their spread if we find them when populations are still small.

It is in the best interest of all of us to find out as soon as possible if the little fire ant has reached Maui—and if so, where it occurs. You can help find out. In this activity, you will collect ants near your school, home, or any place else you visit on the island. You will take these ants back to the classroom or laboratory to identify whether they

are (or might be) *Wasmannia auropunctata*, the little fire ant.

What you should know about the little fire ant

Before heading out into the field to survey for this species, you need to learn a little bit about the little fire ant (*Wasmannia auropunctata*).

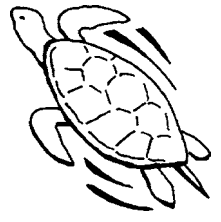
Here is a brief description:

- The little fire ant is a tiny (about 1.5 mm long) ant that is light orange in color.
- Little fire ants move very slowly compared to other ants, and with their small size it is sometimes even difficult to tell they are there — people mistake them for little specks of dirt.
- Little fire ant workers—the ants you are most likely to see and collect—are “monomorphic” (mono = one; morph = shape or type). That means they look alike. They are similar in size, shape, and color.

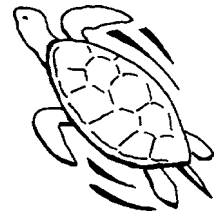


- This ant is both “terrestrial” (ground-dwelling) and “arbo-real” (tree-dwelling), and can survive in a wide variety of habitats. They nest almost anywhere, including on the ground (under logs, sticks, rocks, or debris) and in plants or trees (under the bark or in crevices of the plant).

Little fire ants gather on a bait stick. You’ll be collecting ants in this way. (Photo: Ellen VanGelder)



- Because the ants move very slowly, it is easy to avoid getting stung while surveying for them. In fact, little fire ants often stand relatively still, or simply fall off the bait stick when you disturb it (for example, by picking it up). Many other species, on the other hand, will frantically run up and down the stick if it is disturbed or picked up.
- As with many other “tramp” ant species, the way the little fire ant disperses naturally is via “budding.” This means that the newly mated queens travel on foot to a new location within a few meters of their birth colony. This makes the spread of their populations easier to track, and it makes the populations easier to control or eradicate than species that have queens that fly.



Survey for Little Fire Ants

It's Easy to Do Without Getting Stung!

Five Easy Steps

Your ant survey will be conducted in five easy steps:

- 1) Putting out bait for ants
(For the little fire ant you'll use peanut butter placed on a chopstick.)
- 2) Collecting the ants that come to the bait
- 3) Labeling the collection
THIS IS IMPORTANT!!
- 4) Freezing the ants to kill and preserve them
- 5) Taking your specimens back to the classroom so you can look at them closely in order to identify whether you have found any little fire ants

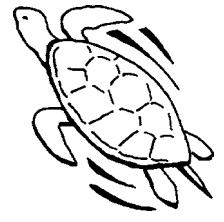
Materials Needed

For field surveys

- Three (or more) clean disposable chopsticks
- Optional: Bright orange paint or felt-tip markers
- Peanut butter (the cheaper generic kind works best; the "natural" kind doesn't work as well)
- A spoon
- Small paper cups
- Small self-sealing plastic bags, such as Ziplocs (sandwich size or the even smaller snack size)
- Sharp or mechanical pencils
- Specimen labels (in this student page)
- Optional: tongs or gloves if you do not want to pick up bait sticks without them and possibly get ants on yourself

For ant identification (in your classroom or laboratory):

- A hand lens of at least 10x or a dissecting microscope (one for each lab group or student)
- Student Page "Wasmannia Identification Key"
- "Color Wasmannia Key" (from your teacher)



Before You Begin—READ THIS!

If you are allergic, or suspect you may be allergic, to bee or wasp stings, please ask for help from your parents or friends. If you cannot get help, do not do this activity.

- Do not wear loose clothing, slippers, or a watch. The ants can get trapped and caught in this attire. Wear clothing with short sleeves, closed-toe shoes, and no watch or bracelet.
- Decide beforehand where you will place your baited chopsticks. Good places for sampling ants are beneath trees and shrubs, in or under potted outdoor plants, near garbage cans or buildings, or where you have seen ants before.

All locations are good to survey, but the best include those in the vicinity of current landscaping projects or ones that have been completed in the past five or six years. Landscaping projects often take place around parks, schools, resorts, shopping centers, and other new public facilities.

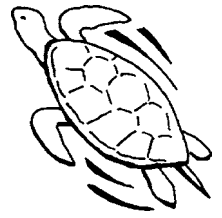
- If you want to go onto private property, be sure to obtain permission from the landowner first.

Procedure

- 1) Take three chopsticks and break them in half, so you have six sticks, each about four inches long. Then, if you think you'll have trouble finding the sticks after you've put them out, use paint or a magic marker to make one half of each stick bright orange. That way, you will be able to easily find them again in the field.
- 2) Take the following to the survey location: The six pieces of painted chopstick, a cup

with about one or two tablespoons of peanut butter in it, six self-sealing bags, six specimen labels, and a sharp pencil. You can also bring tongs or gloves if you are afraid of getting ants on you.

- 3) At the survey site, roll the unpainted half of one of the sticks in the peanut butter. Wipe excess peanut butter off on the edge of the cup. The stick should have just a light coating of peanut butter on the unpainted half, barely enough peanut butter to cover the stick's surface.
- 4) Place the stick on the ground, in a shady area—such as under or next to vegetation, next to potted plants or flowers, or at the base of a tree. These are good places to bait because little fire ants like to forage and nest on or around plants. Also, they don't like direct sun, so if the stick is fully exposed on a sunny day, the ants won't come to the peanut butter. In that case, your conclusion would be that there are no little fire ants at the location, when they may really be there!!
- 5) Place the next stick in a similar location, about 15 feet away from the first stick. Do the same until all six sticks are on the ground. We generally put sticks 15 feet apart because these ants move slowly and don't travel far, so you have to have several sticks in a small area if you want to detect a small population. However, if you choose to survey, for instance, in a recently landscaped area that is mostly lawn, with a few bushes spread far apart, you could also place one stick under each bush.
- 6) Let the sticks sit undisturbed (do not touch them!) for one or two hours. It's also important not to put your face close to the sticks during this time (like leaning over



trying to see if you have any ants)
because many ants will run away if you breathe on them. It is best to just leave the area and go do something else for an hour or two, then come back.

- 7) After the sticks have been out for one or two hours, it is time to collect your specimens! The first thing to do is to fill out labels for your specimens. Use **PENCIL** (Don't use regular pens! The ink will run and the information will not be readable!).

On each specimen label, write the following information:

- **Location of survey site** - Use as much detail as possible, so that someone else reading the label could find the location. Be sure to include the name of the town, because not all people know, for instance, that Olinda Rd. is in Makawao.
Example 1: 535 Olinda Road, Makawao, in garden at *makai* end of front yard
Example 2: Maui Community College, Kahului, along the side of the library building that is facing Ka'ahumanu Avenue
- **Date (month, day, year) and start time of survey** - **Example 1:** May 1, 2000, 1:00 p.m.; **Example 2:** April 30, 2000, 10 a.m.).
- **Your name**
- **Your teacher's name**
- **The name of your school**

Put a label inside each of your plastic bags.

- 8) Go to your first stick and **CAREFULLY** pick it up and drop it in your bag, then quickly seal the bag. Don't try to examine your ants while holding the stick! Some ants will frantically run about on the stick, and even onto YOU if you hold the stick. There are other stinging ants in Hawai'i besides the little fire ant, so you don't want to let any ants run onto you.

Words to the Wise

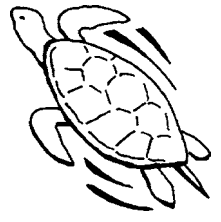
Remember, little fire ants move pretty slowly. So it is easy to avoid getting stung by this species. However, another ant that we have in Hawai'i, *Solenopsis geminata*, also stings, and tends to move very quickly when disturbed, so be careful. If you have very fast ants running on your stick, and you fear they might get on you, don't pick it up with bare hands. Instead, use tongs or gloves to pick up the stick, or simply leave the stick alone. Chances are, if the ants are running fast, they are not the little fire ant.

Also remember, little fire ants often stand relatively still, or simply fall off the bait stick when you disturb it (like when you pick it up). So again, be careful. If you pick up one of your sticks and see tiny little ants (which may just look like little specks) dropping off, you may have found the little fire ant!!

Also, don't open the bag again after you've sealed it. Use a new bag for each stick, so there is no chance of ants escaping from a previously sealed bag.

- 9) After all your sticks are collected and sealed in their plastic bags with their labels, take the bags back to school, or home, and put them in the freezer for a couple hours. This will kill the ants, allowing you to examine them closely.

Bring your ants to school with you on the day that your class will do its identification lab.

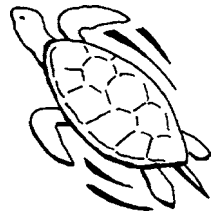


- 10) Take your ants out of the freezer and use the keys that your teacher will give you to determine if any of the ants you collected are little fire ants. If you are not sure about any of your specimens, ask your teacher for help. If you still cannot determine whether or not you have any little fire ants, give the specimen you are unsure about **AND ITS LABEL(!)** to your teacher so he/she can give it to a professional biologist to identify. The biologist will notify your teacher if you've found little fire ants.

- 11) If you've identified any of your specimens as little fire ants, have your teacher give them to a professional biologist for verification. The biologist will notify your teacher if you've indeed located a little fire ant.

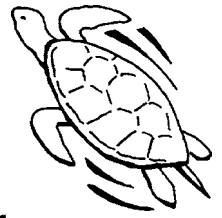
Didn't find little fire ants? Don't be disappointed!

Because "alien" (nonnative) little fire ants in Hawai'i are threats to our unique environment, we hope we do not find them here on Maui! Whether you found little fire ants or not, the information you have gathered is very important. You have contributed scientific data to an important conservation biology project. Thank you for your assistance!



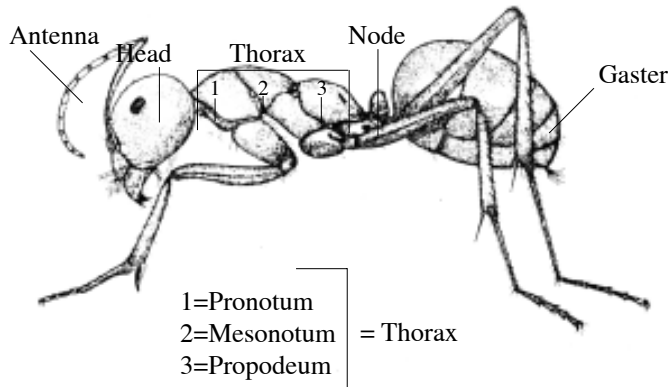
Specimen Labels

<p>Finding the Little Fire Ant Specimen Identification Label</p> <p>Location (detailed description):</p> <p>Date (month, day, year) and start time of survey:</p> <p>Your name:</p> <p>Your teacher's name:</p> <p>Your school:</p>	<p>Finding the Little Fire Ant Specimen Identification Label</p> <p>Location (detailed description):</p> <p>Date (month, day, year) and start time of survey:</p> <p>Your name:</p> <p>Your teacher's name:</p> <p>Your school:</p>
<p>Finding the Little Fire Ant Specimen Identification Label</p> <p>Location (detailed description):</p> <p>Date (month, day, year) and start time of survey:</p> <p>Your name:</p> <p>Your teacher's name:</p> <p>Your school:</p>	<p>Finding the Little Fire Ant Specimen Identification Label</p> <p>Location (detailed description):</p> <p>Date (month, day, year) and start time of survey:</p> <p>Your name:</p> <p>Your teacher's name:</p> <p>Your school:</p>



Wasmannia Identification Key

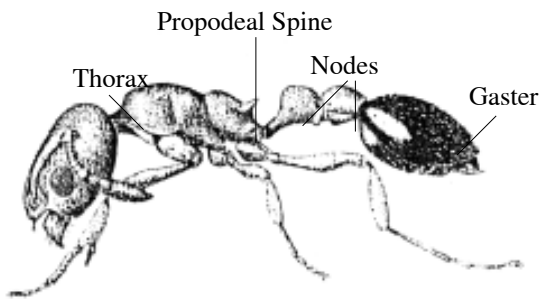
Introduction to Ant Anatomy



NOTE:

This ant has:

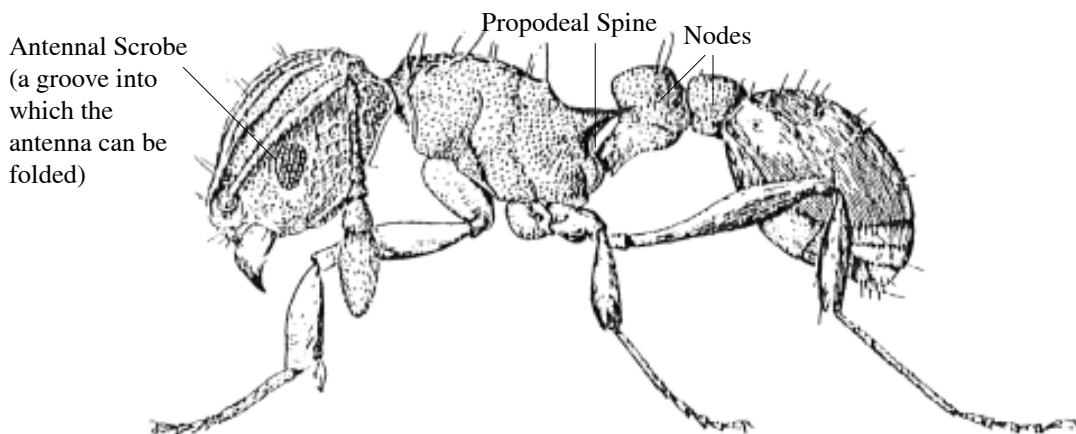
1. One node between thorax and gaster
2. Smooth propodeum (i.e., no spines)



NOTE:

This ant has:

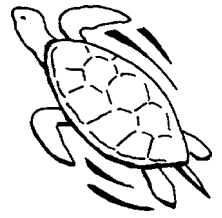
1. Two nodes between thorax and gaster
2. Pair of spines on propodeum (only one is visible in the diagram)



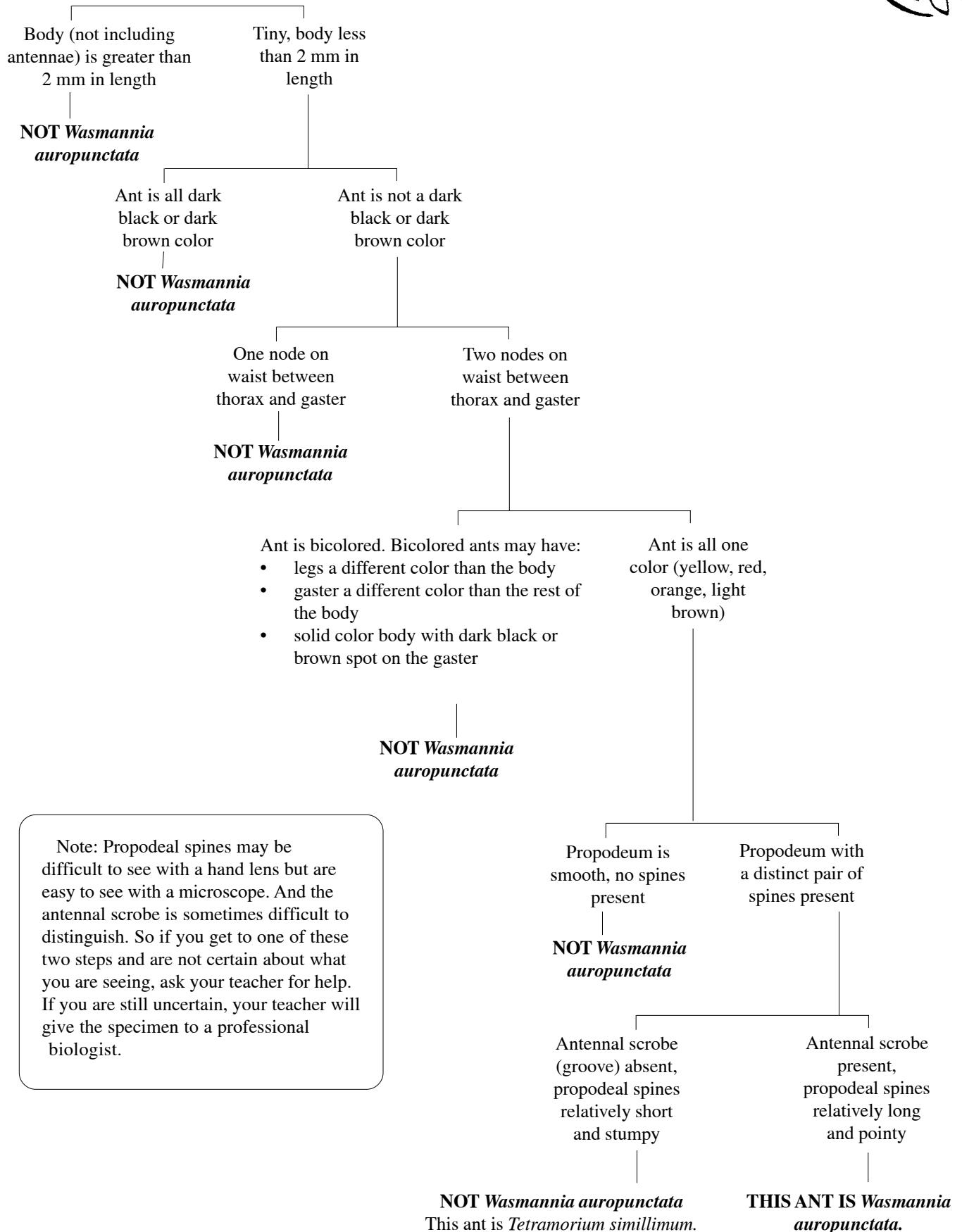
Wasmannia auropunctata



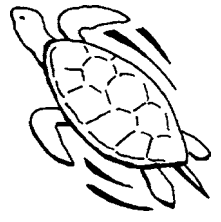
Illustrations: Top and bottom—M. R. Smith, "A generic and subgeneric synopsis of the United States ants, based on the workers (Hymenoptera: Formicidae)," American Midland Naturalist, Vol. 37, No. 3, pp. 521-647; Middle—CSIRO Entomology, reprinted in Bert Holldobler and Edward O. Wilson, The Ants, Harvard University Press, Cambridge, Massachusetts, 1990.



Wasmannia Auropunctata Key

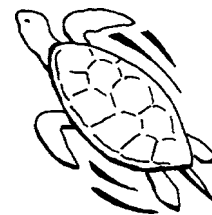


Note: Propodeal spines may be difficult to see with a hand lens but are easy to see with a microscope. And the antennal scrobe is sometimes difficult to distinguish. So if you get to one of these two steps and are not certain about what you are seeing, ask your teacher for help. If you are still uncertain, your teacher will give the specimen to a professional biologist.



4) How are people trying to prevent the little fire ant from getting to Maui on agriculture and nursery items?

5) Why is it important to know as soon as possible if the little fire ant is now on Maui?



Activity #2

Red Imported Fire Ant Prevention & Quick Response Plan

● ● ● In Advance *Research Preparation and Student Reading*

- Student research may go more quickly if you look through the “Research Resources” listing in the Student Page “RIFA Prevention and Quick Response Plan” (p. 31-33). Place an interlibrary loan order for some of the books and journal articles listed there, and put them on reserve in your school library or make them available in your classroom.
- Assign the Student Page “Endangered Water Birds Threatened by . . . Ants?!?” (pp. 27-30)

● ● ● Class Period One *Team Research Projects*

Materials & Setup

Available in the classroom or on reserve in the library

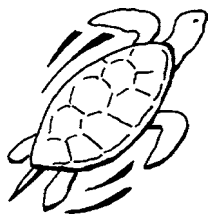
- One or more copies of the “Resource Packet on Red Imported Fire Ants” (included as an appendix to this unit)

For each student

- Student Page “Endangered Water Birds Threatened by . . . Ants?!?” (pp. 27-30)
- Student Page “RIFA Prevention and Quick Response Plan” (pp. 31-33)

Instructions

- 1) Divide the class into teams of four to eight students. Hand out the Student Page “RIFA Prevention and Quick Response Plan.” Each team will be responsible for developing a plan for the island of Maui. The plan’s purpose is to prevent the red imported fire ant (*Solenopsis invicta*) from becoming established on Maui as well as to respond rapidly to control the ants’ spread if it is discovered on the island. Students will be researching and developing their plans during this class period, on their own time, and during the second class period.
- 2) To jump-start students’ thinking, start the class off by reviewing the main points from the reading. Before the teams start their work, brainstorm a list of ideas with the whole class.
One question to brainstorm about is: “Where is the red imported fire ant most likely to be introduced to Maui?” Brainstorming places where entry is likely will help students think about how to target prevention and monitoring efforts.



Research may be done on the Internet, in local college libraries, and through interlibrary loan. See also the “Resource Packet” included as an appendix to this unit, which consists of pages downloaded from various Internet sites listed in the Student Page “RIFA Prevention and Quick Response Plan.” Students may want to check the webpages themselves for updated information.

Each team will produce an outline and rationale for its plan. Use the Student Page “RIFA Prevention and Quick Response Plan” as a guide. As the group works together, each student should take responsibility for doing a particular aspect of the research so that the work—and the learning—gets spread around. Use the four elements of the plan listed on the student page (p. 31) to divide responsibility. For groups of more than four students, have pairs of students work together.

Note

Allow several days between class periods one and two to allow teams time to work on their research and plans.

● ● ● **Class Period Two** *Research Team Meetings*

- 1) Allow student research teams to meet to finalize their plans and to prepare for their in-class presentations.

● ● ● **Class Period Three** *Team Presentations*

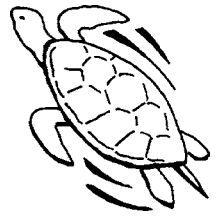
- 1) Student teams make five- to ten-minute presentations of their plans to the class.

Journal Ideas

- How can you help spread the word about the threat of fire ants? What do other people need to know?
- How big of a threat do you think red imported fire ants are to Maui native ecosystems, including wetlands? Explain your reasoning.

Assessment Tools

- Prevention and Quick Response Plans (see the Student Page “RIFA Prevention and Quick Response Plan” for a list of elements that will help you evaluate the plans)
- Team presentations



Endangered Water Birds Threatened by . . . Ants!?!?

In 1992, Keālia Pond National Wildlife Refuge was created from land donated to the government by the Alexander & Baldwin company. A primary purpose of the refuge is to protect habitat for three endangered Hawaiian water bird species: the *ae'ō* (Hawaiian black-necked stilt), *'alae ke'oke'o* (Hawaiian coot), *koloa* (Hawaiian duck).

These endangered species—and other native water birds—breed, nest, raise their young, and reside year round in wetland areas like Keālia Pond, scattered around the islands. All together, eight native species of water birds rely on wetlands, including the ones listed above and the Hawaiian gallinule or moorhen, Laysan duck, pied-billed grebe, fulvous whistling duck, and black-crowned night heron.

In the fall and winter, Keālia Pond and other Hawaiian wetlands come to life with an influx of migratory birds that head south from colder climes. Pintail ducks, Canada geese, sanderlings, and plovers (including the *kōlea*) join some 90 other species of water birds and an occasional gull or osprey blown in by winter storms.

But scientists predict the refuge won't be such a lively place if the red imported fire ant (*Solenopsis invicta*) gets to the Hawaiian Islands. And it's the native species that nest here that are likely to be hardest hit.

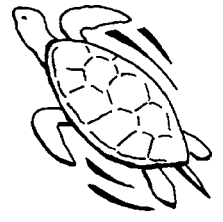
Invicta Means Invincible

Solenopsis invicta was so named by Dr. William Buren in 1972. The meaning of the Latin "invicta" is "invincible," which is an accurate description of the red imported fire ant. The red imported fire ant (or RIFA, as you'll see in much of the nonscientific literature about these ants) is a particularly aggressive invader, even overrunning areas that were once inhabited by another aggressive fire ant species, *Solenopsis geminata*.



Ae'ō in a pond
(Photo: Eric Nishibayashi)

RIFA colonies are extremely dense and grow rapidly, compared to other ant species. Individual colonies consist of hundreds of thousands of ants, and there can be 1500-3000 worker ants *per square meter* in infested areas. Imagine an eighth of a cup of rice grains running around in your bathtub and you get the picture. The red imported fire ant is aggressive, territorial, and predatory—with a powerful sting that makes it a danger to most animals.



Some ant species run away when their nest is disturbed or the object they are on moves. Not so for *Solenopsis invicta*. Thousands of these ants will swarm on and relentlessly sting anything that is unfortunate enough to disturb their colony. One researcher was stung over 250 times on one leg

Solenopsis invicta was unintentionally brought to Mobile, Alabama in the 1930s, probably in soil used as ship ballast. Since that time, it has invaded over 300 million acres in the United States, primarily in southeastern states. Since the red imported fire ant has been around the continental

***Solenopsis invicta* = red imported fire ant = RIFA**

U.S. for decades, scientists have had plenty of time to study the ants' effect on wildlife. Studies in wetlands have reported:

within ten seconds of inadvertently disturbing a nest. These ants are quick, each one can sting repeatedly, and the sting is exceptionally painful, usually turning into a white pustule by the following day.

- Water bird breeding success declines in areas inhabited by *S. invicta*. RIFA attack and prey upon pipped eggs and nestlings of several species of ground- and shrub-nesting birds including egrets, herons, spoonbills, cormorants, and gulls. There was a 92 percent overall reduction in water bird reproduction during the part of the breeding season studied. During one month, hatchling mortality was 100 percent in RIFA-infested areas, compared to 0 percent in non-infested areas (Drees).
- *S. invicta* attacks the nestlings of wood ducks and is thought to exclude wood ducks from natural cavity nest sites. In one study, RIFA destroyed 15 percent of clutches in wood duck nest boxes (Ridlehuber).
- In RIFA-infested areas, chick mortality among endangered least terns is 27 percent higher than in noninfested areas (Lockly). Least terns nest on the ground.

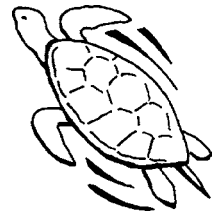
The red imported fire ant is an opportunistic feeder, taking advantage of whatever food source is at hand. They actively prey on invertebrates, vertebrates, and plants. Any animal that is relatively immobile and unable to run away from attacking ants is susceptible to RIFA predatory attacks. These ants are documented to have preyed upon a whole range of animals including birds, lizards, turtles, small mammals, and invertebrates. Human deaths have also been reported among individuals who are hypersensitive to *S. invicta* venom or who were bedridden and immobile.

Nestlings and “pipped” eggs (which have just started to hatch and have a hole broken in them), especially of ground-nesting birds, turtles, and lizards, are particularly vulnerable to predation. If *Solenopsis invicta* makes it to the islands, that fact could spell trouble for Hawaiian wetland birds.

***Solenopsis Invicta* in Wetlands**

The red imported fire ant is well adapted to wetland conditions. It is believed to be native to southern Brazil, in a region where seasonal flooding is the norm. RIFA is able to thrive in seasonally flooded habitats where other ant species are absent.

In Hawai‘i, wetland habitat is extremely rare, comprising only about three percent of the islands’ total land area. Degradation and loss of habitat have been primary contributors to the decline of native water birds. Invasion by red imported fire ants would undoubtedly cause further habitat degradation—a loss that species whose populations number as few as 1500 birds (in the case of the *ae‘o*) may not be able to withstand.



Other Fire Ant Concerns

Protecting endangered water birds is not the only reason people want to keep the red imported fire ant away from Hawai‘i. They are also concerned about what could happen to our quality of life and the future of the tourism industry if *S. invicta* establishes itself here. In some places it has invaded, it is impossible to sit in the grass or stand on a shoreline to fish without being stung. Hunting, ranching, and outdoor recreational activities can be affected by the presence of this ant. And, once it is established, the red imported fire ant has proven impossible to eradicate. In many places, control programs have reduced ant populations to bearable levels with repeated use of chemical pesticides. However, this approach works only for limited areas, and there are concerns about the threats widespread use of these toxicants would pose to water quality and the overall health of ecosystems such as wetlands.

In the 13 states and Puerto Rico where RIFA is found, it has been reported in virtually every crop. Because of its opportunistic feeding habits, including a predilection for seeds of all kinds, *S. invicta* has the potential to cause great damage to crops. It has also been known to cause damage to irrigation systems and cut down on the efficiency of agricultural operations as pickers and equipment operators adjust their work to avoid disturbing or running over nests.

Red imported fire ants also infest electrical equipment, chewing on insulation and causing short circuits or interfering with switching mechanisms. They sometimes nest in buildings and commonly nest in home gardens, landscaped areas, and nursery stock.

Some people point out that RIFA can have benefits, too. Researchers have found that RIFA can be beneficial in sugar cane and cotton fields where they prey upon pest species. And *Solenopsis invicta* predation may help control flea and tick populations. However, in a place

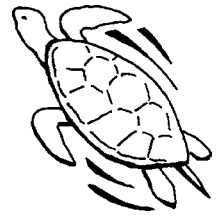
such as Hawai‘i, where native plants and animals evolved with no ant predators whatsoever and where working and playing outdoors is so important, it is difficult to conclude that the benefits of the red imported fire ants would outweigh the long list of negative consequences of its arrival here.



RIFA can be a threat to agricultural operations (Photo: Carol Gentz)

In 1998, the red imported fire ant was found in California. Since then, infestations have been discovered in several counties. Around the state, people are scrambling to determine the best way to minimize the impact of this species. Now that RIFA has gained a foothold in California, some people believe it is just a matter of time before these ants make it to Hawai‘i. With the large volume of goods shipped back and forth between Hawai‘i and California, as well as the numbers of people who use California as a departure point for their air travels to the islands, the ants may have plenty of opportunities to hitch a ride over.

The state Department of Agriculture does have a quarantine and inspection policy for products such as nursery stock shipped to Hawai‘i from infested areas. But *S. invicta* has successfully worked its way across the continental United States, despite the existence of a federal quarantine policy begun in 1958. Many researchers, agricultural operators, and resource managers



believe it will take much more than agricultural quarantine to protect Maui and the other Hawaiian Islands from this invader.

Joining forces as the “Ant Working Group,” they have begun putting together a prevention plan as well as a contingency plan for detecting and limiting the spread of red imported fire ants if they should arrive on the islands. Here are a few of their ideas for preventing RIFA from arriving on Maui:

- 1) Chemically treat goods before they are shipped from RIFA-infested areas.
- 2) Give Hawaii Department of Agriculture inspectors the authority to inspect non-agricultural items such as building materials.
- 3) Establish regular state reviews of first class mail from the mainland, looking for suspicious packages and then applying for federal warrants to inspect these packages.

Can you think of other ideas for preventing this dangerous invader from arriving on Maui—or for quickly responding to stop its spread once it gets here? *Your* idea could be one that ultimately protects Maui—especially its wetland areas—from the “invincible” *Solenopsis invicta*.

Sources

California Department of Food and Agriculture, “Red Imported Fire Ant Information” at pi.cdfa.ca.gov/rifa/newfact.htm, June 26, 2000.

Drees, B., “Red Imported Fire Ant Predation on Nestlings of Colonial Waterbirds,” *Southwest Entomology*, No. 19, 1994, pp. 355-359.

Ducks Unlimited, Inc. “Hawaiian Islands Wetlands Conservation Plan.”

Lockly, T., “Effect of Imported Fire Ant Predation on a Population of the Least Tern — An Endangered Species,” *Southwest Entomology*, No. 20, 1995, pp. 517-519.

Ridlehuber, K., “Fire Ant Predation on Wood Duck Ducklings and Pipped Eggs,” *Southwest Natur.*, No. 27, 1982, p. 222.

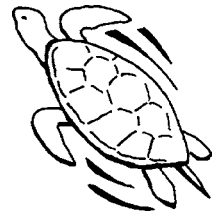
Tanji, Edwin, “Maui Wants Refuge Enlarged; Kealia Pond Important to Wildlife, Near-Shore Reefs,” *The Honolulu Advertiser*, January 20, 1997.

VanGelder, Ellen, “HNIS Report on *Solenopsis invicta*” at www.hear.org/hnis/index.html#HNISreportsavailable.

_____, Personal communication and unpublished work plan for Proactive Protection of Hawaii’s Wetlands and Other Ecosystems from the Red Imported Fire Ant project, June 2000.

Vinson, S. “Impact of the Invasion of *Solenopsis invicta* on Native Food Webs,” in D. Williams (ed.), *Exotic Ants: Biology, Impact, and Control of Introduced Species*, Westview Press, Boulder, Colorado, 1994, pp. 241-258.

Weaver-Missick, T., “The Fire Ant Saga Continues,” *Agricultural Research*, September 1999.



RIFA Prevention and Quick Response Plan

Your team's assignment is to work together to develop a "Prevention and Quick Response Plan" for the red imported fire ant on Maui. You will present an outline and rationale for the plan to the class when you are finished. You may even want to pass some of your ideas along to the Maui Ant Working Group, a collaboration involving scientists and resource managers from around the island.

Goals

Like your team, the Maui Ant Working Group aims to:

- 1) Prevent the arrival of the red imported fire ant on Maui,
- 2) Monitor for its presence to detect it before it is well established, and
- 3) Respond rapidly and effectively to contain the spread of the red imported fire ant if it is found on Maui.

Research

Your plan needs to be backed up with factual information and a clear explanation of what each component is designed to accomplish. You will need to do some research in order to develop your plan. Your teacher has a collection of resources available for classroom use, and there are many other sources available through public and university libraries as well as on the Internet. See the "Research Resources" section of this student page for a beginning list of research leads.

Keywords for Internet searches include:

- red imported fire ant
- *Solenopsis invicta*

If you use the following search terms, double-check to make sure the information you retrieve is about *S. invicta* and not another ant species:

- fire ant
- pest ants
- pest ant control

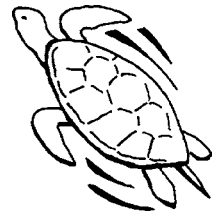
Outlining a Plan

Divide up responsibility for developing your plan among team members. Make sure everyone is responsible for part of the plan. Your plan should include the following elements:

- 1) A description of the problem, including potential threats to ecosystems and humans based on the problems encountered in other states;
- 2) A plan to prevent the ant's arrival;
- 3) A plan to monitor for its presence and detect it before it is well established; and
- 4) A plan to respond rapidly and contain the ant if it invades.

Support *each element* of the plan with:

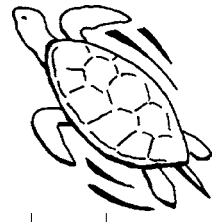
- 1) A description of your reasoning for this part of the plan and factual information that supports your plan;
- 2) Ideas about whom should be involved in implementing this part of the plan; and
- 3) Suggestions for containing costs (e.g., by forming creative partnerships, raising money locally, getting time and resources donated to the project, or involving students and other people who are not normally involved in work like this).



Starting Points

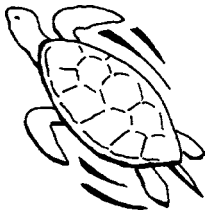
Here are some of the questions being asked by Maui Ant Working Group members as they consider what their plan will be. Use these questions as a starting point for your own thinking.

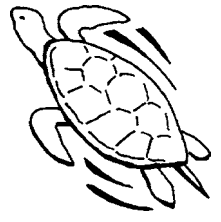
- What kind of information should Maui residents and visitors have about RIFA? What are the best ways to get that information to them? How can we get residents and visitors to pay attention to this threat?
- What is the basic ecology of RIFA—including its colony structure, how it reproduces, what makes it such a successful invader, suitable habitats, etc.? These characteristics affect how and how easily they may become established, how quickly they can spread, where they are likely to invade, and what kinds of controls are likely to work.
- Where is RIFA most likely to be introduced to Maui? In theory, it takes only one mated queen to establish a new colony, although there may be a much greater chance of survival if a whole or partial nest is moved. That is one reason nursery stock receives so much scrutiny, since ants and even nests can be moved in the soil they are shipped with. If RIFA came to Maui in nursery stock, where could it become established? What about other vehicles such as containers in which fruits or vegetables, soil, and other agricultural products are shipped? Airports? Cars being shipped from infested areas? Shipments of lumber and furniture? Where else might RIFA stow away?
- How does the current Hawai‘i and Federal RIFA quarantine system work? Has anything different been tried in other states or countries?
- What are the likely impacts/effects of the RIFA, should it ever become established on Maui or the Hawaiian Islands? Are there certain parts of the island or certain ecosystems that seem particularly threatened and of high priority for protection?
- What control mechanisms are currently being used and recommended in infested areas? What experiments are being tried with new methods such as “biocontrol” (using other insects or diseases to control populations of pest species such as the RIFA)?
- What kinds of permits would be needed to use some of the pesticides being used in other states, here on Maui in the places that are most likely to need protection? Should we be stockpiling pesticides so we can quickly respond if RIFA is found here?



Research Resources

	General Information	RIFA ecology	Control methods	Quarantine	Impacts of RIFA
Texas A&M University, Department of Entomology, "Imported Fire Ant" at <fireant.tamu.edu>.	•	•	•	•	•
VanGelder, Ellen, "Hawai'i Non-Indigenous Invasive Species (HNIS) Report on <i>Solenopsis invicta</i> " at <www.hear.org/hnis/index.html#HNISreportsavailable>.	•	•	•	•	•
California Department of Food and Agriculture, "Red Imported Fire Ant Information" at <pi.cdfa.ca.gov/rifa/newfact.htm>.	•				•
University of Arkansas, Arkansas Cooperative Extension Service, "Red Imported Fire Ant" at <www.arnatural.org/fireants/default.asp>.	•	•	•	•	•
Lockley, T. C., University of Minnesota Integrated Pest Management Program, "Imported Fire Ants" at <ipmworld.umn.edu/chapters/lockley.htm>.	•	•	•		•
County of Los Angeles, Agricultural Commissioner/Weights & Measures, "Red Imported Fire Ant" at <acwm.co.la.ca.us/scripts/RIFA.htm>.	•				•
National Park Service, "National Park Service Integrated Pest Management Manual—Fire Ants" at <www.colostate.edu/Depts/IPM/natparks/fireants.html>. <i>Includes a brief section on monitoring</i>	•		•		
Vinson, S., "Impact of the Invasion of <i>Solenopsis Invicta</i> on Native Food Webs," in D. Williams, (ed.), <i>Exotic Ants: Biology, Impact, and Control of Introduced Species</i> , Westview Press, Boulder, Colorado, 1994, pp. 241-258.		•			•
Drees, B., "Red Imported Fire Ant Predation on Nestlings of Colonial Waterbirds," <i>Southwest Entomology</i> , No. 19, 1994, pp. 355-359.					•
Lockly, T., "Effect of Imported Fire Ant Predation on a Population of the Least Tern — An Endangered Species," <i>Southwest Entomology</i> , No. 20, 1995, pp. 517-519.					•
Ridlehuber, K., "Fire Ant Predation on Wood Duck Ducklings and Pipped Eggs," <i>Southwest. Natur.</i> , No. 27, 1982, p. 222.					•
Weaver-Missick, T., "The Fire Ant Saga Continues," <i>Agricultural Research</i> , September 1999.			•		•
Moulis, R., "Predation by the Imported Fire Ant (<i>Solenopsis invicta</i>) on Loggerhead Sea Turtle (<i>Caretta caretta</i>) Nests on Wassaw National Wildlife Refuge, Georgia," <i>Chelonian Conservation Biology</i> , No. 2, 1996, pp. 433-436.					•
Tschinkel, W., "The Fire Ant (<i>Solenopsis invicta</i>): Still Unvanquished," in B. McKnight, (ed.), <i>Biological Pollution: The Control and Impact of Invasive Exotic Species</i> , Indiana Academy of Science, Indianapolis, 1993, pp. 121-136.	•	•	•	•	•





Activity #3

Race to the Wetlands Game

● ● ● Class Period One *Race to the Wetlands Game*

Materials & Setup _____

For each group of six to eight students

- One die
- “Race to the Wetlands Game Board” (included with this curriculum)
- “Race to the Wetlands Instruction Card” (master, p. 36)
- “Race to the Wetlands Game Cards” (master, pp. 37-61)
- Six to eight player pieces (master, p. 62)
- Six to eight pennies

Instructions _____

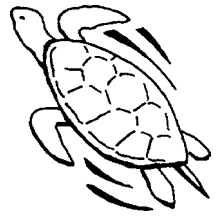
- 1) Divide students into groups of six to eight. Conduct the game. Use the game materials provided with the curriculum and the instruction card. This game is based on the ant collection activity and student reading assignments. Students will be “tested” on what they have read as well as learn new facts.

Journal Ideas _____

- Compare the game version of the race between ants and humans to the real-life efforts that people are making to prevent the arrival and establishment of red imported fire ants on Maui.

Assessment Tools _____

- Participation in the game



Race to the Wetlands

Instruction Card

Object of the Game

In this game, you are either a red imported fire ant or a human. The object is for all members of either species to get to Keālia Pond first. If all the people get to Keālia Pond first, they win and can stop the ants from threatening the native wildlife there. If all the ants get there first, they win and establish a population too large and too widespread for people to eradicate.

Rules

- Out of six to eight players, half are ants and half are people. Roll the die to determine who goes first, and proceed in a clockwise direction.
- Move your player pieces by the roll of the die, answering questions, and/or following instructions given on the game cards.
- Each player rolls the die only once per turn and draws only one card per turn.
- Keep each type of card in a separate pile. Once you have used a game card, put it on the bottom of the pile it was drawn from.
- When you land on a space, follow the symbol. Here's what happens:

✓ = **Hazards and Opportunities**

Another player draws a card and reads you the instructions on it. Follow them.

▼ = **Red Imported Fire Ants**

★ = **Prevention and Control**

◆ = **General Knowledge**

✕ = **Little Fire Ants**

Another player draws a card and reads the question on it. You answer the question.

Movement

Correct answer = Move forward 3 spaces.

Incorrect answer = Move back 1 space.

● = **Cooperation Opportunity**

Work together with your teammates (fellow ants or humans) to answer two questions from your choice of the four question categories

(▼★◆✕).

Movement

Answer both questions correctly = Each player on the team moves forward 3 spaces from where they are.

Get 1 answer wrong = Each player on the team moves backward 3 spaces from where they are.

To Win

Each player who reaches Keālia Pond (the endpoint of the game board) can help their team members (ants or people) answer questions until either all the ants are at the pond or all the people are at the pond. The first team with all members at Keālia Pond wins, and the game ends.

Some teacher-only resources have been omitted from the online document.

They are available as password-protected files at:

www.hear.org/hoike/teachermaterials

Some teacher-only resources have been omitted from the online document.

They are available as password-protected files at:

www.hear.org/hoike/teachermaterials



Coastal Unit 5

Coastal Issues in the News

Overview

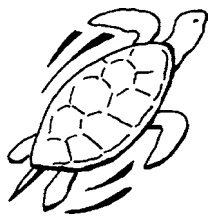
Almost every day, the local news media carry at least one story about issues affecting the coastal areas of Maui and the other Hawaiian Islands. News coverage is an important source of information for many people. This unit engages students in examining coastal issues and how they are covered in local papers.

Length of Entire Unit

Three class periods over a one- to three-week span, plus optional in-class research, coordination, and presentation time

Unit Focus Questions

- 1) What current coastal issues are being covered in local newspapers?
- 2) How do newspaper reporters cover issues when there are multiple points of view?
- 3) How can students develop a deeper understanding of coastal issues through their own investigations?



Unit at a Glance

Activity #1

Coastal Issues in the News

Students collect, analyze, and discuss newspaper articles covering coastal issues on Maui.

Length

One class period, preceded by homework

This unit requires collecting newspaper articles over a two- to three-week period prior to beginning the activity.

Prerequisite Activity

None

Objectives

- Identify stories about coastal issues on Maui from local or state newspapers.
- Analyze the content and presentation of a newspaper article.
- Develop questions about an issue based on media coverage.

DOE Grades 9-12 Science Standards and Benchmarks

LIVING THE VALUES, ATTITUDES, AND COMMITMENTS CHARACTERISTIC OF AN INQUIRING MIND: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- **OBJECTIVITY:** Evaluate various perspectives and their implications before drawing conclusions.

Activity #2

Coastal Journalism Projects

Students research, conduct interviews, and write their own newspaper-style articles on a Maui coastal issue of their choosing.

Length

Two class periods, divided by a one- to three-week investigation period. Optional in-class research, team coordination, and presentation time.

Prerequisite Activity

Activity #1 “Coastal Issues in the News”

Objectives

- Verify and clarify details, and develop a more complete understanding of a selected issue based on student investigation.
- Develop journalistic coverage of a Maui coastal issue.

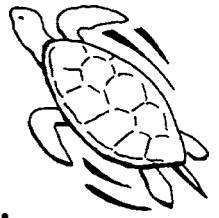
DOE Grades 9-12 Science Standards and Benchmarks

LIVING THE VALUES, ATTITUDES, AND COMMITMENTS CHARACTERISTIC OF AN INQUIRING MIND: Students apply the values, attitudes, and commitments characteristic of an inquiring mind.

- **QUESTIONING:** Ask questions to clarify or validate purpose, perspective, assumptions, interpretations, and implications of a problem, situation, or solution.
- **SELF-DIRECTED:** Use research techniques and a variety of sources to complete a report on a project of one’s choice.

RELATING THE NATURE OF TECHNOLOGY TO SCIENCE: Students use the problem-solving process to address current issues involving human adaptation in the environment.

- Identify and explain current issues or problems based on evidence found in available information.



Enrichment Ideas

- Follow television and radio coverage on coastal issues. Take notes on these stories while watching or listening to them, including noting the name of the reporter; the date, time, and station of the broadcast; and information about the issue including the names of people and organizations that are mentioned. Add these notes to the “Coastal Issues in the News” portfolios.
- Invite a local reporter who covers coastal issues to come into class and talk about how he/she works. Prepare questions for the guest speaker based on the investigations in this unit.
- Write a letter to the editor about a coastal issue.
- Submit the best articles from Activity #2 “Coastal Journalism Projects” to the newspaper.
- Create radio or television news spots based Activity #2 investigations.
- Create a contest in which students or teams devise solutions to the issues they are researching in Activity #2, and write a newspaper article about the proposed solution. Give the whole class the opportunity to vote for the best solution, and give a “Pulitzer Prize” for the best article.
- Student teams make class presentations based on their Activity #2 research and articles.

Resources for Further Reading and Research

Ramsey, J. M., Harold R. Hungerford, and Trudi Volk, “A Technique for Analyzing Environmental Issues,” *The Journal of Environmental Education*, Vol. 21 No. 1, 1989.

Haleakalā Times at <www.mauisfreepress.com>. Includes archives for several months

“The Hawai‘i Newspaper Index” at <www.hcc.hawaii.edu/education/hcc/library/hiindex.html>.

Provides an index to the *Honolulu Advertiser* and the *Honolulu Star-Bulletin*

Access to the Hawaii Newspaper Index is provided through the Hawaii State Public Library System (HSPLS) via Telnet.

Honolulu Advertiser at <www.honoluluadvertiser.com>.

Includes on-line versions of back issues for preceding three months

Honolulu Star-Bulletin at <www.starbulletin.com>.

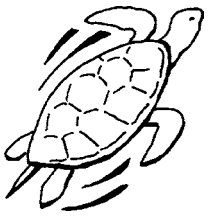
Includes on-line searchable database, and on-line back issues through 1996

Maui News at <www.maui.net/~mauinews/news.html>.

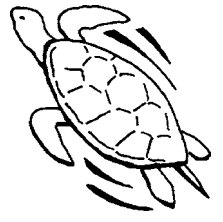
Includes archives for several months of back issues

Maui Weekly at <www.MauiWeekly.com>.

Includes the current issue on-line



Coastal Unit 5



Activity #1

Coastal Issues in the News

● ● ● In Advance *Collecting Coastal News Stories*

Materials & Setup _____

For each student

- Student Page “Newspaper Websites” (p. 7)
- Student Page “Reading the Newspaper With a Critical Eye” (pp. 8-10)

Two to Three Weeks in Advance _____

- Assign students to review local and state newspapers and clip stories about coastal issues on Maui. If students are not finding adequate coverage of coastal issues in current newspapers, have them access earlier time periods through the newspaper websites listed in the Student Page “Newspaper Websites,” (p. 7).
- Do a quick brainstorm session with the class to identify the types of issues and areas that might be covered under the category “coastal issues.” These could include, among other possibilities, beach loss or protection, coastal development, sea turtle nesting, dune damage or restoration, threats or efforts to protect native plants and animals, traditional food gathering practices and rights, protected areas such as ‘Āhihi-Kīna‘u Natural Area Reserve, marine debris, and pollution or sedimentation of coastal areas.

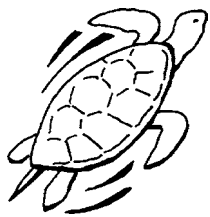
One to Two Days in Advance _____

- Assign as homework the Student Page “Reading the Newspaper With a Critical Eye.”
- Have students start a “Coastal Issues in the News” portfolio with the completed student page and all of their newspaper stories. They should bring their portfolios to class.

● ● ● Class Period One *News Coverage of Coastal Issues*

Instructions _____

- 1) Lead a class discussion about the issues students found covered in the newspaper. For each major issue:
 - Develop a common understanding of the basic story,
 - Identify student questions about these issues and allow students to answer each others’ questions where possible, and
 - Invite students to comment on the quality of the reporting, focusing on characteristics such as fairness and balance, continuity of coverage, completeness of information, and writing quality.
- 2) With student input, identify the best newspaper article (or top three) from all those collected. What makes this article stand out from the others?

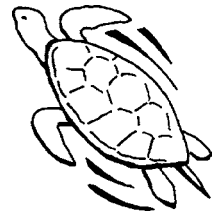


Journal Ideas

- Which newspaper article did you think was the best? Why?
- Do you think the “Five Ws” (who, what, where, when, and why) are important for journalists to include in their articles? Why or why not?
- What issues or events that took place over the course of the last two or three weeks should have gotten newspaper coverage—or more prominent coverage—but did not? Why are these issues and events important?
- Did any of the articles incorporate or make reference to traditional Hawaiian culture or values? If so, how were those connections made?
- Do you think it is appropriate for journalists to allow their own feelings about an issue to come through in their writing? Why or why not?

Assessment Tools

- Student Page “Reading the Newspaper With a Critical Eye”
- Student “Coastal Issues in the News” portfolios
- Journal entries



Newspaper Websites

Gain access to back issues of local and state newspapers through the Internet, using this list of websites.

Haleakalā Times

<www.mauisfreepress.com>

Includes archives for several months

“The Hawai’i Newspaper Index”

<www.hcc.hawaii.edu/education/hcc/library/hiindex.html>

An index to the *Honolulu Advertiser* and the *Honolulu Star-Bulletin*

Access to the Hawaii Newspaper Index is provided through the Hawaii State Public Library System (HSPLS) via Telnet.

Honolulu Advertiser

<www.honoluluadvertiser.com>

Includes on-line versions of back issues for preceding three months

Honolulu Star-Bulletin

<www.starbulletin.com>

Includes on-line searchable database, and on-line back issues through 1996

Maui News

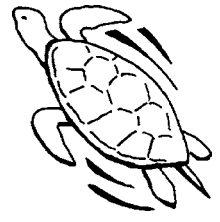
<www.maui.net/~mauinews/news.html>

Includes archives for several months of back issues

Maui Weekly

<www.MauiWeekly.com>

Includes the current issue on-line



Reading the Newspaper With a Critical Eye

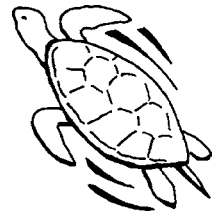
Select one of the newspaper articles that you collected about Maui coastal issues. It is best to collect a longer article, or even a series of articles on the same issue, for this assignment. Read the article carefully and answer the following questions:

1) List the title of the article, the author, and the publication name, page number, and date. (If you have selected a series of articles, list this information for each one.)

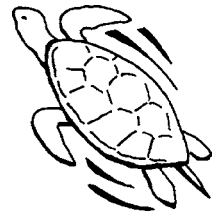
2) In one paragraph, summarize the issue as it is described in this article.

3) List three questions you have about this issue after reading the article.

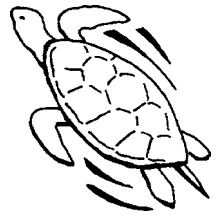
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- 4) Many journalists believe that newspaper stories should answer five basic questions, sometimes called the “Five Ws” (who, what, where, when, and why). Does this article answer the Five Ws? Which, if any, are missed?
- 5) Do you think the reporter provided a balanced account of the story or issue in this article? Why or why not?
- 6) Many news reports present two sides of a story by presenting arguments or quotations from people who hold opposing points of view. Does the story you’ve selected use this approach or a similar approach to present different perspectives? If so, what different perspectives are presented?



- 7) Based on what you know about this issue, do you think people have opinions about the issue that are not represented in this article? If so, briefly describe them. If you can think of people or organizations that would hold that opinion, list their names along with the perspective.
- 8) Have you heard about this issue before or from other sources? If so, what have you heard? Where did you get this information?
- 9) Could you tell how the reporter feels about this issue from reading the article? If so, what do you think the reporter's feelings about the issue are?



Activity #2

Coastal Journalism Projects

● ● ● In Advance *Research Preparations*

At Least One Class Period in Advance

- At the end of Activity #1 “Coastal Issues in the News,” have the class identify a few issues from their research they want to investigate further. Divide the class into teams of four to six students, with each team selecting a different issue to research.
- As part of their investigations, team members are responsible for tracking newspapers, television, and radio for news related to the issue from this class period throughout the remainder of the time devoted to this activity. Have team members divide responsibility for collecting newspaper articles or taking notes on radio or television spots from different newspapers, television stations, and radio stations. Students will share their notes and articles with others on their team, eventually including these in the “Coastal Issues in the News” portfolios begun in Activity #1.
- Photocopy all of the relevant newspaper articles collected by team members for Activity #1 for each member of the appropriate Activity #2 team. Assign the task of making and distributing photocopies to team members, or make copies yourself.

● ● ● Class Period One *Team Planning*

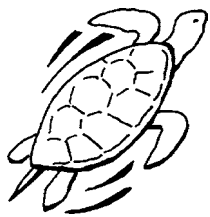
Materials & Setup

For each student

- Student Page “Investigating Coastal Issues” (pp. 14-21)

Instructions

- 1) Allow student teams to meet for the entire class period to devise a plan for investigating their issue further. Teams should use the Student Page “Investigating Coastal Issues” to guide their work.
- 2) Help students come up with schedules for their investigations. They will need to know when their investigations need to be completed, when their articles and portfolios are due, and when any interim products are due. (You may want to collect an interim progress report from each team, outlining what team members have already done and plan to do.)
- 3) Remind students that all of the information they collect and generate should be shared with everyone on their team and go into their portfolios. This includes interview notes and copies of correspondence. (If photocopies need to be made, again assign that task to particular students or make copies yourself.)



Options

- Instead of having individual students keep their own portfolios and write their own articles, have each team keep a portfolio of its issue investigation.
- Have team members collaborate on writing a series of newspaper articles, with different members writing each article. In addition, some team members could serve as illustrators, photographers, or cartographers.

● ● ● Interim Meetings *Investigation Phase*

Student teams will need to meet periodically to share information and update their research plans. You can allocate class time for these meetings or have students meet outside of class. Depending upon the length of time you have allotted for team investigations, one to three of these interim meetings should be sufficient.

● ● ● Class Period Two *Integrating Team Knowledge*

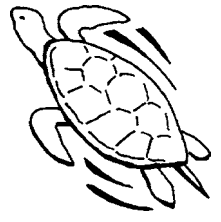
(after the one- to three-week investigation period is completed)

Materials & Setup

- Student Page “What Journalists Learn” (pp. 22-25)

Instructions

- 1) Student teams meet to integrate all of the information they collected about their issue. Each student will be responsible for writing a newspaper article on the issue, and this team meeting is a good opportunity for them to make sure they have the information they need from each other.
If a team is done meeting before the class is finished, individual team members can use the remaining time to begin work on their articles.
- 2) Ask students what they think makes a good newspaper article. Make a list on the board or overhead, and help the class narrow down this list into a brief set of criteria. (Suggested topics for the criteria include accuracy; presenting various perspectives; answering the Five Ws—who, what, where, when, and why; objectivity; and clear writing.)
- 3) As homework, assign students to write a 1000-1500-word article on the issue they have been investigating. Each student may use information gathered by any of the team members in writing the article. The article is to be included and handed in with the portfolio.
- 4) Also assign the Student Page “What Journalists Learn” as homework. (You may want to add some in-class follow-up discussion time using the questions in this student page once students have completed their articles.)

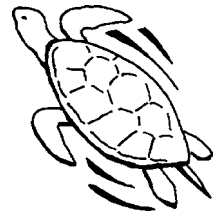


Journal Ideas

- What are some options for resolving this issue? Do you think any of them could work?
- Do you think the journalists who wrote the original articles you collected about this issue truly understood the issue when they wrote about it? Explain your answer.
- What are some of the challenges of reporting on coastal issues?

Assessment Tools

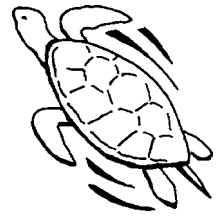
- Student Page “Investigating Coastal Issues” (team plan portion, pp. 19-21)
- Participation in group work
- Student Page “What Journalists Learn”
- “Coastal Issues in the News” portfolio, including a student-written article (Use student-generated criteria for a good newspaper article as one means of assessing articles.)
- Journal entries



Investigating Coastal Issues

Newspapers are one source of information about issues affecting the coastal areas of Maui. But newspapers cannot present the whole story on every issue, so critical readers often use the newspaper story as a starting point for their own investigations. Your team will work together to develop a more in-depth understanding of one issue you select.

- Make a plan for your team’s investigation.
 - 1) Continue to watch the newspapers, radio, and television for more information about this issue. Look on-line or in the library for back issues of local and state newspapers for more information.
 - 2) Come up with a list of questions about the issue using the newspaper article(s) you originally collected as a starting point.
 - 3) Develop a list of people and organizations you will contact for more information about the issue. Use the newspaper article(s) and the list of local resources as a starting point. Make sure you are including a range of viewpoints as you develop this list.
 - 4) Divide responsibility for contacting the people and organizations among team members. Make sure team members know their responsibilities and which questions they are trying to answer.
 - 5) Make a schedule with deadlines for this first phase of research. (This phase will uncover more leads that your team will want to follow up.) Your teacher will help you develop your schedule.
- Write up your team’s plan, including all of the points listed above and any other elements you decide are important. Use the chart in the student page to write it out.
- Select one team member to be the project manager. The project manager’s job is to make sure the project is on schedule and to remind other team members of upcoming deadlines and responsibilities.
- Your team will need to have additional meetings as your investigation goes along. You will need to update each other about what you are learning, identify new questions, questions that haven’t been fully answered, and new ideas and viewpoints that you uncover. Divide up responsibility for new research leads.
- The project manager should keep current research plans and records of which tasks have been accomplished.



As You Contact People

Use the following basic rules:

- 1) Introduce yourself and your project.
- 2) If you are calling, ask if it is a good time to talk, or if you can set up an appointment at another time.
- 3) Have a list of three to five questions you want to ask prepared ahead of time.
- 4) Clarify and probe. Make sure you understand what you're being told. Ask probing questions if it seems to conflict with other information you've gotten.
- 5) After your conversation, or after receiving a response to a letter or e-mail message, thank the person for taking the time to give you information.
- 6) Keep complete notes about your communication with people, including copies of letters and e-mail messages, notes from telephone conversations, and notes about when you left telephone messages.

Resources for Investigating Local Coastal Issues

This is a listing of organizations and information sources that are likely sources of information on Maui coastal issues. Use it as a starting point in your research.

People

- The reporter who wrote the article
- Anyone who is quoted in that article and organizations referred to in the article
- Your friends and family members—if they do not know much about the issue, maybe they know someone who does.

Hawai'i State Government Offices

Department of Health

"Environmental Health" home page at <www.hawaii.gov/doh/eh/>

Department of Land and Natural Resources

<www.hawaii.gov/dlnr/>

(See telephone book and website for divisions not listed below and division website addresses)

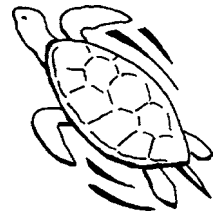
Division of Forestry and Wildlife

Wailuku
984-8100

Na Ala Hele Maui Office

Kahului
871-2831

Establishes and maintains trails that help support recreational activities such as fishing, hiking, camping, hunting, picnicking, and nature photography



Division of Aquatic Resources

243-5294

Manages the State's marine and freshwater resources

Division of Boating and Ocean Recreation, Maui District Office

Wailuku

243-5824

Manages and administers ocean recreation and coastal areas programs

Division of Conservation and Resources Enforcement

Wailuku

984-8110

Enforces state laws and rules involving state lands, parks, historic sites, forest reserves, aquatic life and wildlife areas, coastal zones, conservation districts, and state shores

Hawai'i State Legislature

<www.capitol.hawaii.gov/>

"Public Access Room" at <www.state.hi.us/lrb/par/>

Provides means for public knowledge and participation in the legislative process

Hawai'i Tourism Authority

<www.state.hi.us/tourism/>

Kaho'olawe Island Reserve

<www.hawaii.gov/kirc/main/home.htm#Overview>

Department of Business, Economic Development, and Tourism

"The State of Hawaii Data Book 1997," <www.state.hi.us/dbedt/db97/index.html>

Contains statistical information about Hawai'i and its people

Maui County Government Offices

County Council

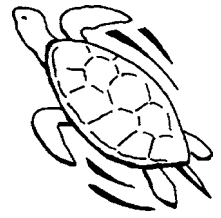
<www.co.maui.hi.us/council/index.html>

Includes contact information for county council members and information about land use, planning, and parks & recreation committees

Department of Parks and Recreation

<www.co.maui.hi.us/departments/parks/index.html>

270-7230



Department of Planning

<www.co.maui.hi.us/departments/planning/index.html>
270-7735

Includes coastal zone management program, including special management areas and development restrictions to avoid permanent losses of valuable resources and to ensure that adequate access to beaches, recreation areas and natural reserves is provided

Federal Government Offices

Keālia Pond National Wildlife Refuge

<pacificislands.fws.gov/wnwr/mkealianwr.html>
P.O. Box 1042
Kīhei, Hawai‘i 96753
875-1582

Hawaiian Islands Humpback Whale Sanctuary

<www.hihwnms.nos.noaa.gov/>
726 South Kīhei Road
Kīhei, Hawai‘i 96753
879-2818

Organizations

Hawai‘i Sea Grant Extension Service

<www.soest.hawaii.edu/SEAGRANT/extension.html>
Links university resources to community needs on issues including coastal ecosystem health and public safety

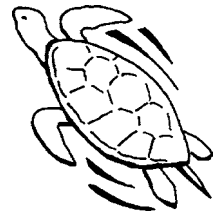
Maui Invasive Species Committee

<www.hear.org/misc/>
579-2115
e-mail: maui.invasivespecies@gte.net

A voluntary partnership of private, government, and nonprofit organizations organized to prevent new pest species from becoming established in Maui County and to stop established pests from spreading wherever possible

The Nature Conservancy

<www.tnc.org-hawaii>
Information about each of this nonprofit organization’s preserves in Hawai‘i, including the Mo‘omomi Preserve on Moloka‘i, which includes an intact beach and sand dune system



Online Information

EE-Link Endangered Species page

<eelink.net/EndSpp/>

A comprehensive starting point for internet information on endangered species

Final Recommendations from the Fourth International Marine Debris Conference on Derelict Fishing Gear and the Marine Environment, August 6 - 11, 2000, Honolulu
<www.hihwnms.nos.noaa.gov/special_offerings/sp_off_imdc/recommendations.html#top>

Hawai'i Ecosystems at Risk project

<www.hear.org>

Attn: Research

P.O. Box 369

Makawao, HI 96768

891-1754

e-mail: pt@hear.org

Provides technology, methods, and information to decision makers, resource managers, and the general public, to aid in the fight against harmful alien species in Hawai'i

Maui Chamber of Commerce Community Reference Guide

<www.mauichamber.com/quick.htm>

Names and telephone numbers of many community organizations and services, including environmental groups and professional associations

Natural Heritage Program

<www.natureserve.org>

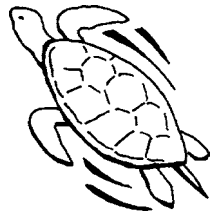
Click on the map of Hawaii on the map of the US on the homepage to get information on rare species in the islands.

Detailed, comprehensive information on the rarest biological resources nationwide, including Hawai'i. Its HINHP database is the state's largest computerized inventory of endangered, threatened, and rare plants, animals, and ecosystems, extracted from all available sources.

Sierra Club, Maui Group

<www.mauimapp.com/community/sierra.htm>

Works through political and regulatory action and community education on a range of issues related to protecting native habitat and species

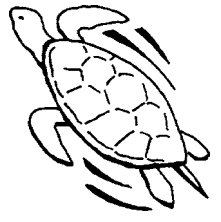


Issue Investigation Plan

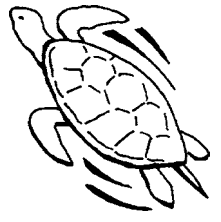
Team members:

Issue:

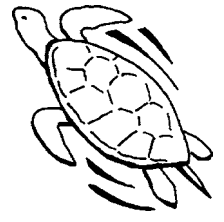
Your team's questions about the issue:



Person or organization to contact	Team member who will make the contact	Date to be completed



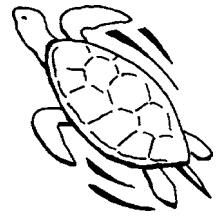
Person or organization to contact	Team member who will make the contact	Date to be completed



What Journalists Learn

Answer the following questions based upon your experience investigating and reporting on a Maui coastal issue.

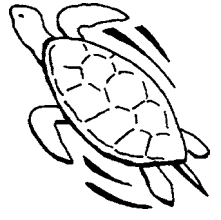
- 1) Describe the major positions people are taking on the issue you investigated. In your description of each position, include the beliefs and values that seem to be behind it and whether you think these ideas are based on fact or opinion.



2) Look at the following list of value systems. Which of these systems do you think are the most influential in each position, and how? (There may be more than one.) Explain your answer.

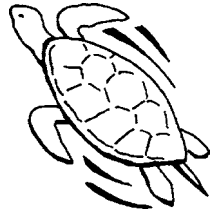
Aesthetic	focus on appreciation of intrinsic and subjective qualities, such as the beauty of an area
Cultural	related to maintaining the practices and attitudes of a culture
Ecological	concerned with living things and the function of ecological systems
Economic	related to the exchange of goods and services
Educational	concerned with benefits derived from learning
Egocentric	focus on self-satisfaction and personal fulfillment
Legal	concerned with the law and its enforcement or application
Recreational	related to the use of leisure time

From 'Ō'hia Project, Grades 7-8, Bernice Pauahi Bishop Museum and Moanalua Gardens Foundation, Honolulu, 1992, p. 284. Adapted from Ramsey, J.M., H.R. Hungerford, and T. Volk, "A Technique for Analyzing Environmental Issues," The Journal of Environmental Education, Vol. 21 No. 1, 1989.



3) Where do you stand on this issue? What beliefs and values influence your position? Do you think your ideas are based on fact or opinion?

4) Did what you learned during your investigation change your perspective? If so, how?



5) What did you learn about journalism in this unit?