Unit 2 at a Glance

Grades 6 - 8

Content Standards and Benchmarks	Focus Questions and Activities	Key Concepts	Assessment
Science: Earth in the Solar System Students describe how the Earth's motions and tilt on its axis lead to changes in seasons.	**2C.** How do Earth-Sun-Moon relationships create seasons and tides? How do marine organisms respond to changes in seasons and tides? **Activity: *Seasons and Tides: Marine Responses to Celestial Changes***	• Earth-Sun-Moon relationships create seasons and tides in Hawai'i that affect the behavior of marine life.	Students: • Diagram how Earth-Sun-Moon relationships create seasons and tides. • Write a fishing tale based on an interview with a fisher that summarizes how seasonal and tidal changes affect marine life.
Science: Doing Scientific Inquiry Develop questions and hypotheses that can be answered through scientific investigations. **Science: Cycle of Matter and Energy Flow** Explain how plants use the energy from sunlight and matter from the atmosphere to make food.	**2D.** How do the tides affect the growth of phytoplankton and the level of dissolved oxygen in a fishpond? What other factors affect the growth of phytoplankton? **Activity: *Kai Moku: The Turn of the Tide***	• Phytoplankton uses energy from the sun and nutrients from fish wastes to make food. • Tidal circulation helps prevent accumulation of wastes that leads to stagnation and loss of dissolved oxygen needed by fish.	Students: • Write a scientific report describing the hypothesis, prediction, methodology and results. • Diagram how phytoplankton uses energy from the sun and nutrients from fish wastes to make food.

Culminating Activity

Students work in pairs or small groups to create a seasonal change calendar (one month for each pair of students) that highlights lunar and seasonal changes and includes conservation notes for harvesting marine species.

Materials needed: 12 sheets of poster-size paper, preferably paper that can receive watercolor paint, crayons (light colored and bright; neon colors are best), watercolor paints (Crayola brand works well; the colors are bright and brilliant), yardstick, and calendar cards (provided at the end of this unit)

Calendar pages should include:

- Color illustration of at least one species featured on the calendar card that depicts how the plant or animal responds to the season*
- Conservation notes about harvesting one of the species noting seasonal fishing regulations and students' recommendations for any additional conservation practices; (Encourage students to include feedback from the community about their ideas for conservation.)
- Moon phases for the month, indicating days of new, full and quarter moons; (Add tide information using a tide chart, if desired.)
- ʻŌlelo noʻeau (Hawaiian proverb) related to the time of year; (Samples provided on calendar cards may be used, or students may research others.)

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Culminating Activity (continued)

Direct students to information on current Hawai'i fishing regulations at the Hawai'i Division of Aquatic Resources Website: http://www.hawaii.gov/dlnr/dar. Additional references to obtain more information about species on the calendar cards are listed in the Appendices. See Additional Resources and pond life cards.

Teachers' Note: The calendar cards provided for this activity list the Hawaiian months as coinciding with the months used in modern-day calendars. These are only rough approximations since in ancient times the months were marked by the appearance of different stars and constellations in the eastern sky at sunset. Some of these celestial appearances are listed on the cards to provide additional information to students. Also, different islands had divergent naming of months. The names chosen on the calendar cards are based on *Hawai'i: A Calendar of Natural Events* (Foster et al., 1988), which match month names for Hawai'i island. Encourage students to research the Hawaiian month names specific to their island or refer them to the information provided at the end of this unit. Note that some of the 'ōlelo no'eau may refer to events that are not as common today due to alteration of coastal habitat and its effect on native species.

*Field test teacher, Zennie Sawyer at Kilohana School had her students create crayon-resist drawings for their calendar pages. The colorful result was beautiful.

Creating Crayon-Resist Illustrations

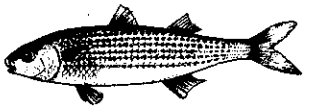
1. Have students draw the picture at the top of the calendar page lightly in pencil so that the pencil marks won't show after painting. Drawing should use lots of line repetition in contour patterns (similar to the contour lines on Hawaiian quilts) for the best effect of the technique.
2. Go over the pencil drawing with crayons. Use light, bright colors rather than dark colors. Crayon markings must be heavy. Students need to think ahead and select crayon colors and paint colors that will contrast. (Using blue paint on blue crayon will not be effective!) The more contrast that the students use, the better and the more outstanding their results will be. Students may have to get over their mindset of green lines and green paint for mountains; they should experiment with pink or orange lines with rich dark green paint. The effects are outstanding, even if it sounds wierd at first! It would be wise to have students experiment with the technique to see the beauty of colors that they can obtain. Don't overlook the use of white crayon, even though you can't see it on white paper. Once painted over, white shows up strikingly for waves or wind.
3. Go over the crayon markings with contrasting paint colors. Encourage students to use minimal strokes in applying the paint and not to overdo the application of paint or it will rub through. Mix rich dark colors that will contrast with the crayons. And avoid using dark crayon colors with dark paint. Do not paint one color over the whole drawing; think through the picture and use multiple colors.

Mahalo, Zennie!

Review criteria for assessing students' work (see sample rubric on the following page).

Ask students to present their calendar pages to the class with the name of the month covered. Challenge their classmates to listen carefully to the information and see if they can determine which month is being presented. Post the calendar pages around the room or in a central area of your school. Set aside times to review the calendar each month and encourage students to add their observations of seasonal changes.

Sample Rubric for Culminating Activity



Performance Indicators	Kūlia Exceeds Standard	Mākaukau Meets Standard	ʻAno Mākaukau (Almost at Standard)	Mākaukau ʻOle (Below Standard)
Science: Earth in the Solar System Explain how seasonal changes of light intensity affect marine life. ***Points*** ____	Calendar page illustration and/or description clearly shows how two different marine species respond to seasonal change.	Calendar page illustration and/or description clearly shows how a marine species responds to seasonal change.	Calendar page illustration and/or description does not clearly show how a marine species responds to seasonal change.	Calendar page illustration and/or description depicts a marine species but does not show how it responds to seasonal change.
Science: Mālama I ka ʻĀina - Conservation of Resources Discuss and evaluate present natural resource conservation practices and propose additional practices relevant to the community. ***Points*** ____	Presentation includes accurate information and skillful discussion and evaluation of current fishing regulations. Ideas for additional conservation practices are relevant and include feedback from the community.	Presentation includes accurate information and understandable discussion and evaluation of current fishing regulations. Ideas for additional conservation practices are relevant and thoughtful.	Presentation includes accurate information but needs prompting and focus to clearly discuss and evaluate current fishing regulations. Ideas for additional conservation practices need to be more developed.	Discussion and evaluation of current fishing regulations is unclear or inaccurate. Ideas for any additional conservation practices are not presented.
Effort/Task Commitment ***Points*** ____	Rigorous effort; shows commitment to strive for best work	Appropriate effort; successful in completing task	Inadequate effort for completing task	Minimal effort; unsuccessful in completing task

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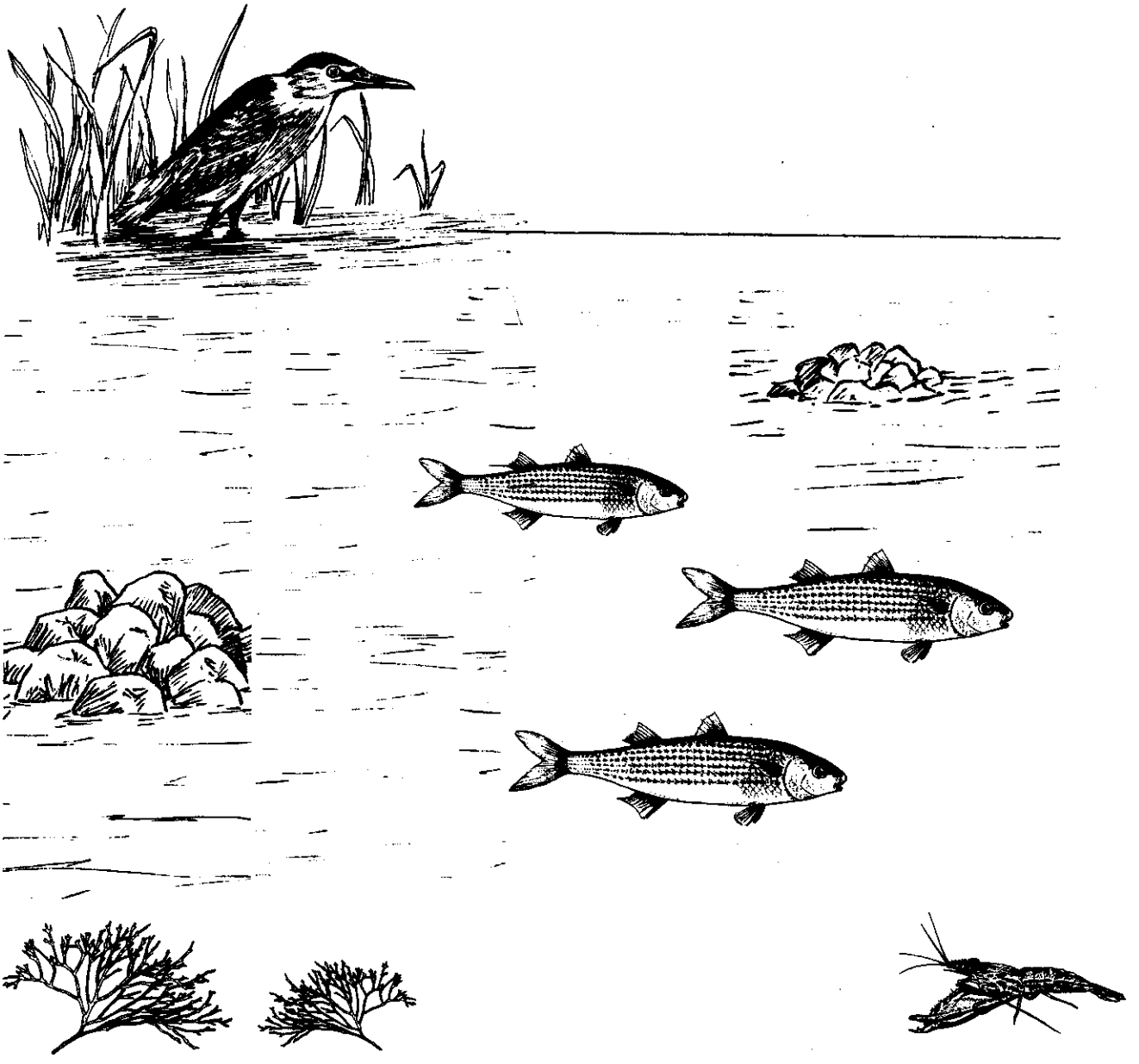

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Seasons and Tides:

Marine Responses to Celestial Changes

- How do Earth-Sun-Moon relationships create seasons and tides?
- How do marine organisms respond to changes in seasons and tides?

Hawai'i DOE Content Standard

Science: Earth in the Solar System

- Students discuss how the Earth-Sun-Moon system causes seasons, moon phases, climate, weather and global changes.

Grades 6 - 8 Performance Indicators

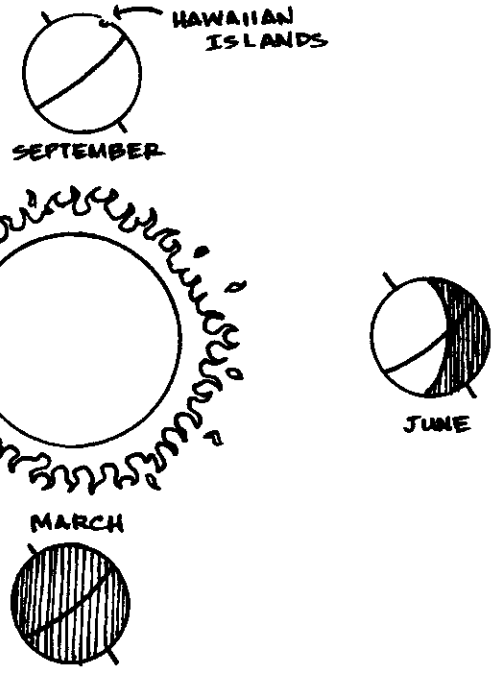
- Diagram the Earth's rotation and revolution around the Sun.
- Demonstrate the cause and effect relationship between the Earth's rotation/tilt of its axis and the change in seasons.
- Explain how seasonal changes of light intensity affect marine life.

Key Concept

Earth-Sun-Moon relationships create seasons and tides in Hawai'i that affect the behavior of marine life.

Activity at a Glance

Groups of students teach one another how Earth-Sun-Moon relationships create tides and seasons.



Skills

observation, research, oral communication

Assessment

Students:

- Diagram how Earth-Sun-Moon relationships create seasons and tides.
- Write a fishing tale based on an interview with a fisher that summarizes how seasonal and tidal changes affect marine life.

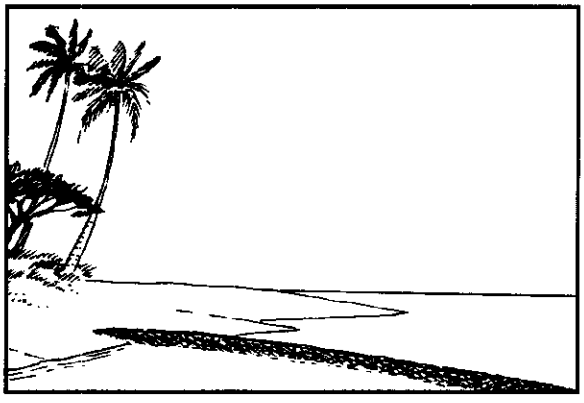
Time

3 - 4 class periods

Vocabulary

spawning – producing or depositing eggs
larva – early life form that is fundamentally unlike parent and metamorphoses to become adult
ʻōlelo noʻeau – Hawaiian proverb
kau wela – the hot, dry season in Hawaiʻi from May through September
hoʻoilo – the wet, cool season in Hawaiʻi from October through April

Materials



Provided:
- student information sheets
- Hawaiian Moon calendar

Needed:
- lamp with 100 watt light bulb
- globe
- softball
- tide chart for Hawaiʻi

Advance Preparation

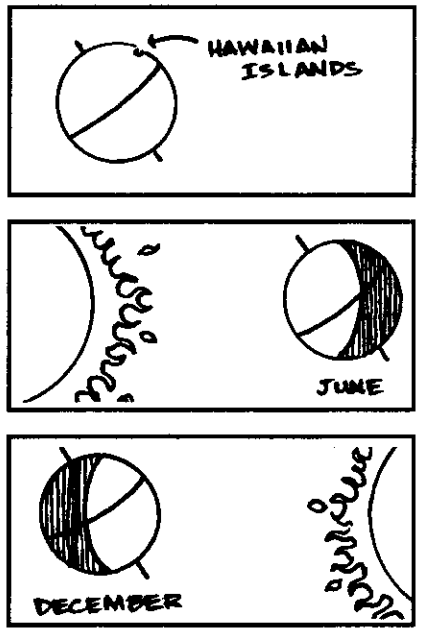
Copy the information sheets (one sheet for each of four groups). Note that two groups will have the same sheet on tides; assign one to complete the task for Group A and one to complete the task for Group B.

Background

The Earth rotates about an imaginary line that passes through the north and south poles of the planet. This line is called the axis of rotation. Earth's rotational axis always points in the same direction, so that the North Pole points towards the star Polaris or the North Star. Think of the Earth as a spinning top, tipped over to one side at an angle of 23.5 degrees.

For an observer at a fixed position on Earth, the rotation of the Earth makes it appear as if the sky is revolving around the Earth. In other words, if one is standing for long enough in a field at night, it looks like the sky is moving, not the Earth.

The tilt of Earth's rotational axis and the Earth's orbit work together to create the seasons. As the Earth travels around the Sun, it remains tipped in the same direction, towards the star Polaris. This means that sometimes the northern half of the Earth is pointing towards the Sun (summer), and sometimes it is pointing away (winter). These points in the Earth's orbit are called solstices. Notice that when the northern hemisphere is tilted towards the Sun, the southern hemisphere is tilted away. This explains why the hemispheres have opposite seasons (UCAR, 2000).



The tilt of Earth's rotational axis and the Earth's orbit work together to create the seasons.

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The rotation of the Earth on its axis (every 23 hours and 56 minutes and 4 seconds, or Sidereal day) and its annual revolution around the Sun create fluctuations in tides, currents, day length (the hours of light) and temperature that affect the behavior of marine life. (The solar day of 24 hours measures the time between the moment of sunrise and the same moment the next day.) Hawaiians were keenly aware of these natural rhythms and they timed their fishing and harvesting practices accordingly. Today, Hawaiian proverbs and traditional knowledge provide a window to the past where the daily activities of the early Hawaiians were centered around celestial and biological rhythms.

Hawaiian Moon Calendar

The Hawaiian Moon calendar was developed over the centuries by the ancient Polynesians, whose lives literally depended on their ability to catch fish. The Polynesians discovered that the biological clocks of all life forms resonate in predictable relationships with the Earth, Sun and Moon and they were able to forecast the times of heightened activity for all forms of sea life wherever they were (Rothery, 2003). It was the duty of the kilo lani (astronomers) to keep the annual calendar and watch the moon to determine when certain kapu should be placed on the fish or land. Some say that the kilo lani knew when to add extra days or an extra month to the moon calendar at the end of the Makahiki so that the seasons would correspond with the Sun. Kilo lani on the different Islands and the different moku (districts) had various methods of adjusting, as the name of the lunar months vary on each Island (Taylor, 1995).

The Hawaiian time frame for a day included the period from sunset to sunset rather than from sunrise to sunrise, and a day might not be a full twenty-four hours. The Hawaiian calendar actually alternated months of thirty days with months of twenty-nine days. Having established thirty days (one of them half as long as the other twenty-nine), the monthly calendar was further divided into three lunar phases of ten days (Richards, 1999).

To the Hawaiians, the three phases marking the Moon's increase or decrease in size were: 1) the first appearance of the new Moon in the west in the evening; 2) the time of the full Moon when it stood directly over the Islands at midnight; and 3) the period when the Moon was waning or decreasing and showed itself in the east late at night. It was with reference to these three phases of the Moon that names were given to the nights that made up the month (Malo, 1951).

During a full Moon, the Sun and Moon are nearly opposite each other and very few minutes pass without one or the other being in our sky. During a new Moon, both bodies are in near-perfect rhythm traveling the skies together with their forces combined. Because of the interaction between the many lunar solar cycles, no two days, months or years are ever identical. There is one day each month (near the last quarter of the Moon) on which there is no moonrise. The Moon rises about 30 to 70 minutes later each day than the previous day, thus there will always be a day on which the moonrise cannot fit. The Moon rotates about its own axis in the same length of time it takes to orbit the Earth. That's what keeps the same side of the Moon always facing the Earth. (U.S. Naval Observatory, 2003.) Note also that the moonrise can occur at any time during the day or night.

The climactic seasons also comprised divisions of the yearly calendar in addition to twelve – and sometimes thirteen – months. Fishing seasons were intricately woven into the calendar as well with accompanying religious rituals. It was believed that particular religious rites made it possible to fish for a specific type of fish. It was taboo to catch fish out of the proper season (Handy et al., 1991). Scientific studies show that fish are more active for four days leading up to the full Moon and for four days after the new Moon. There are many other

variables to take into consideration as well, not just the Moon phases. Things such as water temperature/color, the presence of baitfish/food items, cloud cover, bird activity, and ocean current speed/direction (Electric Blue Fishing, 2002/2003).

The information cards provided with this activity are designed to provide students with background information on the tides and the two Hawaiian seasons—kau wela the hot, dry season, and ho'oilo the wet, cool time. Plants respond to the change in seasons with the timing of flowering and fruiting; animals respond with the timing of spawning, and in some species, with the onset of migrations. Changes in day length that occur with the change in seasons are a trigger that sets off responses in both plants and animals. Many fishes have two bones at the roof of the skull and between them is the pineal gland or "third eye." Light shining on the surface of the skin covering the gland causes the pineal gland to secrete the hormone called melatonin. During the night phase, melatonin is secreted and during daylight melatonin secretion is inhibited. In this way, an environmental cue (day length) is transformed into a physiological cue (hormone secretion). The pineal gland is also called the master clock in the lower vertebrates (fishes, amphibians, reptiles). For more information on the pineal gland, see the Virtual Creatures Website (http://summit.stanford.edu/creatures) developed by The Summit Lab at Stanford University (1997).

The spawning seasons and spawning times for each species are the result of its evolution. Throughout the life history of a species (from larvae to fry, and from juvenile to adult), it is under intense selection pressure. Until the larvae reach adulthood, they are especially vulnerable to being eaten by predators. Why a species spawns at a particular time of year, particular time of the month (lunar phases), and particular time of the day (sunset), has been forged through natural selection. The marine life forms have timed their stages of reproduction so that their young have the best chance for survival.

Teaching Suggestions

1. Write the following question on the board: ***In what ways does the Earth-Sun-Moon relationship affect life on Earth?*** Divide the class into four groups and give students a few minutes to come up with a list of responses.

2. Ask students to share their ideas and award a point for each correct item on their lists.

3. Have students help you demonstrate the annual movement of the Earth around the Sun using a lamp as the Sun and a globe as the Earth. Ask students to point out the tropics, the equator, and the Hawaiian Islands on the globe.

4. Distribute the information sheets on seasons and tides and the Hawaiian Moon calendar (one to each of the four groups). Review the Moon calendar with students. Assign the different challenges listed on the sheets and give each group of students time to prepare a way to teach the information on their respective sheets to the other groups. Let them know that they may use the globe, softball and lamp in their teaching.

5. Ask one student group to teach their classmates about the season of kau wela. Note: If students use the globe and lamp to demonstrate the seasons, suggest that they darken the classroom. Tilt the globe at about a 23 degree angle to simulate the Earth's tilt on its axis. When the globe is tilted toward the "Sun" in its orbit, this simulates summer in the northern hemisphere – when the Sun's rays shine more directly over the Tropic of Cancer and Hawai'i experiences kau wela.

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6. Have another group demonstrate what causes the season of ho'oilo. If students use the globe and lamp, they should keep the same tilt and walk the globe around the "Sun" to the opposite side of the Earth's "orbit" to simulate summer in the southern hemisphere, when the Sun's rays shine more directly over the Tropic of Capricorn and Hawai'i experiences ho'oilo—the cool, wet season. (See diagram on page 25.)

7. Have the other two groups demonstrate the gravitational forces that create the tides. One group should demonstrate what happens when the Sun, Moon and Earth are lined up (full and new Moon – highest spring tides); and the other should demonstrate what happens when the pull of the Moon and of the Sun are at right angles (first or last quarter Moon – lowest neap tides). Note: students may need to conduct this demonstration a few times so that they grasp it.

8. Ask each group to share an example of how marine animals respond to changes in tides or seasons. Discuss other ways that living organisms respond to seasonal changes.

   Discussion Questions

   - What are some other examples of plant and animal responses to seasonal changes? *(Animals such as the kōlea [Pacific golden plover] and humpback whale migrate to Hawai'i. Plants such as mango and 'ōhi'a 'ai [mountain apple] bear fruit in kau wela.)*

   - How do students respond to seasonal changes? *(They make changes in their selection of fishing and surfing spots and in the clothing they wear.)*

9. Read the 'ōlelo no'eau (Hawaiian proverb) below and discuss its meaning.

   Pua ke kō, ku ka he'e.
   (When the sugar cane tassels, the octopus season is here.)

   Discussion Questions

   - What does the proverb mean? *(When the sugar cane flowers, it's time to catch he'e [octopus]. It probably refers to the month of October or 'Ikuwā, when the he'e mauli is abundant. It lives in shallow water and is active during the daylight hours.)*

   - Do you know of other examples when plant life cycles signal a time when it's good to harvest marine species? *(See calendar cards at the end of this Unit.)*

   - Why are some of us unaware of these seasonal changes and how might this traditional knowledge be useful to us today? *(People spend less time outside and many of us spend little time fishing or growing food. This knowledge may help with gardening and fishing and raising awareness of our relationship to the land and sea.)*

10. As a homework assignment, ask students to complete the assessment activities.

Adaptations/Extensions

- Invite some fishers and/or kūpuna to visit the class and talk about their experiences with plant and animal responses to seasons and tides.
- Challenge students to write their own proverbs about seasonal changes that affect them.
- Ask a kupuna to teach the Hawaiian Moon chant to students and encourage them to practice it and teach it to younger students.

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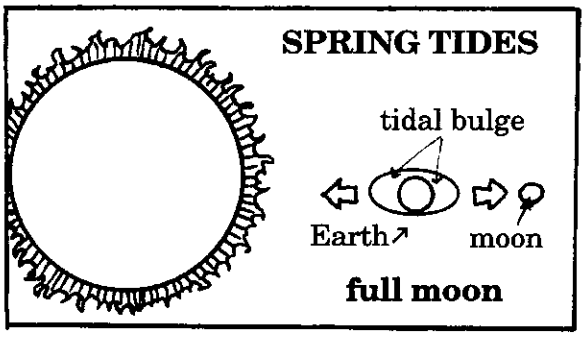
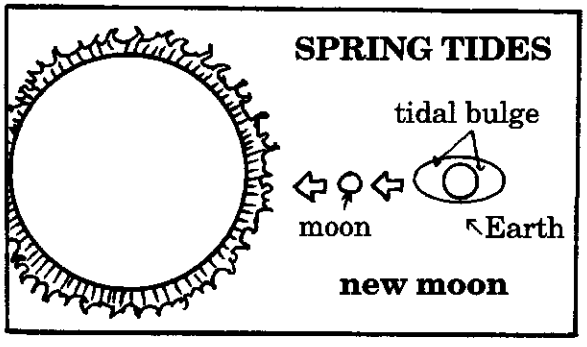
Windows to the Universe Team. 1995. *Moon Phases & Tides.* (Boulder, CO: ©2000-01 University Corporation of Atmospheric Research (UCAR), ©1995-1999, 2000. The Regents of the University of Michigan, September 1, 2000) <rmjohnson@umich.edu> http://www.windows.ucar.edu.

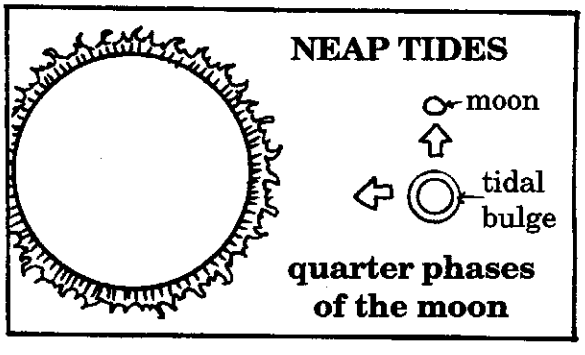
Student Information Sheet — Tides

How does the mahina (Moon) affect our lives on Earth? One of the most noticeable effects is the tides. The gravitational pull of the Moon causes a bulge in the oceans on the side nearest the Moon and on the side of the Earth away from the Moon. In the course of one day's rotation, points on the Earth will experience two high tides from the lunar bulge and two low tides. The average period between high tides is approximately 12 hours and 25 minutes. Take a look at a tide chart for Hawai'i and study the pattern of the high and low tides.





The Sun's gravitational pull also helps to create tides in the oceans, but they are much smaller and are usually masked by the lunar tides. The exception is twice during the month when the Earth, Moon and Sun are nearly in line—the times of full Moon and new Moon. During these times, the combined gravitational pull of the Sun and Moon creates higher tides known as spring tides. When the Moon is in its first or last quarter, the pull of the Moon is at right angles to the pull of the Sun so their forces interfere with each other and the tides are lower. These exceptionally low tides are referred to as neap tides.



Marine plants and animals respond to these tidal rhythms just as they respond to seasonal changes in day length and temperature. Currents resulting from the changes in tides can be quite strong in nearshore areas. In a shoreline fishpond and in the loko 'ume iki style of fishtrap, the movement of the tide through the 'auwai kai (channel) creates a current that attracts fish. When the tide is going out, fish outside the fishpond or trap swim toward the 'auwai kai. When the tide is coming in, the fish in the pond or trap swim against the current through the 'auwai kai toward the open ocean. In olden days, it was during these times that fish could most easily be scooped out of the 'auwai kai with a net. The 'auwai kai are favorite spots for fishing for the 'ama'ama (striped mullet), awa (milkfish) and the predators that lay in wait for them—the kākū (barracuda) and awa 'aua (ladyfish) and pāpio (jacks).

Student Information Sheet — Tides (continued)

Student Challenges

Group A – Spring Tides

Develop a way to teach your classmates about:

- what causes spring tides; and
- how marine life respond to spring tides. Refer to the Hawaiian Moon calendar.

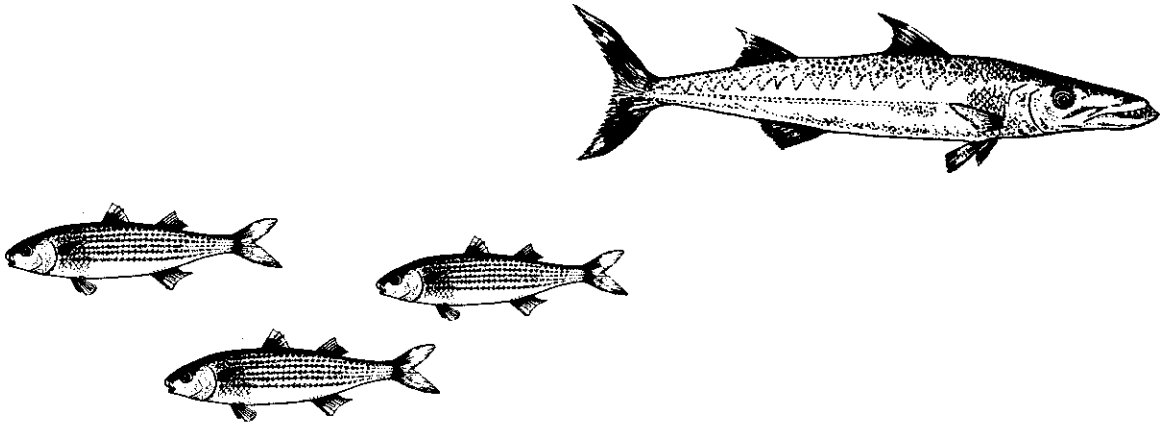
Group B – Neap Tides

Develop a way to teach your classmates about:

- what causes neap tides; and
- how marine life respond to neap tides. Refer to the Hawaiian Moon calendar.

Additional information is available at the following Website:

Missouri Botanical Gardens. *Currents, Waves & Tides.* (Copyright © 2003 Missouri Botanical Gardens) <jennifer.krause@mobot.org> http://mbgnet.mobot.org/salt/motion/ (Biomes of the world, Freshwater and Marine Ecosystems)



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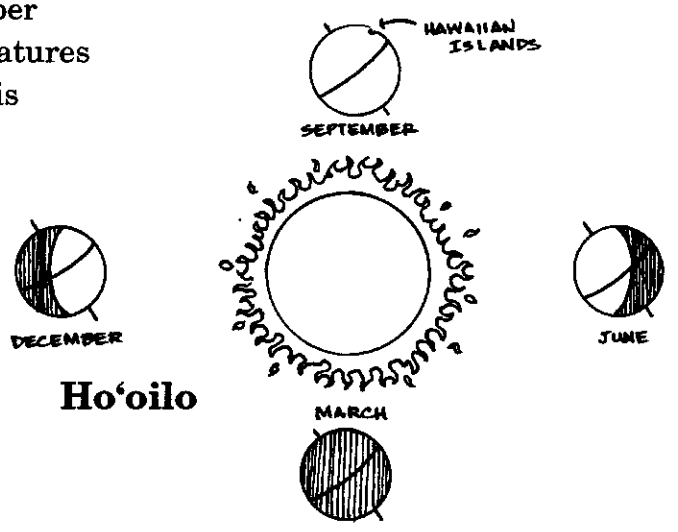
Student Information Sheet — Ho'oilo

Ho'oilo is the cool, wet season from October through April. During this season, temperatures are cooler, particularly at night, and there is more rain. This is the time of year when we in Hawai'i usually have storms from the Kona (leeward) direction. These storms bring southerly winds and heavy rain.



The change of seasons occurs because of the Earth's annual orbit around the Sun and the tilt of the Earth's axis. The Earth makes one full rotation on its axis approximately every 24 hours, which causes night and day. The Earth's axis is tilted at a 23.5 degree angle relative to the Sun. As the Earth revolves around the Sun, the Hawaiian Islands are tilted away from the Sun during ho'oilo.

The main Hawaiian Islands are located above the equator, south of the Tropic of Cancer where the Sun passes directly overhead twice each year, in late May and in late July. Because the Islands are not directly on the equator, there is a change in day length during the two seasons, with the shortest days occurring in December and the longest days in June.

The 'ama'ama (striped mullet) begins spawning in December when day length is short. The adults head out to the open ocean when they are fat with sperm and eggs. The females release one to three million tiny eggs and the males release sperm. The fertilized eggs hatch about 36 hours later. In the open ocean, salinity and temperature are fairly stable and hatched larvae grow best under these conditions. What other ways have you observed marine life responding to the ho'oilo season?

For more information about spawning seasons and related Hawai'i fishing regulations see the Division of Aquatic Resources Website: http://www.hawaii.gov/dlnr/dar.

Student Challenge

Group A – Ho'oilo

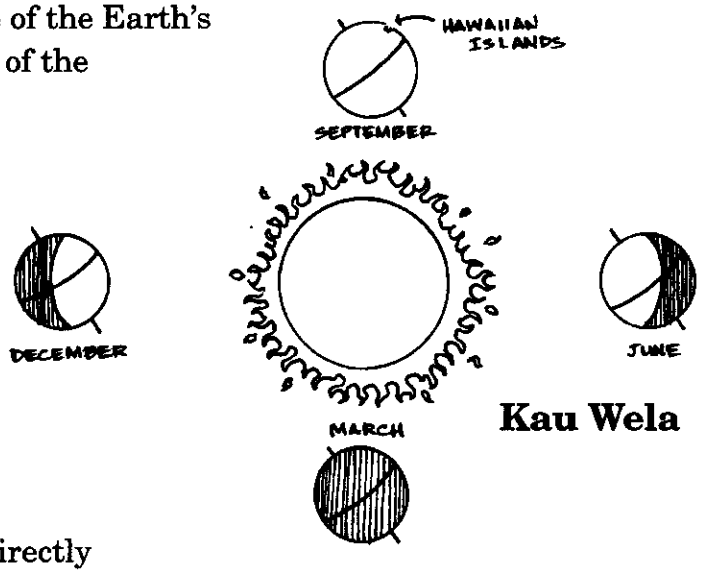
Develop a way to teach your classmates about:

- what causes ho'oilo; and
- at least one way that marine life responds to the season. Refer to the Hawaiian Moon calendar.

Student Information Sheet — Kau Wela

The Hawaiian season of kau wela occurs from May through September. It is the hot, dry season when trade winds blow more consistently.

The change of seasons occurs because of the Earth's annual orbit around the Sun and the tilt of the Earth's axis. The Earth makes one full rotation on its axis approximately every 24 hours, which causes night and day. The Earth's axis is tilted at a 23.5 degree angle relative to the Sun. As the Earth revolves around the Sun, the Hawaiian Islands are tilted toward the Sun during kau wela.



Kau Wela

The main Hawaiian Islands are located above the equator, south of the Tropic of Cancer where the Sun passes directly overhead twice each year, in late May and in late July. Because the Islands are not directly on the equator, there is a change in day length during the two seasons, with the shortest days occurring in December and the longest days in June.

In the summer months during the third quarter of the Moon after sunset, moi (Pacific threadfin) spawn. The timing of this spawn is tied to the survival of the eggs. During this time, zooplankton are plentiful as food for the hatched larvae, and being spawned at night, the eggs avoid most predators.

What other ways have you observed marine life responding to the kau wela season? For more information about spawning seasons and related Hawai'i fishing regulations see the Division of Aquatic Resources Website: http://www.hawaii.gov/dlnr/dar.

Student Challenge

Group B – Kau Wela

Develop a way to teach your classmates about:

- what causes kau wela; and
- at least one way that marine life responds to the season. Refer to the Hawaiian Moon calendar.

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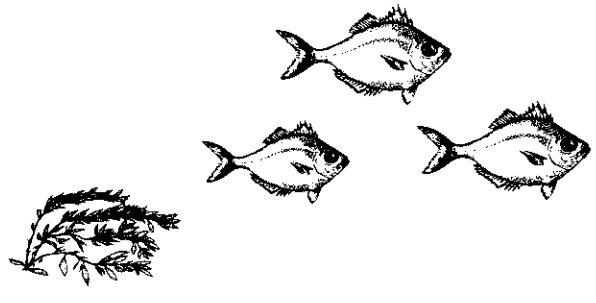
Student Activity Sheet — Fishing Tales

Name of person giving me information: _____

Do you know any of the kapu seasons for fishing?

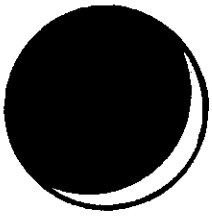
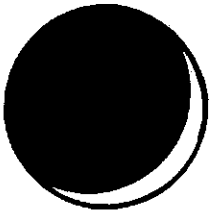
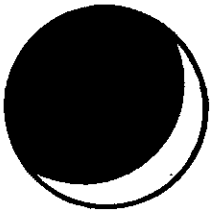
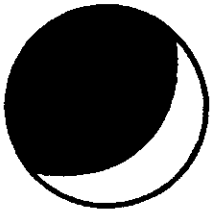
How do you use the tide in your fishing?

Have you ever used the phases of the Moon to help in fishing, diving, or other sea activities? Please explain.



My Name:: _____

Hawaiian Moon Calendar

Moon Phases	Name and Translation	Seasons and Tides	Fish Response to Tides
	**1. Hilo** The moon appears as a slender or twisted sliver (hilo). Night of the new Moon, appearing in the west.	Hoʻoilo Kāʻelo (January – February) Kai ʻume lua – (spring tide occurs)	Tide is down in the evening and rough during the day. Beach and night fishing are good. The nehu (anchovy fish) are plentiful during this Moon. Uhu, moana, weke and kūmū are also caught. Hīnālea and maomao spawn.
	**2. Hoaka** The Moon is clear and like an arch (crescent) with points curving up on both sides like horns. The ʻuhane (soul of the spirit) casts shadows.	Hoʻoilo Kaulua (February – March)	Torch fishing for kūmū and manini is good on the reef. It's low tide until the morning and the night is calm. One might hear someone say *"Mai hele maʻō e hoaka ai i ke kai o holo ka iʻa"* or "Don't go over there and cast your shadow in the sea lest the fish run away." Fishermen prepare nets for catching mālolo next month. Aku is caught for ceremonial purposes in preparation for Kū Kapu.
	**3. Kū Kahi** This is the first night of Kū Kapu. The men spend this and the next three nights in worship.		Any fishing is done during the day before the Sun stands overhead. Ocean currents will soon change. Torch fishing is good on the reef. Tides are low during the day with the reefs exposed. Reef fish such as kūmū, kākū and manini can be easily caught. This and the next three nights are not good for ocean fishing.
	**4. Kū Lua** This is the second night of Kū. Men worship for four nights.		Morning fishing is good at low tide. The water is low on the reefs and the beach is crowded with fishermen before "kau i ka lolo" (the sun rests on the brains). Kākū and manini are plentiful inside the reefs.

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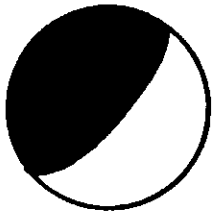
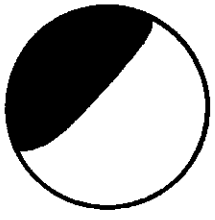
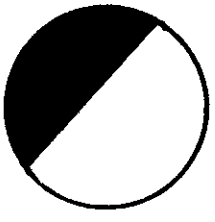
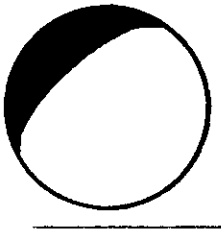
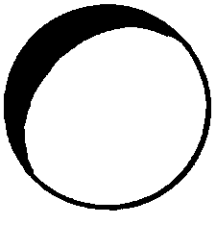
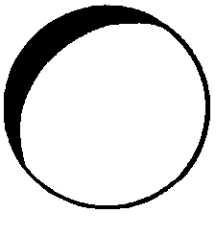
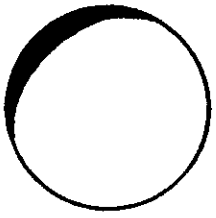
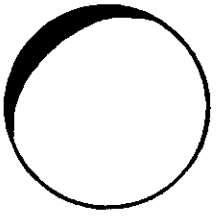
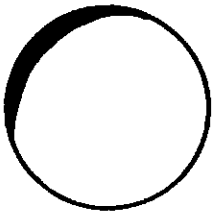
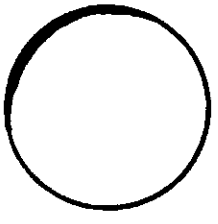
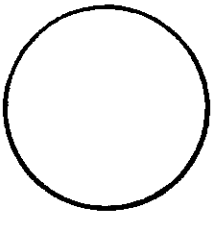
Hawaiian Moon Calendar

Moon Phases	Name and Translation	Seasons and Tides	Fish Response to Tides
	**5. Kū Kolu** This is the third night of Kū.	Ikuwa (October – November)	Fish are abundant during the dry season. It's low tide in the afternoon. During the Makahiki, men cannot fish in canoes. Women dive for sea urchin and gather limu and crab. ʻOʻopu, hinana, ʻōpae, and hīhīwai are gathered from freshwater streams.
	**6. Kū Pau** The last night of Kū	Kai mau mau (neap tide) begins.	It's fair fishing on the reef and low tide in the afternoon. Manini, weke, moana are caught. On this night, the fishermen say prayers for abundant fishing. Elaborate ceremonies take place in the heiau.
	**7. ʻOle Kū Kahi** The first of four nights of the ascending Moon This is an unproductive time, for ʻole means nothing.	Hoʻoilo Kāʻelo (January) Kai mau mau continues.	The tides are dangerous and high. During the wet season there are more storms, and the neap tide is almost two feet. Fishing is poor. The ʻāweoweo (bigeye fish) are plentiful. If the fisherman's wife and children do not behave, the fish will know it and run away.
	**8. ʻOle Kū Lua** Nothing will be had from the sea.	Kai mau mau ends.	Fishermen mend their gear. The room where the fishermen work on their nets is kapu to women and children.
	**9. ʻOle Kū Kolu** This is an unproductive time for ʻole means nothing.		Nets must never be walked over lest they become dirty and drive the fish away.
	**10. ʻOle Kū Pau** The last of four unproductive days		Fishermen mend gear or make nets. Women must never touch the fishermen's equipment.

Hawaiian Moon Calendar

Moon Phases	Name and Translation	Seasons and Tides	Fish Response to Tides
	**11. Huna (Hoʻāo)** The Moon is concealing its horns.	Hoʻoilo Welehu (November – December)	The turtle comes ashore to lay her eggs during the month of Kāʻelo. The tides are low. This is a good time for fishing. Fish can be found in their hiding holes. ʻŌʻio spawn.
	**12. Mohalu (Mōhaluhalu)** Mohalu means clearness; the clearness of the Moon. The night is sacred to Kāne.		Good fishermen do not fish on this day. They spend this night in prayer. Fish and limu are kapu, for this night is sacred to Kāne, the life-giver. *"Mōhaluhalu ka ʻai ʻana a ka iʻa"* – "The fish are opening [their mouths] to bite."
	**13. Hua** The Moon is rounded like an egg. The night brings fruitfulness.	Kai ʻume lua (spring tide) begins.	The tide goes out during the evening hours. Low tide prevails during the morning. The smart fishermen go with their canoes to do deep-sea fishing. Offerings are made to akua to increase fish (hoʻoulu iʻa).
	**14. Akua** The Moon has become a god (akua). It is on this night that the great round Moon becomes separated from Earth.	Kai ʻume lua continues.	Fishing is good at sea in the daytime, but the weather is changeable, and the sea might be rough or it might be calm. The night is kapu and spent in prayer. Night Marchers may be seen.
	**15. Hoku** The Moon is as bright as a star. Hoku is the fullest Moon of the month.	Kau Wela Welo (April – May) Kai ʻume lua continues.	ʻUpāpalu (cardinal fish) are seen at night. During the night of Hoku the tide is indefinite with high waves. The ʻupāpalu come to surface in great numbers to feed. Akule, weke and moi are caught. Manini spawn.

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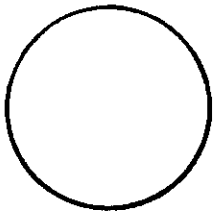
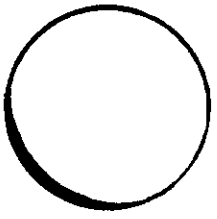
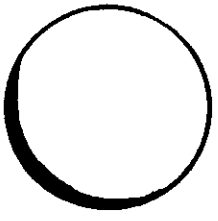
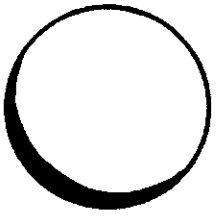
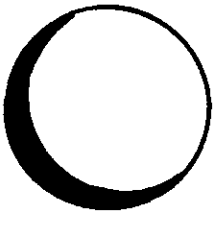
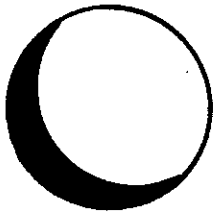
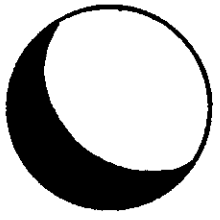
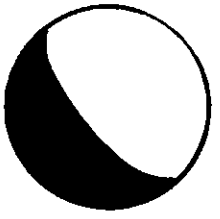
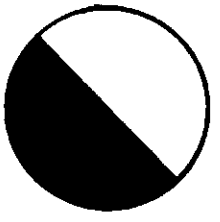
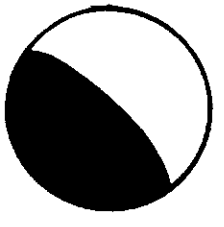
Hawaiian Moon Calendar

Moon Phases	Name and Translation	Seasons and Tides	Fish Response to Tides
	**16. Māhealani** An additonal night of full Moon. Symbolizes good luck and fertility.	Hoʻoilo Kaʻelo (January – February) Kai ʻume lua (spring tide) continues.	Lobsters come ashore. Mullet make their first run about the Islands. Ōiʻo, āholehole, kala (at their best) and uouoa (false mullet) are plentiful. If the head of the uouoa is eaten, sleeplessness and nightmares can occur.
	**17. Kū Lua** This is the second night after the full Moon. The Moon sets after sunrise.	Kai ʻume lua continues.	A high tide of the evening hours recedes during the night. The incoming tide gathers up the sand and restores it to the beaches bringing with the sand much limu.
	**18. Lāʻau Kūkahi** Lāʻau days favor growth in plants and trees; also a good time to use medicine. The first of three lāʻau days	Kau Wela Ikiiki (May – June) Kai ʻume lua ends.	Ailing fishermen might go to the kauka lapaʻau (doctor) to be healed. If the fisherman leaves bait at home, no one can eat it, no matter how hungry they are.
	**19. Lāʻau Kūlua** The second lāʻau night	Hoʻoilo Welo (April – May)	Fishing is fair. Fishing is best at sea. Fishing gear is stored in high places in the hale to keep it from being soiled by children and animals. Fishermen prepare their nets for catching ʻōpelu.
	**20. Lāʻau Pau** Lāʻau nights are finished.	Kau Wela Ikiiki (May – June)	Seas become rough. This is the last day to take advantage of using medicines for healing. ʻŌpelu start to run.

Hawaiian Moon Calendar

Moon Phases	Name and Translation	Seasons and Tides	Fish Response to Tides
	**21. 'Ole Kū Kahi** This is the first of three nights of the descending Moon.		The three days of 'Ole are a signal for rough seas and poor fishing.
	**22. 'Ole Kū Lua** The second night of the descending Moon	Ho'oilo Welehu – Kā'elo (December – January)	'Ole is the name of the wind that blows during the phases of the first quarter and third quarter.
	**23. 'Ole Pau** 'Ole nights are finished.		When the fisherman went fishing, no one was allowed to ask him where he was going, and he would never say he was going fishing. Hawaiians believed that the fish have ears and can overhear conversations.
	**24. Kāloa Kūkahi** First night of Kāloa Kapu for the deity Kanaloa	Kau Wela Mahoe Mua (August – September) Kai mau mau (neap tide) begins.	The seas are still rough. The women can gather limpets and limu. Women go fishing along the shore using their hands (hahamau). They feel along rocky ledges and boulders and coral reefs where the surf breaks. They seize wrasse, cowries, 'opihi, and he'epali (small rock octopus).
	**25. Kāloa Kū Lua** Second night of Kāloa Kapu	Kai mau mau continues.	The seas begin to calm and fishing is good on the reefs and at sea. The women gather shellfish and limu and wade into the tidal waters and catch fish with their hands or baskets.

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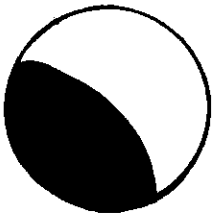
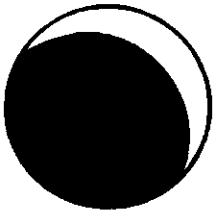
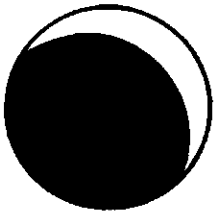
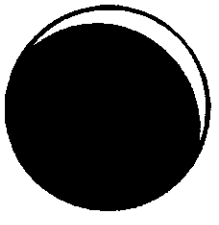
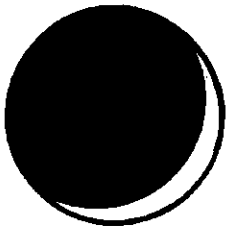
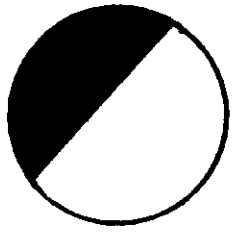
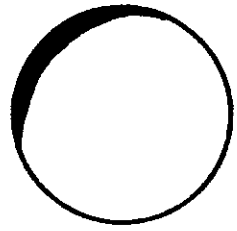
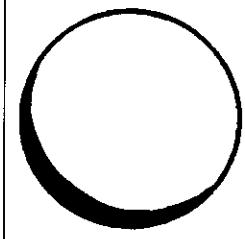
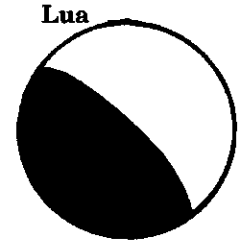
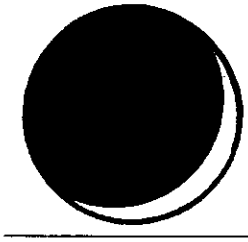
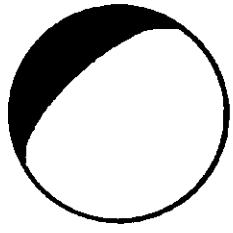
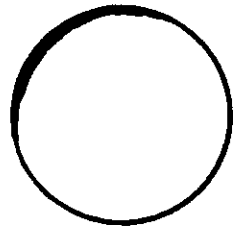
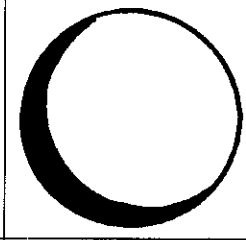
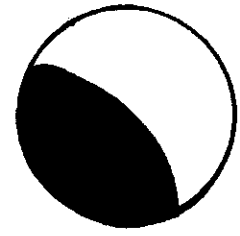
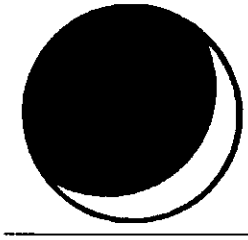
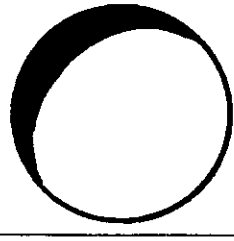
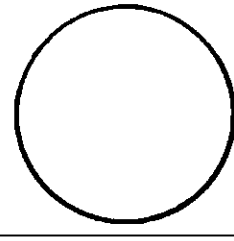
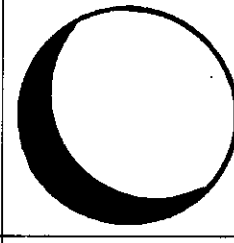
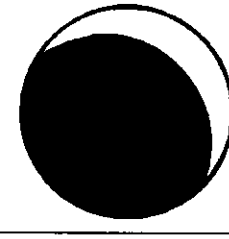
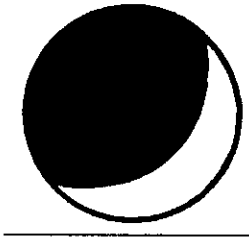
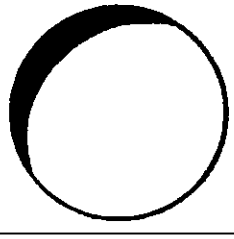
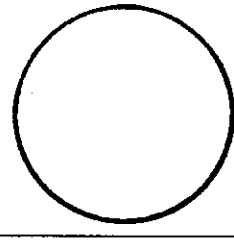
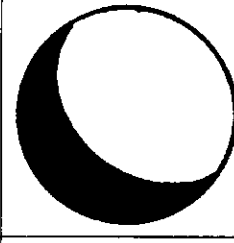
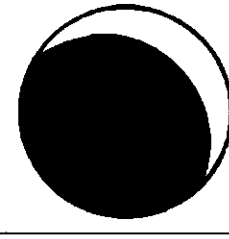
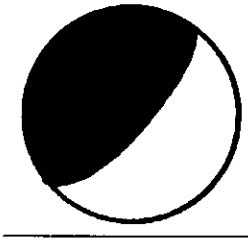
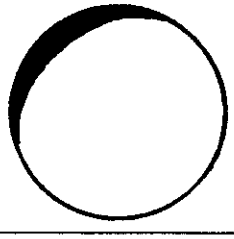
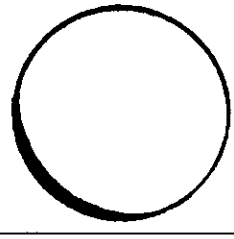
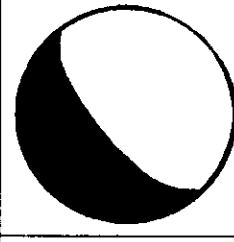
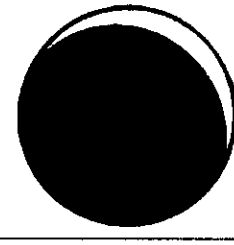
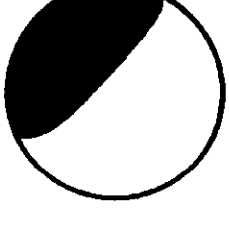
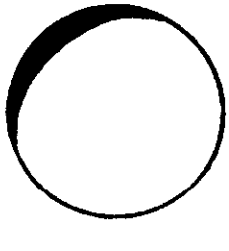
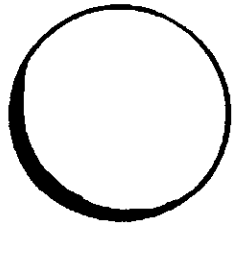
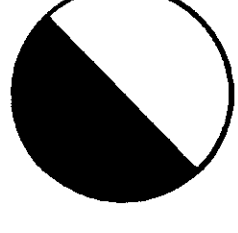
Hawaiian Moon Calendar

Moon Phases	Name and Translation	Seasons and Tides	Fish Response to Tides
	**26. Kāloa Pau** The night of Kanaloa ends.	Kai mau mau ends.	A good day for reef fishing and hunting for shellfish. Good time to gather limu.
	**27. Kāne** Deity of all living things; the night is kapu to Kāne. No fires can be made. Sound is forbidden.		No fishing is allowed. Families who have sharks as 'aumakua might choose this day to transfigure their recently deceased relative into sharks. Night Marchers may be seen. The Moon rises at the dawn of day.
	**28. Lono** Deity of fertility The night is kapu to Lono. No noises can be made at all.		Excellent day and night for pole fishing, diving, and torching. Fishermen pray for good fishing and good spawning of fish. If weke pueo are eaten at night, nightmares can occur. If the fish are caught near Lāna'i, the nightmares are worse.
	**29. Mauli** The last breath The feeble Moon rises a little before sunrise and is seen for the last time.		Good day for reef fishing. Good night for ulua fishing. In the afternoon the fishermen set sail, arriving at the fishing ground in the evening. Mālolo and lobster are used for bait.
	30. Muku Finished or dying, cut short The utterly dark night has no Moon at all.		Good day for fishing offshore and on the reefs. The tide brings back the sand to the beaches. At night, weke, kūmū, moana, and many other reef fishes can be caught easily by spear because they are sleeping.

Hawaiian Moon Phases

1. Hilo 	7. ʻOle Kū Kahi 	13. Hua 	19. Lāʻau Kūlua 	25. Kāloa Kū Lua 
2. Hoaka 	8. ʻOle Kū Lua 	14. Akua 	20. Lāʻau Pau 	26. Kāloa Pau 
3. Kū Kahi 	9. ʻOle Kū Kolu 	15. Hoku 	21. ʻOle Kū Kahi 	27. Kāne 
4. Kū Lua 	10. ʻOle Kū Pau 	16. Māhealani 	22. ʻOle Kū Lua 	28. Lono 
5. Kū Kolu 	11. Huna (Hoʻāo) 	17. Kū Lua 	23. ʻOle Pau 	29. Mauli 
6. Kū Pau 	12. Mohalu (Mōhaluhalu) 	18. Lāʻau Kūkahi 	24. Kāloa Kūkahi 	30. Muku

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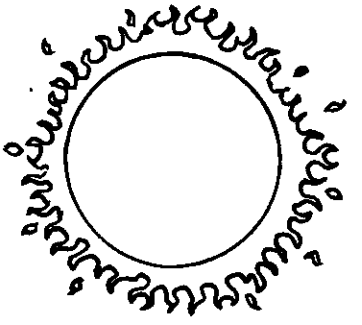
Kai Moku:

The Turn of the Tide

- How do the tides affect the growth of phytoplankton and the level of dissolved oxygen in a fishpond?
- What other factors affect the growth of phytoplankton?

Hawai'i DOE Content Standards



Science: Doing Scientific Inquiry

- Students develop questions and hypotheses that can be answered through scientific investigations.

Science: Cycle of Matter and Energy Flow

- Explain how plants use the energy from sunlight and matter from the atmosphere to make food.

Grades 6 – 8 Performance Indicators

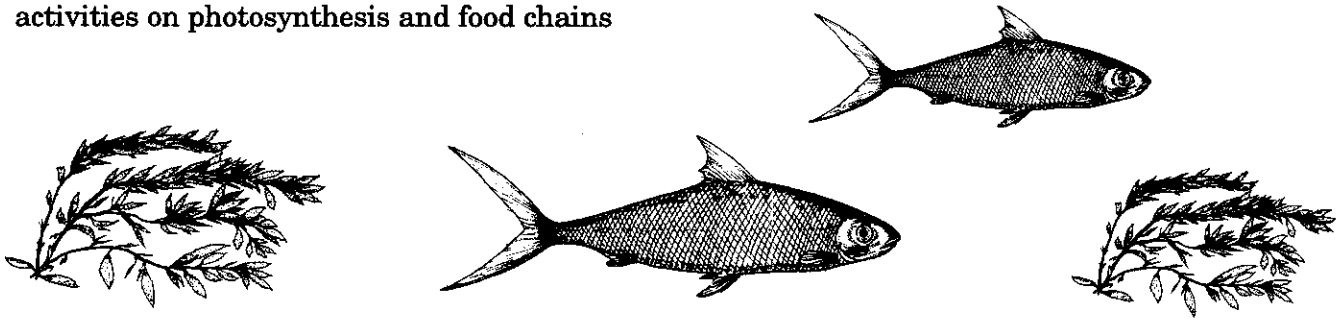
- Develop hypotheses that can be answered through investigations.
- Describe clearly a plan to answer the question or test the hypothesis.
- Collect and organize accurate data and interpret data to explain clearly what the data suggests or infers.
- Draw logical conclusions and explanations showing the link between evidence and results of the investigation.
- Summarize major findings and connect them with the "real world." Reflect on new evidence from other valid sources and revise conclusion and explanation as needed. Include recommendations for improving the investigation.
- Explain how all living things use food energy and matter from the atmosphere to provide energy for life.
- Explain the cycle of matter and energy in photosynthesis and respiration.

Key Concepts

- Phytoplankton uses energy from the sun and nutrients from fish wastes to make food.
- Tidal circulation helps prevent accumulation of wastes that leads to stagnation and loss of the dissolved oxygen needed by fish.

Suggested Prerequisites

activities on photosynthesis and food chains



Activity at a Glance

Students develop hypotheses about how the tides affect the growth of phytoplankton and levels of dissolved oxygen in a fishpond and then conduct experiments to test their hypotheses.

Skills

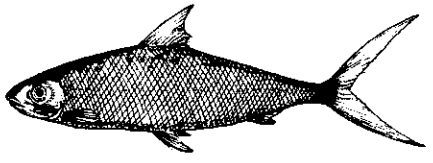
predicting, reasoning, measuring, recording, writing

Assessment

Students:
- Write a scientific report describing the hypothesis, prediction, methodology and results.
- Diagram how phytoplankton uses energy from the sun and nutrients from fish wastes to make food.

Time

2 class periods plus partial class periods for 7 - 10 days

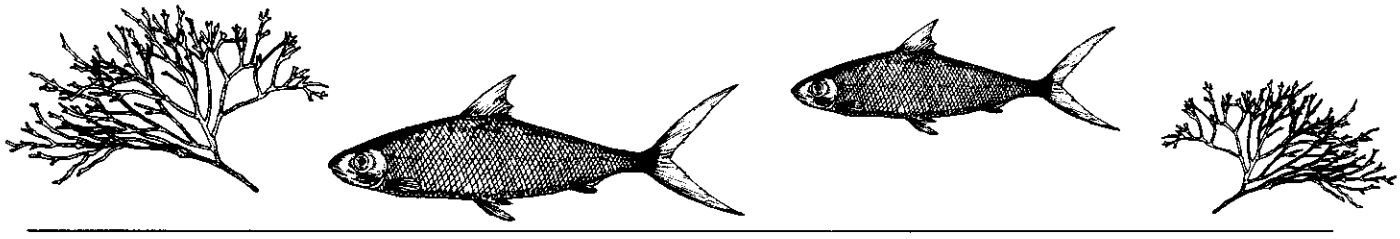


Skills

hypothesizing, analyzing, writing

Vocabulary

phytoplankton – the tiny plant organisms in plankton
dissolved oxygen – molecules of atmospheric oxygen near the water surface that become mixed in and stay dissolved among the water molecules, expresed in milligrams per liter (mg/l) or parts per million (ppm)
nutrient – any matter that, taken into a living organism serves to sustain it, promote growth, replace loss, and provide energy
hypothesis – assumption or guess
stagnation – to become stale or foul from standing, as a pool of water
scientific method – a process to generate new knowledge that involves asking a question, stating a hypothesis, planning and conducting an investigation to test the hypothesis, gathering data, analyzing data, communicating findings, and defending or revising conclusions based on evidence
zooplankton – the tiny animal organisms in plankton
photosynthesis – the production of carbohydrates using sunlight energy to combine carbon dioxide and water in the presence of chlorophyll
siltation – to become filled or choked with silt
decomposition – the process of organic and inorganic materials being broken down into smaller fragments or simpler compounds
silt – earthy matter or fine sand carried by moving or running water and deposited as sediment



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Materials

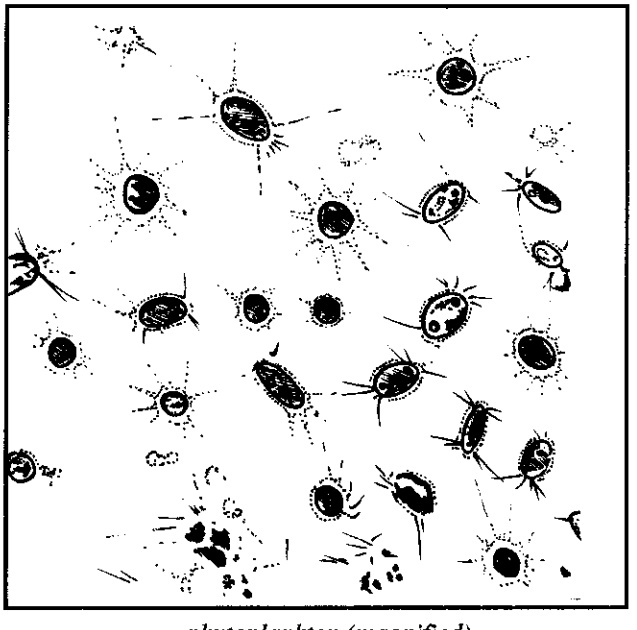
Provided:
- student data sheet
- vocabulary cards

Needed:
- 2 10-gal. aquaria or any large clear containers (see Advance Preparation)
- 20 - 30 guppies
- fish food
- small fish net for use in aquaria
- pitcher (for pouring water)
- water test kit for dissolved oxygen
- water hardness test kit (optional: available from pet stores)
- microscopes (optional)

Advance Preparation

Place the two aquaria near a window and fill them with fresh water up to the half-way point. Add half of the guppies to each tank. Optional: collect some rainwater for students to compare with tap water in a test of water hardness (mineral content). Note: water hardness, or the amount of calcium carbonate ($CaCO_3$) in tap water, ranges between 80 and 120 ppm (parts per million) and rainwater contains around 10 to 20 ppm ($CaCO_3$). Test kits for dissolved oxygen and hardness are available from a variety of sources including LaMotte (www.lamotte.com/) and Hach (www.hach.com/); for additional information see Resources in the Appendices.

What to expect: If the aquaria are placed where there is ample sunlight (near a window) and the fish are fed on a daily basis with fish food (but not overfed, where leftover food remains on the bottom of the aquaria), in a few days the water in the aquarium that is not replenished by "tides" will begin to get cloudy and murky. After a week to ten days, the water will start to turn green. Small microscopic algal cells (phytoplankton) have begun to grow in response to the nutrients (fertilizer) in the water as a result of the food that has been fed to the fish. Fish food is being used to make the fish grow, and in the process, waste products (feces and urine) serve as fertilizer to the phytoplankton. In the fish tank with the water replenished by "tides," the build-up of phytoplankton will be prevented by the replenishment of water twice per day. Note: the individual phytoplankton cells can only be seen under a compound microscope at high magnification.



phytoplankton (magnified)

Background

The shallow depth (two to three feet) of Hawaiian fishponds provides the optimal light conditions for plankton and limu growth. Natural fertilizers such as nitrogen, come from marine animal wastes in the pond. Minerals such as phosphate and calcium, come from incoming streams, and to a lesser degree from the tides, which also contribute salt (NaCl, or sodium and chloride). The fishpond mākāhā (sluice grate) and pond walls were designed to allow water circulation from the tides. They help control water circulation and prevent stagnation and the build-up of sediments, which is critical to maintaining a healthy, balanced fishpond ecosystem.

Natural Fertilizers

Limu and microscopic plankton provide food for the fish grown in the pond—the 'ama'ama (striped mullet) and awa (milkfish). The kia'i loko (fishpond caretaker) guarded and cared for the pond, just as a farmer tends his pastures for cattle. In addition to the nutrients that occur naturally in the pond, the kia'i sometimes "fertilized" the pond by adding additional food for fish, such as kalo (taro), 'ulu (breadfruit), uala (sweet potato), and mussels and stones with limu.

kia'i loko
(fishpond caretaker)

Fishpond Maintenance

To maintain the pond, the kia'i loko kept the pond walls intact and checked for excessive limu growth and build-up of pond sediments. If the mats of limu in the pond grew too thick, the limu was thinned by hand. This helped to prevent the depletion of dissolved oxygen in the pond which occurs when large amounts of limu decays. And when the bottom sediments of soil and decayed organic matter got too thick, the commoners were called upon to help clear this layer of sediment. The sediments were stirred up and the pond was flushed as the incoming tide circulated in the pond through the mākāhā and the outgoing tide washed some of the sediment out to sea. Another way of preventing siltation may have been to divert some of the stream water that carries heavy loads of sediments down to the pond during the rainy season. To avoid pollution from human wastes and to protect water quality, Hawaiians located their homes away from the fishponds. These practices helped to prevent stagnation and maintain the level of dissolved oxygen needed by fish.

The ancient 'auwai kai with mākāhā did not have the movable water gates that appeared at the turn of the twentieth century. So the location of the different mākāhā in the early ponds was critical to water circulation. In the early 1900s, the Chinese and Japanese introduced movable water gates on the ocean side of the mākāhā that allowed them to cut down the rate of water exchange and manipulate the phytoplankton density by closing the gates. As with an aquarium of guppies that lacks filtration, the water in the fishponds will begin to turn green after a few days, when the phytoplankton grow due to the build-up of nutrients (excrement/fertilizer).

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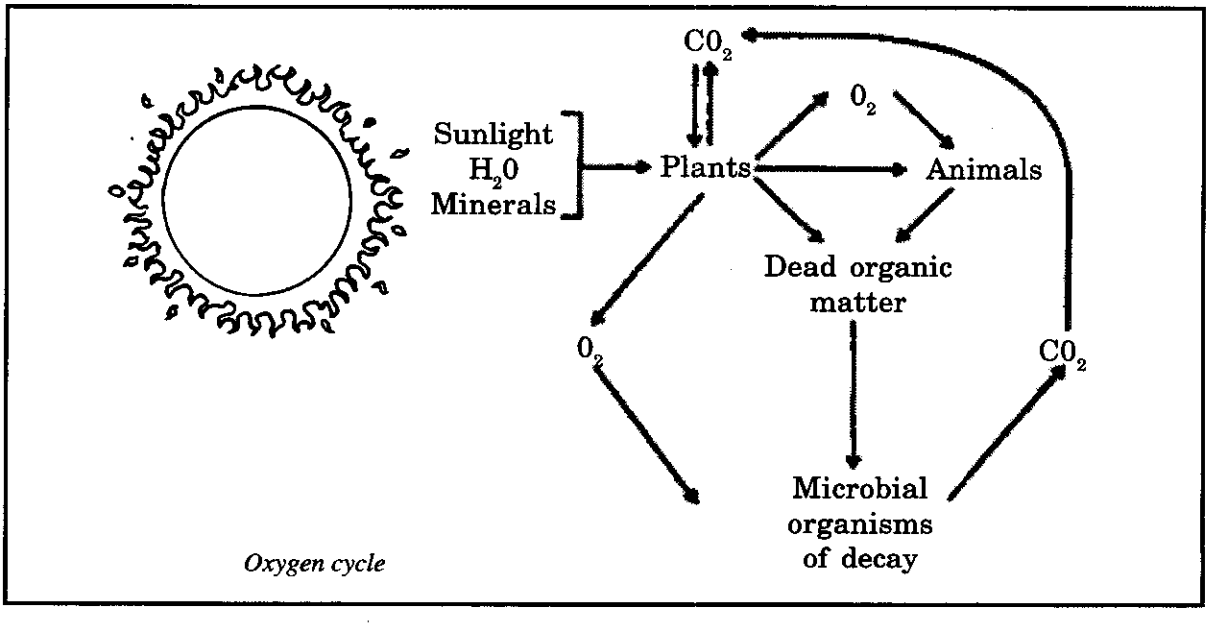
Some Factors Affecting Fishpond Productivity

- *water depth*: ponds 2 to 3 feet deep allow sunlight penetration that favors the growth of phytoplankton, zooplankton and limu.

- *salinity*: The salinity (amount of mineral salts dissolved in the water) fluctuates with tides, depth, and proximity to freshwater streams and springs. Apple and Kikuchi (1975) reported a range of salinity in fishponds they studied to be from 2 to 32 ppt (parts per thousand).

- *circulation*: water circulates with the incoming tide to wash sediments out to sea and prevent stagnation and accumulation of bottom sediments. Bottom sediments are composed of silt and a layer of decomposing organic matter—partly digested limu eaten by fish and other animals. These sediments appear as black mud that smells like rotten eggs since these decomposing sediments take dissolved oxygen out of the water and produce hydrogen sulfide. In areas of the pond with this decomposing layer, Apple and Kikuchi (1975) report that if the hydrogen sulfide rises above 3 ppm (parts per million) it is considered injurious to young fish.

- *dissolved oxygen*: Apple and Kikuchi (1975) tested dissolved oxygen levels in 18 fishponds and found a range from 6 to 13 ppm. The mean level of 7.9 ppm indicated high levels of photosynthetic activity in the ponds. Like temperature, the level of dissolved oxygen will vary throughout the day with changes in temperature, light and cloud cover. When there are excess nutrients and the phytoplankton concentration is high, a potentially lethal situation can occur, especially during the night, when there is no sunlight and no wind or circulation. During the evening the phytoplankton that were making oxygen during the day stop as the photosynthetic "machinery" shuts down. Because the phytoplankton are also alive and need oxygen to live, they begin to take up oxygen along with the other living organisms in the pond. And if the phytoplankton level becomes too high and there is a large amount of fish, there will be almost no oxygen left in the water. This causes the fish to come to the surface of the water to breathe or gasp for air. Usually, in Hawai'i, we are blessed with the trade winds, but during times of Kona winds, when there is almost no breeze and the water is still, catastrophic overnight fish kills in fishponds have been recorded due to the lack of oxygen in the water.



Oxygen cycle

- *turbidity* (water clarity): the clarity of the water is related to the presence of mineral or organic particles suspended in water. Clear water allows sunlight to penetrate to the bottom and warm the cooler water. Cloudy water as a result of high turbidity reduces this sunlight and may reduce the growth rate of the limu, phytoplankton and fish.

- *pH:* the pH, (degree of alkalinity or acidity) of the water is measured on a scale of 1 to 14, with 1 being most acidic, and 14 being most alkaline. Due to the presence of minerals in Hawaiian waters, the pH of brackish water fishponds is generally alkaline (8.0 – 9.0).

- *water temperature:* the temperature varies seasonally and throughout the day. In a healthy pond, the temperature is relatively even in the water column and ranges from 64 to 88 degrees Fahrenheit.

- *nutrient composition*: the nutrients from the wastes of aquatic organisms provide natural fertilizer for the phytoplankton and limu. If too many nutrients are added (chemical fertilizers or pollutants) algal blooms may form. These blooms can decrease clarity and light penetration, which causes limu to die. As the limu decompose, dissolved oxygen is depleted. Decreased dissolved oxygen then adversely affects the fish population. However, if algal blooms are rich in diatoms they can enhance the natural productivity of the pond. The diatoms in these blooms are nutritious and allow sunlight to warm the lower water layer and enhance natural productivity. According to Carol Wyban (1992), "Chinese aquaculturists manage their water quality by color. Diatom-rich waters are a golden-brown color."

Teaching Suggestions

1. Gather students around the aquaria and ask them to imagine that these are fishponds. Discuss what makes the fishpond work.

   Discussion Questions

   - If the guppies represent the 'ama'ama or the awa, what conditions do they need for survival?
     (food—limu and plankton, and oxygen)

   - What environmental conditions do limu and plankton need in order to grow? *(sunlight, water, nutrients – review the process of photosynthesis.)*

   - Where do the nutrients come from?
     (*decay of dead plants and animals in the pond, and animal wastes and minerals washed in from streams and tides*)

2. To reinforce students' knowledge of the scientific terms, distribute the vocabulary cards and have them play a matching game. Give half of the class cards with just the terms on them and the other half of the class the definitions. Challenge students to find the classmate that has the matching card. Then have pairs of students share the terms and definitions with their classmates.

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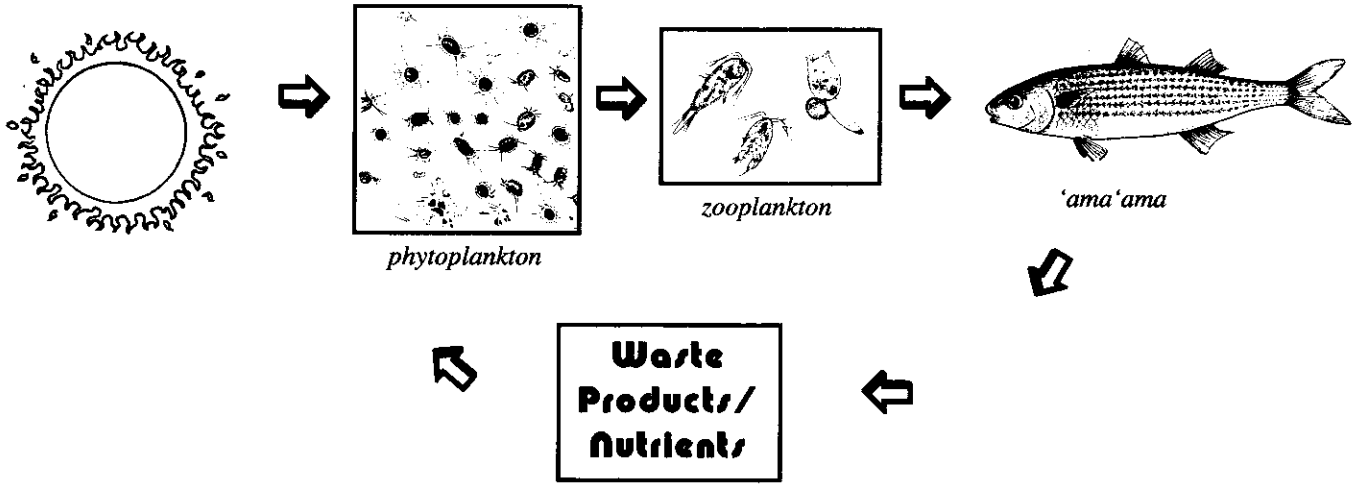
3. Review the basic fishpond food chain and nutrient cycling by drawing a diagram on the board.



4. Diagram the cycle of oxygen in the pond (see diagram in Background). Ask students to predict when the oxygen level would be highest in the pond and explain their ideas.

5. Explain that your classroom "fishponds" are going to be in a race to see which one grows the most phytoplankton and which has the most dissolved oxygen. For one week, pond 1 will have "tides." Pond 2 will be the control and will have no tides. Twice each day, the tide will turn. To simulate this, students will remove one-third of the water from pond 1 (low tide) and then add the same amount of clean water (high tide). Both ponds will receive the same amount of fish food twice per day (about 1/8 tsp.).

6. Ask students to cast written votes for the pond that they believe will grow the most phytoplankton and have the most dissolved oxygen. Collect their ballots and tally their votes.

7. Distribute the student data sheets and ask students to write up the research question, the variables, the method, and their hypotheses. Review students' responses and discuss carrying out the method. Assign different groups of students to care for the ponds during each day of the experiment.

8. All students should record the amount of nutrients added each day, test the dissolved oxygen levels, and make written notes of their daily observations of the "ponds."

9. At the end of the experiment period (7 - 10 days), have students decide which pond is greener (indicating the level of phytoplankton build-up). If microscopes are available, view the phytoplankton under high magnification.

10. Have students take a final measurement of the level of dissolved oxygen in the "ponds." Declare the winning pond.

11. Ask each student to complete the assessment activity and conduct a class discussion.

Discussion Questions

- What appear to be the most important environmental conditions for growing phytoplankton?
  (sunlight, nutrients)
- Which pond has a higher level of dissolved oxygen? Why?
  (The pond with "tides" may have more dissolved oxygen since there is less phytoplankton buildup and decomposition, which uses up oxygen.)
- What are the shortcomings of this experiment in actually simulating the tides in a fishpond?
  (The water in the experiment is tap water and does not contain the minerals in seawater. The tank doesn't have the rock walls or mākāhā of a fishpond and water is removed from the experiment instead of flowing, mixing and recirculating as it does in the pond.)
- What can you apply from this experiment to the question of how the tides in the fishpond affect the growth of phytoplankton and the level of dissolved oxygen in the pond?
- How does the amount of phytoplankton in a pond relate to the amount of fish that can be raised?
  (In a healthy pond where sunlight penetrates to the bottom and where the water is circulating with the tides, there is sufficient phytoplankton for fish, but not so much that the water becomes stagnant.)
- What's the critical missing link in our simplified "pond" food chain?
  (Zooplankton such as rotifers or daphnia will eat the phytoplankton and help to control their growth.)
- How did the early Hawaiians design their ponds to promote the best conditions for limu and fish growth?
  (mākāhā for circulation of water; stream inputs)

Adaptations/Extensions

- Add rotifers or daphnia (zooplankton) to the "ponds" and see how long it takes for the water to become clear again. View the zooplankton under a microscope and have students sketch them.
- Have students conduct research to learn more about cultural uses of limu (seaweed). Hawaiians identified more than 60 kinds of limu that were edible. Limu pahe'e (slippery) is seasonal; it appears in winter on rocks in areas of heavy surf where fresh water mixes with the sea. During drier months, it takes a microscopic form and is not visible. This rare limu was reserved for ali'i and kapu to commoners. Today related species of seaweed are cultivated in northern Asia and packaged as nori. See the pond life cards in the Appendices for some additional information on limu.

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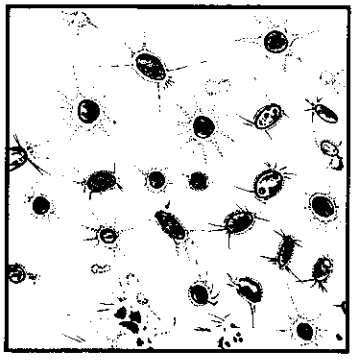
Student Data Sheet

Name_____

Research Question: What are we trying to find out?



phytoplankton magnified 1000x

Variables: What things might affect the growth rate of phytoplankton? What might affect the level of dissolved oxygen?

Hypothesis: What do we think is the answer to our research question?

Method: How will we test our hypothesis?

Observations: Record your daily observations on the other side of this page. Be sure to note anything that is added to your "ponds" and the exact amount added.

Conclusion: What did you learn? Write up the results of this experiment on a separate piece of paper. Explain how the phytoplankton grew and any differences in the two "ponds."

Student Data Sheet (continued)

Name _____

Date	Observations

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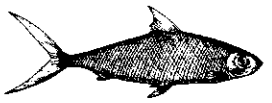

Vocabulary Cards (front)

phytoplankton	**zooplankton**
nutrients	**photosynthesis**
dissolved oxygen	**hypothesis**
stagnation	**siltation**
decomposition	**scientific method**

Vocabulary Cards (back)

the tiny animal organisms in plankton

the tiny plant organisms in plankton

the production of carbohydrates using sunlight energy to combine carbon dioxide and water in the presence of chlorophyll

any matter that, taken into a living organism, sustains it, promotes growth, replaces loss and provides energy

assumption or guess

oxygen dissolved in water

to become filled or choked with silt

to become stale or foul from standing, as a pool of water

a process to generate new knowledge that involves asking a question, stating a hypothesis, planning and conducting an investigation to test the hypothesis, gathering data, analyzing data, communicating findings, and defending or revising conclusions based on evidence

the process of organic and inorganic materials being broken down into smaller fragments or simpler compounds

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The Hawaiian Calendar

It can sometimes become quite confusing to understand the traditional Hawaiian view of what we call a calendar. The most obvious example of this is the celebration of the New Year, the Makahiki. The beginning of the year is celebrated in a different month on each of the four major islands. This is because a separate calendar was kept for each island. This included lunar, solar, and star calendars. The New Year, Makahiki, began anywhere from October to January, depending on the various island systems used. This happens approximately on November 20 in our current era, in the month of Makali'i. One thousand years ago this event would have occurred in October and even as early as September (Magic Island Calendar, 1998).

Since the Hawaiians did not develop a written version of their language until the 1830s, the tracking of time and all other events was done from memory through a tradition of prayers and chants that were passed orally from generation to generation. A system of stone markers was used on the island of Hawai'i which designated the positions of the sun during the year. Stones were "used to track the sun's limits north and south in order to mark the seasons in addition to use of the seasonal migrations of the plover on their course north and south during the year" (Richards, 1999).

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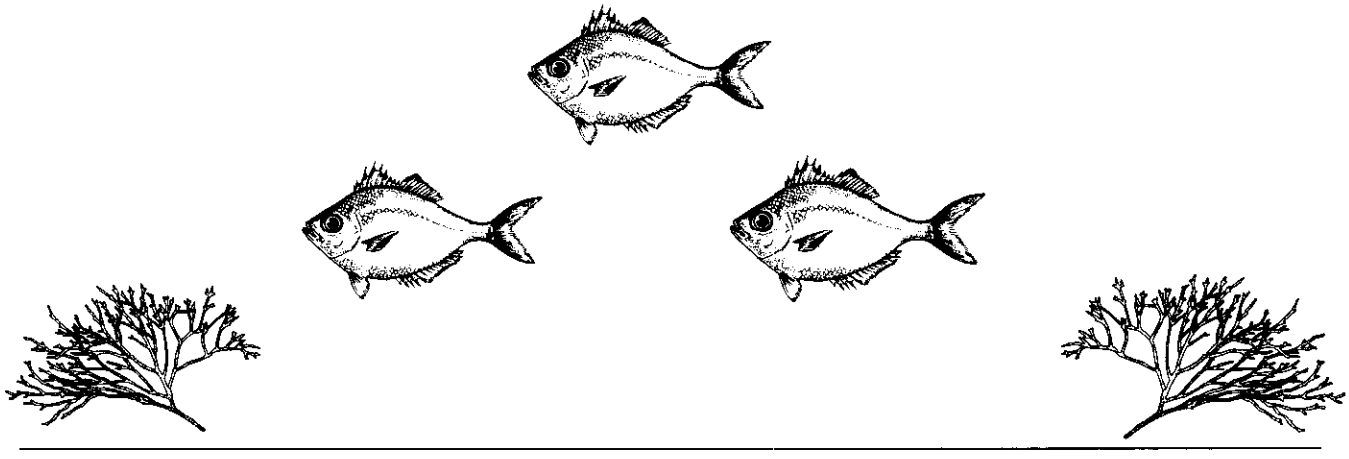

Hawaiian Names for Months by Island

Month	Hawai'i	Moloka'i	O'ahu	Kaua'i	Maui
November	Welehu	Hilina Mā	Kā'elo	Hilina Mā	'Ikuwā
December	Makali'i	Welehu	Kaulua	Hilina Ehu	Welehu
January	Kā'elo	'Ikuwā	Nana	Hilioloho	Makali'i
February	Kaulua	Hinaia'ele'ele	Welo	Hilionalu	Kā'elo
March	Nana	Welo	Ikiiki	Hulipau	Kaulua
April	Welo	Makali'i	Ka'aōna	'Ikuwā	Nana
May	Ikiiki	Kā'elo	Hinaia'ele'ele	Welehu	Welo
June	Ka'aōna	Kaulua	Māhoe Mua	Kā'elo	Ikiiki
July	Hinaia'ele'ele	Nana	Māhoe Hope	Ikiiki	Ka'aōna
August	Māhoe Mua	Ikiiki	'Ikuwā	Hinaia'ele'ele	Hinaia'ele'ele
September	Māhoe Hope	Ka'aōna	Welehu	Māhoe Mua	Hilin Ehu
October	'Ikuwā	Hilina Mā	Makali'i	Māhoe Hope	Hilina Mā

Source: Malo, David. 1951. *Hawaiian Antiquities.* Bernice P. Bishop Museum, Spec. Pub. 2, Second Edition, Bishop Museum. Honolulu, HI.

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Kā'elo / January

O Kā'elo ka malama, pulu ke aho a ka lawai'a.
(January is the month when the fisherman's lines are wet.)

This is a good time for fishing for bottom fish like 'ōpakapaka (pink snapper) and nearer shore fishing is good for 'ō'io (bonefish) and ulua (trevally). It's also a time to look for the constellation of Orion, which is now visible in the eastern evening sky.

Puleileho ke kai o Kā'elo.
(A rough sea in the month of January.)

Limu kala washes ashore in the heavy surf during this time of year and it can be gathered along the beach. Fish are drawn to the limu so this can be a good time to fish.

Conservation Notes:

Kaulua / February

Pōhai ka manu maluna, he i'a ko lolo.
(When the birds circle above, there are fish below.)

This is the time when the four-month Makahiki season came to a close in old Hawai'i. At this time, the kapu began for catching 'ōpelu (mackerel scad), and the kapu on catching aku (bonito) was lifted. Hawaiians located schools of aku by watching where the seabirds like the noio (Hawaiian noddy tern) would gather. They lured the fish with nehu (native anchovy).

Conservation Notes:

Calendar Cards

Nana / March

O Nana ka mālama; momona ka pāpa'i.
(March is the month; the crabs are fat.)

During this time female crabs are carrying eggs on the underside of their abdomens. If you catch a crab carrying her eggs, be sure to carefully release her so that the eggs can hatch and the young can grow. Pua 'ama 'ama (baby mullet) begin showing up along the shores of estuaries during this time. Look for schools with hundreds or thousands of these tiny fish near shore. This is a good time to stock fishponds with 'ama'ama. This is also the time when the kapu on catching 'ama'ama was lifted in old Hawai'i.

This is the time of an equinox—the sun rises due east and sets due west.

Conservation Notes:

Welo / April

Ka i'a ho'āla i ka pō, wai lama i ke ahi.
(The fish that wakes people up at night and causes a glowing of torches over the water.)

Swarms of mālolo (flying fish) appear at this time of year. Look for them skimming the surface of the water and watch for the lights of the fishers at night. This is the month when the moi (Pacific threadfin) begins to spawn, usually during the third quarter of the moon. This is the peak nesting season for 'alae ke'oke'o (Hawaiian coot). Native coots build a floating nest platform near the edge of a pond. These endangered birds lay five to six eggs in a nest cup several inches above water level.

The constellation Leo is in the eastern sky in the evening.

Conservation Notes:

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Ikiiki / May

Ka iʻa hoʻopā ʻili kanaka o Waimea.
(The fish of Waimea that touch the skins of people.)

Young ʻoʻopu nākea (hinana) move from the sea up into streams usually between December and July. At Waimea on Kauaʻi, there were so many hinana at this time that one couldn't go into the water without rubbing against the fish. Naiʻa (spinner dolphins) remain near shore at this time since food is plentiful. These naiʻa were ʻaumakua (personal gods) for some families. If a person jumped to conclusions, another might say, "He naiʻa, he iʻa lele!" (It is a dolphin, a leaping fish!)

The star Hōkūleʻa (Arcturus) is visible in the east-northeast evening sky.

Conservation Notes:

Kaʻaōna / June

Ola aku la ka ʻāina kaha, ua pua ka lehua i kai.
(Life has come to the kaha lands, for the lehua blooms are seen at sea.)

This is the time when ʻōhiʻa lehua trees blooming on shore were visible from canoes off Kekaha on the Kona coast of the island of Hawaiʻi. This was the time of deep-sea fishing for aku (bonito or skipjack tuna), which Hawaiians called "pua ka lehua" (flowers of the lehua). They didn't want to call the aku by name since this might scare the fish away.

Hua ka ʻulu ku mai ka heʻe.
(When the breadfruit is ripe, the squid comes in.)

ʻUlu (breadfruit) bears fruit most heavily at this time of the year. This is a reminder that (heʻe) squid are abundant now too. The orange-backed flying squid is more plentiful at this time and fishers would have been able to catch it where there are sudden drop-offs to deeper waters.

Conservation Notes:

Calendar Cards

Hinaia'ele'ele /July

Pala ka hala, momona ka hā'uke'uke.
(When the pandanus fruit ripens, the sea urchin is fat.)

When the orange fruit of the hala tree is ripe, sea urchins are fat with eggs. This type of sea urchin has blunt, short spines and lives on rocks in inshore waters. The ripe hala fruit is also a cue to search for uhu (parrot fish) that feed on the sea urchins. If you catch an uhu under 14 inches long, let it go so it can grow to reproduce. Pua awa (milkfish fry) begin showing up near shore in sheltered areas at this time of year. This is a primary time to stock fishponds with awa. Pua 'ō'io, (bonefish fry) make their appearance at the same time as the milkfish fry and are very similar in appearance. Both fish are prized for food.

Look for Manaiakalani (Māui's fishhook or Scorpio) in the southeast evening sky.

Conservation Notes:

Māhoe Mua /August

Ehuehu kai, oho ka moi.
(Where the sea broils, there the moi fish dwell.)

Large schools of juvenile fish including halalū (akule), moi li'i (immature moi or Pacific threadfin), 'oama (young weke or yellowstripe goatfish) move close to shore to sheltered bays and coves at this time of year. Fishers go out with nets and poles both day and night to catch these fish. If you catch these fish be sure observe the minimum catch sizes.

Pupuhi ka he'e o kai uli.
(The octopus of the deep spews its ink [into the water]).

This proverb refers to a person who goes off in secret. The octopus uses an ink-like substance to hide and escape from its enemies. This is a good time to catch he'e (octopus) with lures.

Look for the constellation Leo in the western evening sky.

Conservation Notes:

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Māhoe Hope / September

Lawelawe ke ō! Lawelawe ke ō!
(Take the food! Take the food!)

The whistle call of the kioea (bristle-thighed curlew) was said to urge fishers to launch their canoes to go to sea and "take the food." Kioea migrate to Hawai'i at this time of year and can be found along the shore. Also look for the 'ūlili (wandering tattler) that migrates to Hawai'i now for the winter. Watch for this gray bird with yellow legs along the shore or on rocks in streams searching for food. In old Hawai'i, the kapu for catching 'ōpelu (mackerel scad) was lifted this month.

This is an equinox time when the sun rises due east and sets due west.

Conservation Notes:

'Ikuwā / October

'Ōpelu ha'alili i ke kai.
('Ōpelu that make the sea ripple.)

This old Hawaiian saying about 'ōpelu (mackerel scad) refers to energetic people. These fish are plentiful now, swimming in schools near the surface of coastal waters. The traditional way to catch 'ōpelu is to lure them with kalo (taro) into a funnel-shaped net. It's also a good time to catch moi (Pacific threadfin).

Look for the constellation Makali'i (Pleiades) to appear in the east-northeast sky after sunset around the middle of this month. This marks the beginning of Makahiki—a four-month long harvest festival, dedicated to Lono, a Hawaiian god of rain and agriculture. Kapu begins for aku (bonito or skipjack tuna) to allow these fish to reproduce and their populations to grow.

Conservation Notes:

Calendar Cards

Welehu / November

Ka iʻa a ka wai nui i lawe mai ai.
(The fish borne along by the flood.)

At this time of year, ʻoʻopu nākea (goby fish) come downstream to spawn in heavy rain. Hawaiians diverted streams to bring ʻoʻopu into their upland fishponds. Āholehole fish move to stream mouths at this time of the year to catch the larva of animals like the ʻoʻopu and ʻōpae (shrimp) that have been washed downstream by the rain.

Kau ke poʻo i ka uluna o Welehu ka malama.
(Rest the head on the pillow; November is the month.)

This proverb refers to the time of year when work is done, weather is stormy, and people can rest.

Conservation Notes:

Makaliʻi / December

Ka iʻa kāohi aho o na kai uli.
(The fish of the deep that pulls the line taut.)

This proverb refers to the ulua, a strong fish, or to a strong, young man. Ulua aukea (giant trevally) finish spawning during this month. If you catch a young, small ulua, let it go! They don't spawn until they are 3.5 years old and approximately 21 inches long.

Naueue ka hiʻu o ka iʻa lewa i ke kai.
(The tails of the fish that move in the sea tremble.)

The kapu season begins now for the ʻamaʻama (striped mullet). The adults spawn in the open ocean where stable salinity and temperature conditions are good for the growth of their newly hatched fish.

Conservation Notes:

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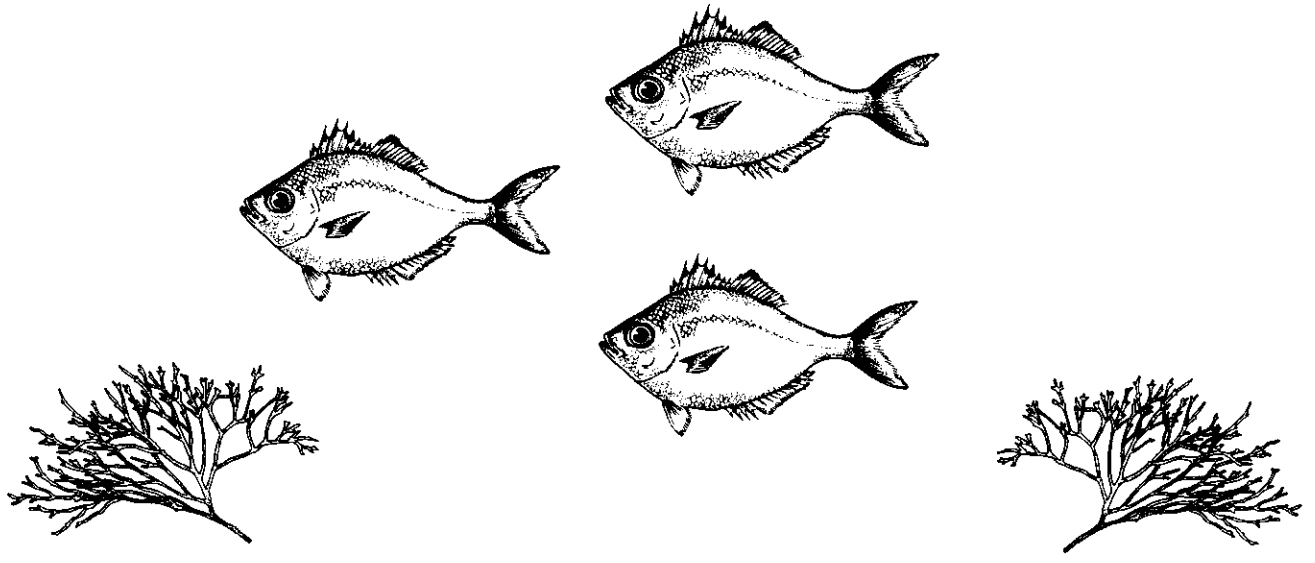

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